PREDICT

Paediatric Research in Emergency Departments International Collaborative

Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children

2021

Version 1.0

This document should be cited as: Babl FE, Tavender E, Dalziel S. On behalf of the Guideline Working Group for the Paediatric Research in Emergency Departments International Collaborative (PREDICT). *Australian and New Zealand Guideline for Mild to Moderate Head injuries in Children – Full Guideline*. 2021. PREDICT, Melbourne, Australia.

This document and supportive additional documents can be downloaded from the PREDICT website: http://www.predict.org.au. If alternative file formats are required, please email: predict@mcri.edu.au

Disclaimer: The *PREDICT Australian and New Zealand Guideline for Mild to Moderate Head injuries in Children* aims to combine a review of the available evidence for the management of mild to moderate head injuries in children with current clinical and expert practice and develop general clinical practice recommendations based on the best evidence available at the time of publication. The content provided is not intended to replace personal consultation with, diagnosis and treatment by a qualified health care professional. Care should always be based on professional medical advice, appropriate for a patients specific circumstances.

CONTENTS

TABLES

Abbreviation and definitions

Abbreviations

Abbreviation	Term
5P	Predicting Persistent Post-Concussive Problems in Pediatrics
AAN	American Academy of Neurology
ACE	Acute Concussion Evaluation
ACR	American College of Radiography
AHT	abusive head trauma
AIEOP	Italian Association of Pediatric Hematology and Oncology
ALARA	As Low As Reasonably Achievable
ANAM	Automated Neuropsychological Assessment Metrics
APHIRST	Australasian Paediatric Head Injury Rules Study
APTT	Activated Partial Thromboplastin Time
BESS	Balance Error Scoring System
BSI	Brief Symptom Inventory
BVMT-R	Brief Visuospatial Memory Test – Revised
CBCL	Child Behavior Checklist
CBR	consensus-based recommendation
CDC	Centers for Disease Control and Prevention (United States)
CISG	International Concussion in Sport Group
ciTBI	Clinically-important traumatic brain injury
COAT	Children's Orientation and Amnesia Test
CSF	cerebrospinal fluid
CSI	Concussion Symptom Inventory
CT	computed tomography
ECI	extracranial injury
ED	emergency department
EEG	Electroencephalography
EIR	evidence-informed recommendation
FAD	Family Assessment Device
FP	false positive
FN	false negative
GCS	Glasgow Coma Scale
GSC	Guideline Steering Committee
GP	general practitioner
GWG	Guideline Working Group
HBI	Health Behaviour Inventory
HVLT-R	Hopkins Verbal Learning Test – Revised
ICH	intracranial haemorrhage
ILSF	isolated linear skull fractures
ImPACT	Immediate Post-Concussion Assessment and Cognitive Test
INR	International Normalised Ratio
LOC	loss of consciousness
LoE	level of evidence
MRI	magnetic resonance imaging
mTBI	mild traumatic brain Injury
mTBI-DS	Mild Traumatic Brain Injury – Discriminant Score
NAI	non-accidental injury
NICE	National Institute of Health and Care Excellence (United Kingdom)

Abbreviation	Term
NICE CG176	NICE Clinical Guidance [CG176] Head injury: assessment and early management
NOC	New Orleans Criteria
NPV	negative predictive value
PCS	post-concussion syndrome
PCSC	Post-Concussion Syndrome Checklist
PCSI	Post-Concussion Symptom Inventory
PCSS	Post-Concussion Symptom Scale
PECARN	Pediatric Emergency Care Applied Research Network
PICO (T)	patient/population, intervention/indicator, comparison, outcome, time (optional)
PP	practice point
PPCS	persistent post-concussive symptoms
PPVT	Peabody Picture Vocabulary Test
PREDICT	Paediatric Research in Emergency Departments International Collaborative
PSU	Pennsylvania State University Cancellation Task
PTA	post traumatic amnesia
Rowe BRI	Rowe Behavior Rating Inventory
RPQ	Rivermead Post Concussion Symptoms Questionnaire
SAC	Standardised Assessment of Concussion
SCAT	Sports Concussion Assessment Tool
SDMT	Symbol Digit Modalities Test
SIMEUP	Italian Society of Pediatric Emergency Medicine
SIP	Italian Society of Pediatrics
SRC	sport-related concussion
STAI-S	Spielberger State-Trait Anxiety Inventory – State Anxiety Scale
TMT	Trail Making Test
TN	true negative
TP	true positive
TSS	Total Symptom Scale
Vigil/W CPT	Vigil/W Continuous Performance Test
WPTAS	Westmead PTA Scale
WTAR	Wechsler Test of Adult Reading

Definitions

Term	Definition
Mild to moderate head injury	Definitions of mild to moderate head injury are heterogeneous, and are not consistent in the literature. The focus of this Guideline is predominately children who present to an acute care setting with a head injury and have a Glasgow Coma Scale (GCS) score of 14 or 15 on initial clinician assessment. However, some children who present with a GCS of 13 or less have a normal computed tomography (CT) scan of the head and return to normal baseline neurological function within a few hours of hospital presentation and are often then suitable for discharge. Therefore, such children are also included in our definition of mild to moderate head injury.
Trivial head injury	Trivial head injury includes ground-level falls, and walking or running into stationary objects, without loss of consciousness, a GCS of 15, and no signs or symptoms of head trauma other than abrasions (adapted from Kuppermann et al (2009) (1)).
Clinically-important traumatic brain injury (ciTBI)	Death from traumatic brain injury (TBI), neurosurgical intervention for TBI, intubation for more than 24 hours for TBI, or hospital admission of 2 nights or more associated with TBI on CT (Kuppermann et al (2009) (1)).
Children	Unless otherwise specified, this term refers to children of all ages including infants and adolescents less than 18 years of age.
Age definitions (unless indicated otherwise)	
Infant	Less than 12 months of age
Adolescent	13 years to less than 18 years of age
Structured observation	Observation of head injured children in the outpatient, emergency department or inpatient setting by qualified medical and nursing staff with repeated clinical assessments for a period of time.

Age-appropriate Glasgow Coma Scale

Glasgow Coma Scale and Children's Glasgow Coma Scale

Glasgow Coma Scale (≥4 years)		Children's Glasgow Coma Scale (<4 years)	
Response	**Score**	**Response**	**Score**
Eye opening		**Eye opening**	
Spontaneously	4	Spontaneously	4
To verbal stimuli	3	To verbal stimuli	3
To pain	2	To pain	2
No response to pain	1	No response to pain	1
Best motor response		**Best motor response**	
Obeys verbal command	6	Spontaneous or obeys verbal command	6
Localises to pain	5	Localises to pain or withdraws to touch	5
Withdraws from pain	4	Withdraws from pain	4
Abnormal flexion to pain (decorticate)	3	Abnormal flexion to pain (decorticate)	3
Abnormal extension to pain (decerebrate)	2	Abnormal extension to pain (decerebrate)	2
No response to pain	1	No response to pain	1

Best verbal response		Best verbal response	
Orientated and converses	5	Alert; babbles, coos words to usual ability	5
Disorientated and converses	4	Less than usual words, spontaneous irritable cry	4
Inappropriate words	3	Cries only to pain	3
Incomprehensible sounds	2	Moans to pain	2
No response to pain	1	No response to pain	1

Reproduced with permission from *Advanced Paediatric Life Support A Practical Approach to Emergencies, Chapter 4 The child with a decreased conscious level. Samuels M., Wieteska, S. (Eds). John Wiley and Sons Sixth Edition 2017.*(2)

Acknowledgements

The *PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children* was developed with funding support from the National Health and Medical Research Council (NHMRC) Centre of Research Excellence grants for Paediatric Emergency Medicine (GNT1058560/GNT1171228), Canberra, Australia, administered by the Murdoch Children's Research Institute, and from the Royal Children's Hospital Foundation, Melbourne, Australia.

The Guideline Steering Committee was initially established by the Paediatric Research in Emergency Departments International Collaborative (PREDICT), who convened a multidisciplinary Guideline Working Group (GWG). We acknowledge the generous, thoughtful contributions of the members of the GWG. Their sustained assistance in the development of the Guideline ensured stakeholder input and representation from specific specialty areas and the broad relevance of the Guideline. The Guideline development process was organised from inception to publication by Dr Emma Tavender, an implementation scientist.

Guideline Steering Committee
Professor Franz Babl (co-chair)
Professor Stuart Dalziel (co-chair)
Dr Emma Tavender
Dr Dustin Ballard
Professor Ed Oakley
Professor Meredith Borland
Associate Professor Liz Cotterell

Guideline Working Group
Professor Franz Babl (co-chair)
Professor Stuart Dalziel (co-chair)
Professor Vicki Anderson
Dr Dustin Ballard
Associate Professor Karen Barlow
Associate Professor Peter Barnett
Mr Scott Bennetts
Dr Roisin Bhamjee
Professor Meredith Borland
Dr Joanne Cole
Associate Professor Liz Cotterell
Dr John Craven
Professor Gavin Davis
Professor Stacy Goergen
Dr Lambros Halkidis
Ms Libby Haskell
Dr Ben Lawton
Dr Anna Lithgow
Ms Glenda Mullen
Professor Ed Oakley
Ms Sharon O'Brien
Mrs Michelle Paproth
Dr David Perry
Dr Emma Tavender
Ms Cate Wilson

We would like to acknowledge the input and feedback provided as part of the consultation phase for the Guideline by stakeholders to ensure relevance to the Australian and New Zealand emergency and paediatric setting. Formal feedback was received from: Australasian College for Emergency Medicine; New Zealand Emergency Medicine Network; The Royal Australasian College of Physicians; Paediatric Society of New Zealand; Australasian College of Paramedicine; Council of Ambulance Authorities Inc.; Royal Australian and New Zealand College of Radiologists; Australian Society of Medical Imaging and Radiation Therapy; New Zealand Institute of Medical Radiation Technology; Neurosurgical Society of Australasia; Royal Australasian College of Surgeons; Sports Medicine Australia; Australian Haemophilia Centre Directors' Organisation; Royal Flying Doctor Service; College of Emergency Nurses New Zealand; Australian College of Nurse Practitioners; College of Emergency Nurses Australasia; Australian College of Nursing; Metro & Regional Paediatrics Network, Agency for Clinical Innovation New South Wales; Advanced Paediatric Life Support Australia; Advanced Paediatric Life Support New Zealand; The Royal Australian College of General Practitioners; Australian College of Rural and Remote Medicine; Victorian Department of Education. We thank the numerous clinicians who provided valuable informal feedback on the Guideline during the consultation phase.

We are grateful for external input from Professor Nathan Kuppermann, University of California Davis, United States of America (USA); Professor Peter Dayan, Columbia University, New York, USA; Professor Erik Hess, The University of Alabama Birmingham, USA; Professor Silvia Bressan, University of Padua, Italy; Associate Professor Johan Undén, Lund University, Lund, Sweden; and Professor Paul Monagle, Department of Clinical Haematology and Laboratory Services, The Royal Children's Hospital, Melbourne.

We thank Dr Jenny Ring and Dr Agnes Wilson, Hereco, Sydney, Australia, for their expertise and input in finalising the Technical Report and the Guideline Recommendations. We thank Dr Grace Leo from Don't Forget the Bubbles for her work on the graphic design of the Algorithm.

We thank Mr Quincy McCrary and Ms Sara Pimental, Kaiser Permanente Librarian Services, USA and Ms Poh Chua, Royal Children's Hospital, Melbourne, Australia for their literature searching expertise.

We thank Ms Marian Chandler for her administrative support.

Executive summary

Children with head injuries represent some of the most common clinical presentations seen in acute paediatric care. Key management decisions need to be made with respect to triage, diagnostic imaging, admission or observation, and appropriate discharge and follow-up. Failure to do so can have both short-term and long-term sequelae.

The *PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children* (PREDICT Guideline) was designed to provide the highest level evidence and accurate guidance for clinicians providing care for children with mild to moderate head injuries presenting to acute care settings in Australia and New Zealand. The evidence review process was completed in 2019, with the Guideline development process conducted between 2019 and 2020. This Guideline has been developed in accordance with the principles set out in the 2016 National Health and Medical Research Council's (NHMRC) *Standards for Guidelines* (3). We followed a guideline adaption process, modifying steps from the ADAPTE Guideline development framework and the GRADE (Grading of Recommendations Assessment, Development and Evaluation)-ADOLOPMENT approach, including an assessment of existing international high-quality head injury guidelines for children, followed by a systematic review of the literature to update the evidence since the development of those guidelines (4).

The Paediatric Research in Emergency Departments International Collaborative (PREDICT) convened a multidisciplinary Guideline Working Group (GWG) comprising members from across Australia and New Zealand, including emergency physicians, paediatricians, neurosurgeons, paediatric neurologists, sports medicine doctors, radiologists, retrieval specialists, nurses and nurse practitioners, neuropsychologists, general practitioners, ambulance staff, implementation scientists and consumers. The GWG developed 33 consensus-based clinical questions in three key areas – triage, imaging and discharge of children with mild to moderate head injuries presenting to acute care settings. The 33 questions were then considered with respect to recommendations from the existing international guidelines identified and an assessment of new evidence from the updated systematic review of the literature. A decision was then made on whether to adopt or adapt recommendations from existing guidelines, or to develop new recommendations to address the clinical questions and be relevant to the Australian and New Zealand clinical environment. Recommendations were classed as 'evidence-informed recommendations (EIR)', 'consensus-based recommendations (CBR)' or 'practice points (PP)'.

The PREDICT Guideline is presented here; a summary document and a clinical algorithm (*Algorithm*: *Imaging & Observation Decision-Making for Children with Head Injuries*) are available on the PREDICT website (www.predict.org.au). Further implementation materials for clinicians, children, their families, and schools have also been developed.

We trust that this Guideline will contribute to improved care and greater consistency in clinical practice for children presenting to acute care settings with head injuries.

On behalf of the Guideline Working Group.

Prof Franz Babl, Dr Emma Tavender and Prof Stuart Dalziel.

Recommendations

Type of recommendation	Description
Evidence-informed recommendation (EIR)	Recommendation formulated with evidence from source guideline and/or PREDICT literature search
Consensus-based recommendation (CBR)	Recommendation formulated by consensus, where evidence was sought but none was identified, or where the identified evidence was limited by indirectness
Practice point (PP)	A recommendation that was outside the scope of the evidence search and was based on consensus

Each recommendation is classed as new (i.e. created by the Guideline Working Group), adopted (i.e. taken from existing guidelines) or adapted (i.e. adapted from existing guidelines).

Triage

1 CBR Children with head injury should be assessed in a hospital setting if the mechanism of injury was severe[1] or if they develop the following signs or symptoms within 72 hours of injury: New

- seizure or convulsion
- double vision, ataxia, clumsiness or gait abnormality
- loss of consciousness
- deteriorating level of consciousness
- weakness and tingling in arms or legs
- presumed skull fracture (palpable fracture, 'raccoon eyes' or Battle's signs)
- vomiting[2]
- severe headache
- not acting normally, including abnormal drowsiness, increasing agitation, restlessness or combativeness (in children aged less than 2 years, not acting normally as deemed by a parent)
- occipital or parietal or temporal scalp haematoma (in children aged less than 2 years only).[3]

2 CBR Children with trivial head injury[4] do not need to attend hospital for assessment; they can be safely managed at home.[3] New

3 EIR Consultation with a neurosurgical service may not be routinely required for infants and children with an isolated, non-displaced, linear skull fracture on a head CT scan without intracranial injury and a GCS score of 15.[5] New

[1] Severe mechanism of injury: motor vehicle accident with patient ejection, death of another passenger or rollover; pedestrian or bicyclist without helmet struck by motorised vehicle; falls of 1 m or more for children aged less than 2 years, and more than 1.5 m for children aged 2 years or older; or head struck by a high-impact object.
[2] A case of a single isolated vomit can be assessed in general practice.
[3] In children aged less than 2 years the signs of intracranial injury may not be apparent in the first hour.
[4] Trivial head injury includes ground-level falls, and walking or running into stationary objects, with no loss of consciousness, a GCS score of 15 and no signs or symptoms of head trauma other than abrasions.
[5] Measured using an age-appropriate GCS.

A	PP	Children aged less than 2 years with a suspected or identified isolated, non-displaced, linear skull fracture should have a medical follow-up within 1–2 months to assess for a growing skull fracture.[6]	New
B	PP	In all children presenting with mild to moderate head injury, the possibility of abusive head trauma should be considered.	New
4	CBR	Consultation with a neurosurgical service should occur in all cases of intracranial injury or skull fracture shown on a head CT scan, other than in infants and children with an isolated, non-displaced, linear skull fracture on a head CT scan without intracranial injury and a GCS score of 15.[5]	Adapted

Decision rules for CT scan

5	EIR	In children with mild to moderate head injury and a GCS score of 14–15[5] who have one or more risk factors for a clinically-important traumatic brain injury[7] (see below or Box A for risk factors, and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*), clinicians should take into account the number, severity and persistence of signs and symptoms, and family factors (e.g. distance from hospital and social context) when choosing between structured observation and a head CT scan.[8] ***Risk factors for clinically-important traumatic brain injury:***[7] – GCS score of 14[5] or other signs of altered mental status[9] – Severe mechanism of injury[1] – Post-traumatic seizure(s) – Abnormal neurological examination Specific risk factors for children aged less than 2 years: – Palpable skull fracture[10] – Occipital or parietal or temporal scalp haematoma[11] – History of LOC 5 seconds or more – Not acting normally per parent Specific risk factors for children aged 2 years and older: – Signs of base of skull fracture[12] – History of LOC – History of vomiting[13] – Severe headache.	New

[6] A growing skull fracture is a rare complication of linear skull fractures. It can occur in children aged less than 2 years with a skull bone fracture, and it represents the diastatic enlargement of the fracture due to a dural tear, with herniating brain tissue or a cystic cerebrospinal fluid-filled mass underneath. In the setting of a known skull fracture, a growing fracture is indicated by any of the following: persistent boggy swelling along a fracture line; palpable diastasis; an enlarging, asymmetrical head circumference; or delayed onset neurological symptoms. This can be assessed by a neurosurgeon, paediatrician or GP who is able to assess for a growing skull fracture.

[7] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

[8] Sedation is usually not required in children for non-contrast CT scans as they generally only take seconds to complete. If sedation is required for uncooperative children requiring imaging local safe sedation practice should be followed.

[9] Agitation, drowsiness, repetitive questioning, slow response to verbal communication.

[10] Palpable skull fracture: on palpation or possible on the basis of swelling or distortion of the scalp.

[11] Non-frontal scalp haematoma: occipital, parietal or temporal.

[12] Signs of base of skull fracture: haemotympanum, 'raccoon eyes', cerebrospinal fluid (CSF) otorrhoea or CSF rhinorrhoea, Battle's signs.

[13] Isolated vomiting, without any other risk factors, is an uncommon presentation of clinically-important traumatic brain injury. Vomiting, regardless of the number or persistence of vomiting, in association with other risk factors increases concern for clinically-important traumatic brain injury.

6	EIR	For children presenting to an acute care setting within 24 hours of a head injury and a GCS score of 15,[5] a head CT scan should not be performed without any risk factors for clinically-important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*).	New
7	EIR	Children presenting to an acute care setting within 72 hours of a head injury and a GCS score of 13 or less[5] should undergo an immediate head CT scan.[8]	New
8	CBR	Children with delayed initial presentation (24–72 hours after head injury) and a GCS score of 15[5] should be risk stratified in the same way as children presenting within 24 hours.	New
C	PP	For children with mild to moderate head injury, consider shared decision-making[14] with parents, caregivers and adolescents (e.g. a head CT scan[8] or structured observation).	New
D	PP	All cases of head injured infants aged 6 months and younger should be discussed with a senior clinician. These infants should be considered at higher risk of intracranial injury, with a lower threshold for observation or imaging.[8]	New
Ventricular shunts			
9	EIR	In children with a ventricular shunt (e.g. ventriculoperitoneal shunt) presenting to an acute care setting following mild to moderate head injury, who have no risk factors for clinically-important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors), consider structured observation over an immediate head CT scan.	Adapted
E	PP	In children with a ventricular shunt and mild to moderate head injury, consider obtaining a shunt series, based on consultation with a neurosurgical service, if there are local signs of shunt disconnection, shunt fracture (e.g. palpable disruption or swelling), or signs of shunt malfunction.	New
Anticoagulant or antiplatelet therapy, and known bleeding disorders			
10	EIR	In children with congenital or acquired bleeding disorders, following a head injury that results in presentation to an acute care setting, where there are no risk factors for clinically-important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm:Imaging & Observation Decision-making for Children with Head Injuries*), consider structured observation over an immediate head CT scan. If there is a risk factor for intracranial injury, a head CT should be performed. If there is a deterioration in neurological status, a head CT should be performed urgently.	Adapted
F	PP	In children with coagulation factor deficiency (e.g. haemophilia), following a head injury that results in presentation to an acute care setting, the performance of a head CT scan or the decision to undertake structured observation must not delay the urgent administration of replacement factor.	New
G	PP	In all children with a bleeding disorder or on anticoagulant or antiplatelet therapy, following a head injury that results in presentation to an acute care setting, clinicians should urgently seek advice from the haematology team treating the child in relation to risk of bleeding and management of the coagulopathy.	New

[14] Validated tools should be adapted for shared decision-making with parents, caregivers and adolescents.

11	CBR	In children with immune thrombocytopaenias, following a head injury which results in presentation to an acute care setting, where there are no risk factors for clinically-important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm:Imaging & Observation Decision-making for Children with Head Injuries*), consider structured observation over an immediate head CT scan. If there is a risk factor for intracranial injury, a head CT should be performed. If there is a deterioration in neurological status, a head CT should be performed urgently. Clinicians should check a platelet count in all children with immune thrombocytopaenias, and blood group in all symptomatic patients, if not already available.	Adapted
H	PP	In children with immune thrombocytopaenia with mild to moderate head injury and platelet counts of less than 20×10^9/L, consider empirical treatment after discussion with the haematology team treating the child.	New
12	EIR	In children with mild to moderate head injury on warfarin therapy, other anticoagulants (e.g. direct oral anticoagulants) or antiplatelet therapy, consider a head CT scan regardless of the presence or absence of risk factors for clinically-important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm:Imaging & Observation Decision-making for Children with Head Injuries*). Seek senior clinician review to inform timing of the head CT scan. Discuss the patient with the team managing the anticoagulation regarding early consideration of reversal agents. Check the appropriate anticoagulant measure (if available); for example, international normalised ratio (INR), activated partial thromboplastin time (APTT) or anti-Xa assay.	Adapted
I	PP	In adolescents with mild to moderate head injury and taking anticoagulants, including warfarin, consider managing according to adult literature and guidelines.	New

Neurodevelopmental disorders

13	CBR	It is unclear whether children with neurodevelopmental disorders presenting to an acute care setting following mild to moderate head injury have a different background risk for intracranial injury. Consider structured observation or a head CT scan for these children because they may be difficult to assess. For these children, shared decision-making with parents, caregivers and the clinical team that knows the child is particularly important.	New

Intoxication

14	CBR	In children who are drug or alcohol intoxicated presenting to an acute care setting following mild to moderate head injury, treat as if the neurological findings are due to the head injury. The decision to undertake structured observation or a head CT scan should be informed by the risk factors for clinically-important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm:Imaging & Observation Decision-making for Children with Head Injuries*) rather than the child being intoxicated.	New

Discharge without CT scan

15	EIR	In children presenting to an acute care setting following mild to moderate head injury, the risk of clinically-important traumatic brain injury[7] requiring hospital care is low enough to warrant discharge home without a head CT scan if the patient has no risk factors for a clinically important traumatic brain injury[7] (see PREDICT Recommendation 5 or Box A for risk factors), has a normal neurological examination and has no other factors warranting hospital admission (e.g. other injuries, clinician concerns [e.g. persistent vomiting], drug or alcohol intoxication, social factors, underlying medical conditions such as bleeding disorders or possible abusive head trauma).	New
J	PP	In children undertaking structured observation following mild to moderate head injury, consider observation up to 4 hours from the time of injury, with discharge if the patient returns to normal for at least 1 hour. Consider an observation frequency of every half hour for the first 2 hours, then 1-hourly until 4 hours post injury. After 4 hours, continue observation at least 2-hourly for as long as the child remains in hospital.	Adapted
K	PP	The duration of structured observation may be modified based on patient and family variables, including time elapsed since injury or signs and symptoms, and reliability and ability of the child or parent to follow advice on when to return to hospital.	New

Normal initial CT scan

16	EIR	After a normal initial head CT scan in children presenting to an acute care setting following mild to moderate head injury, the clinician may conclude that the risk of clinically-important traumatic brain injury[7] requiring hospital care is low enough to warrant discharge home, provided that the child has a GCS score of 15,[5] normal neurological examination and no other factors warranting hospital admission (e.g. other injuries, clinician concerns [e.g. persistent vomiting], drug or alcohol intoxication, social factors, underlying medical conditions such as bleeding disorders or possible abusive head trauma).	Adapted
L	PP	The duration of structured observation for children with mild to moderate head injury who have a normal initial head CT scan but do not meet discharge criteria should be based on individual patient circumstances. Consider an observation frequency of every half hour for the first 2 hours, then 1-hourly until 4 hours post injury. After 4 hours, continue at least 2-hourly for as long as the child remains in hospital.	New

Repeat imaging

17	EIR	After a normal initial head CT scan in children presenting to an acute care setting following mild to moderate head injury, neurological deterioration should prompt urgent reappraisal by the treating clinician, with consideration of an immediate repeat head CT scan and consultation with a neurosurgical service. Children who are being observed after a normal initial head CT scan[15] who have not achieved a GCS score of 15[5] after up to 6 hours observation from the time of injury, should have a senior clinician review for consideration of a further head CT scan or MRI scan and/or consultation with a neurosurgical service. The differential diagnosis of neurological deterioration or lack of improvement should take account of other injuries, drug or alcohol intoxication and non-traumatic aetiologies.	Adapted

Abusive head trauma

18	EIR	In children presenting to an acute care setting following mild to moderate head injury where abusive head trauma is suspected, a head CT scan should be used as the initial diagnostic tool to evaluate possible intracranial injury and other injuries (e.g. skull fractures) relevant to the evaluation of abusive head trauma. The extent of the assessment should be coordinated with the involvement of an expert in the evaluation of non-accidental injury.	Adapted
M	PP	Detection of skull fractures, even in the absence of other intracranial injury, is important in cases of suspected abusive head trauma.	New

X-ray

19	EIR	In children presenting to an acute care setting following mild to moderate head injury, clinicians should not use plain X-rays of the skull prior to, or in lieu of, a head CT scan to diagnose skull fracture or to determine the risk of intracranial injury.	Adapted

Ultrasound

20	EIR	In children presenting to an acute care setting following mild to moderate head injury, clinicians should not use ultrasound of the skull prior to, or in lieu of, a head CT scan to diagnose or determine the risk of intracranial injury.	Adapted
21	EIR	In infants presenting to an acute care setting following mild to moderate head injury, clinicians should not use transfontanelle ultrasound prior to, or in lieu of, a head CT scan to diagnose intracranial injury.	Adopted

MRI versus CT scan

22	EIR	In children presenting to an acute care setting following mild to moderate head injury, for safety, logistical and resource reasons, MRI should not be routinely used for primary investigation of clinically-important traumatic brain injury.[16]	Adopted
N	PP	In certain settings with the capacity to perform MRI rapidly and safely in children, MRI may be equivalent to a head CT scan in terms of utility.	New

[15] The initial head CT scan should be interpreted by a radiologist to ensure no injuries were missed.
[16] If an MRI is planned, the concurrent imaging of the spine should be considered and may warrant discussion with other specialist teams.

Biomarker testing

23	EIR	In infants and children with mild to moderate head injury, presenting to an acute care setting, healthcare professionals should not use biomarkers to diagnose or determine the risk of intracranial injury outside of a research setting.	Adopted

CT scan protocols

24	EIR	In children with head injury, radiation dose should be optimised for head CT scans, with the primary aim being to produce diagnostic quality images that can be interpreted by the radiologist and are sufficient to demonstrate a small volume of intracranial haemorrhage (e.g. thin-film subdural haematoma).	New
25	EIR	Age-based CT scanning protocols that are optimised and as low as reasonably achievable (ALARA) for a paediatric population should be used.	New
26	EIR	Soft tissue and bone algorithm standard thickness and fine-slice images and multiplanar 2D and bony 3D reconstructions should be acquired, archived and available to the radiologist for review at the time of initial interpretation.	New
27	CBR	Cervical spine imaging should not be routine in all children with mild to moderate head injury who require imaging.	New

Follow-up and discharge advice

28	EIR	Children presenting within 72 hours of a mild to moderate head injury can be safely discharged into the community if they meet all the following criteria: • deemed at low risk of a clinically-important traumatic brain injury[7] as determined either by a negative head CT scan, or structured observation, or the absence of risk factors for a clinically-important traumatic brain injury (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm:Imaging & Observation Decision-making for Children with Head Injuries*) • neurologically normal • a GCS score of 15[5] • no other factors that warrant admission or a longer period of structured observation (e.g. other injuries or suspected abusive head trauma, clinician concerns [e.g. persistent vomiting], drug or alcohol intoxication).	Adapted
29	CBR	Children presenting within 72 hours of a mild to moderate head injury, and deemed appropriate for discharge with respect to low risk of a clinically-important traumatic brain injury[7] should be discharged home according to local clinical practice regarding their ability to return to hospital (in terms of distance, time, social factors and transport).	Adapted
30	CBR	Children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should have a suitable person at home to supervise them for the first 24 hours post injury.	Adapted
31	EIR	All parents and caregivers of children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should be given clear, age-appropriate, written and verbal advice on when to return to the emergency department; this includes worsening symptoms (e.g. headache, confusion, irritability, or persistent or prolonged vomiting), a decreased level of consciousness or seizures.	Adopted

32	EIR	All parents and caregivers of children discharged from hospital after presenting within 72 hours of mild to moderate head injury should be given contact information for the emergency department, telephone advice line or other local providers of advice.	Adopted
33	EIR	All parents and caregivers of children discharged from hospital after presenting within 72 hours of mild to moderate head injury should be given clear, age-appropriate written and verbal advice on the possibility of persistent or delayed post-concussive symptoms, and the natural history (including the recovery process) of post-concussive symptoms in children.	Adopted
34	EIR	All parents and caregivers of children discharged from hospital after presenting within 72 hours of mild to moderate head injury should be given clear, age-appropriate written and verbal advice on exercise, return to sport, return to school, alcohol and drug use, and driving.	Adopted
35	EIR	Children presenting within 72 hours of a mild to moderate head injury deemed at low risk of a clinically-important traumatic brain injury,[7] as determined by any of the following – a negative head CT scan, structured observation or the absence of risk factors for clinically-important traumatic brain injury (see PREDICT Recommendation 5 or Box A for risk factors) – do not require specific follow-up for an acute intracranial lesion (e.g. bleeding).	New
36	EIR	All parents and caregivers of children discharged from hospital after presenting within 72 hours of mild to moderate head injury should be advised that their child should attend primary care 1–2 weeks post injury for assessment of post-concussive symptoms and to monitor clinical status.	New
37	EIR	In children at high risk of persistent post-concussive symptoms (more than 4 weeks) (see Practice point O), clinicians should consider provision of referral to specialist services for post-concussive symptom management.	Adapted
O	PP	For children presenting within 72 hours of mild to moderate head injury, emergency department clinicians should consider factors known to be associated with an increased risk of developing post-concussive symptoms. Examples include, but are not restricted to, a high degree of symptoms at presentation, girls aged over 13 years, previous concussion with symptoms lasting more than a week, or past history of learning difficulties or attention deficit hyperactivity disorder (ADHD). There are validated prediction rules (e.g. Predicting Persistent Post-concussive Problems in Pediatrics (5P) clinical risk score) or risk tables to provide prognostic counselling and follow-up advice to children and their caregivers on their potential risk of developing post-concussive symptoms (see Tables 6.3.3 and 6.3.4 in full Guideline for further details).	New
38	EIR	In children whose post-concussive symptoms do not resolve within 4 weeks, clinicians should provide or refer the child to specialist services for persistent post-concussive symptom management.	Adapted

Return to sport

39	CBR	Children with mild to moderate head injury should not return to contact sport until they have successfully returned to school. Early introduction (after 24 hours) of gradually increasing, low to moderate physical activity is appropriate, provided it is at a level that does not result in exacerbation of post-concussive symptoms.	Adapted

40	CBR	Children with post-concussive symptoms should avoid activities with a risk of contact, fall or collisions that may increase the risk of sustaining another concussion during the recovery period.	Adapted
41	CBR	Children with post-concussive symptoms who play sport should commence a modified non-contact exercise program and must subsequently be asymptomatic before full contact training or game day play can resume.	Adapted
P	PP	A modified non-contact exercise program can be supervised by a parent (for younger children) or sports or health personnel (for children with ongoing significant symptoms or older children wanting to resume contact sport).	New
Physical rest			
42	EIR	Children with mild to moderate head injury should have a brief period of physical rest post injury (not more than 24–48 hours post injury).	Adapted
43	EIR	Following a mild to moderate head injury, children should be introduced to early (between 24 and 48 hours post injury), gradually increasing, low to moderate physical activity, provided that it is at a level that does not result in significant exacerbation of post-concussive symptoms. Physical activities that pose no or low risk of sustaining another concussion can be resumed whenever symptoms improve sufficiently to permit activity, or even if mild residual post-concussive symptoms are present.	Adapted
Cognitive rest			
44	EIR	Children with mild to moderate head injury should have a brief period of cognitive rest[17] post injury (not more than 24–48 hours post injury).	New
45	EIR	Following a mild to moderate head injury, children should be introduced to early (between 24 and 48 hours post injury), gradually increasing, low to moderate cognitive activity, at a level that does not result in significant exacerbation of post-concussive symptoms.	New
Return to school			
46	EIR	Children with post-concussive symptoms should gradually return to school at a level that does not result in significant exacerbation of post-concussive symptoms. This may include temporary academic accommodations and temporary absences from school.	Adapted
47	EIR	All schools should have a concussion policy that includes guidance on sport-related concussion prevention and management for teachers and staff, and should offer appropriate short-term academic accommodations and support to students recovering from concussion.	Adopted
48	EIR	Clinicians should assess risk factors and modifiers that may prolong recovery and may require more, prolonged or formal academic accommodations. In particular, adolescents recovering from concussion may require more academic support during the recovery period.	Adopted

[17] Low-level cognitive activity, in appropriate short periods, that does not exacerbate symptoms.

Q	PP	Protocols for return to school should be personalised and based on severity of symptoms, with the goal being to increase student participation without exacerbating symptoms. Academic accommodations and modifications after concussion may include a transition plan and accommodations designed to reduce demands, monitor recovery and provide emotional support (see Box B).	New

Screen time

49	CBR	Following a mild to moderate head injury, children's use of screens should be consistent with the recommendation for gradually increasing, low to moderate cognitive activity; that is, activity at a level that does not result in significant exacerbation of post-concussive symptoms.	New
R	PP	Parents and caregivers should be aware of general recommendations for screen use in children aged 2–5 years; that is, limiting screen use to 1 hour per day, no screens 1 hour before bed, and devices to be removed from bedrooms before bedtime.	New
S	PP	Parents and caregivers should be aware of general recommendations for screen use in children aged over 5 years; that is, promote that children get adequate sleep (8–12 hours, depending on age), recommend that children not sleep with devices in their bedrooms (including TVs, computers and smartphones) and avoid exposure to devices or screens for 1 hour before bedtime.	New

Return to driving/operating machinery

50	CBR	Adolescents (and children as appropriate) who have had a mild to moderate head injury causing loss of consciousness must not drive a car, motorbike or bicycle, or operate machinery for at least 24 hours.	New
51	CBR	Adolescents (and children as appropriate) who have had a mild to moderate head injury should not drive a car or motorbike, or operate machinery until completely recovered or, if persistent post-concussive symptoms are present, until they have been assessed by a medical professional.	New

Repeat concussion

52	CBR	Children diagnosed with a repeat concussion soon after the index injury (within 12 weeks) or after multiple repeat episodes are at increased risk of persistent post-concussive symptoms. Parents and caregivers of children with repeat concussion should be referred for appropriate medical review (e.g. to a paediatrician).	New

Box A Head injury risk factors for clinically-important traumatic brain injury[1]	
GCS score of 14[2] or other signs of altered mental status[3] Severe mechanism of injury[4] Post-traumatic seizures Abnormal neurological examination	
Age less than 2 years	**Age 2 years or older**
Palpable skull fracture[5] Occipital or parietal or temporal scalp haematoma[6] History of LOC ≥5 seconds Not acting normally per parent	Signs of base of skull fracture[7] History of LOC History of vomiting[8] Severe headache
Adapted from the PECARN rule, Kuppermann et al. (2009) (1)	

1 Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

2 Measured using an age-appropriate GCS.

3 Other signs of altered mental status: agitation, drowsiness, repetitive questioning, slow response to verbal communication.

4 Severe mechanism of injury: motor vehicle accident with patient ejection, death of another passenger or rollover; pedestrian or bicyclist without helmet struck by motorised vehicle; falls of 1 m or more for children aged less than 2 years and more than 1.5 m for children aged 2 years or older; or head struck by a high-impact object.

5 Palpable skull fracture: on palpation or possible on the basis of swelling or distortion of the scalp.

6 Non-frontal scalp haematoma: occipital, parietal or temporal.

7 Signs of base of skull fracture: haemotympanum, 'raccoon' eyes, cerebrospinal fluid (CSF) otorrhoea or CSF rhinorrhoea, Battle's signs.

8 Isolated vomiting, without any other risk factors, is an uncommon presentation of clinically important traumatic brain injury. Vomiting, regardless of the number of vomits or persistence of vomiting, in association with other risk factors increases concern for clinically-important traumatic brain injury.

Box B	Examples of academic accommodations and modifications that may be used following concussion to facilitate increasing school participation without exacerbating symptoms

Transition plan

- Notify school of concussion before or upon returning to school.
- Develop a plan for gradual return to school day and activities.
- Provide a medical certificate to account for any missed assignments or exams, or design a plan of assistance to support completion of these.

Accommodations designed to reduce demands, monitor recovery and provide emotional support

- Provide an appropriate environment with low stimulus for break times and potential rest times.
- Consider exemption from exams.
- Reduce both the number and size of classroom and homework assignments.
- Allow participation in classes or activities requiring physical activity that does not exacerbate symptoms.
- Reschedule, coordinate or pace exams; hold exams when the student is asymptomatic or experiencing low level symptoms that are not exacerbated by the task.
- Negotiate the timing of large assignments, to reduce co-occurring deadlines.
- Assign a counsellor to meet with the student to evaluate the student's emotional status, assist with problem-solving and ensure that homework needs are being addressed.

Additional commonly used academic accommodations

- Use preferential seating that is designed to reduce exposure to distracting lights and/or noises, allow for teacher monitoring and facilitate focused attention.
- Allow for test-taking in a distraction-free environment.
- Allow extended time for in-class and out-of-class exams and assignments.
- Use a notetaker, whose notes can be photocopied or shared electronically and provided to the student.

Adapted from O'Neil et al. (2017) (5) (Table 3) and DeMatteo et al. (2020) (6)

CBR: consensus-based recommendation; CT: computed tomography; EIR: evidence-informed recommendation; GCS: Glasgow Coma Scale; GP: general practitioner; LOC: loss of consciousness; MRI: magnetic resonance imaging; PP: practice point

1 Introduction

1.1 Background

Mild to moderate head injury is one of the most common reasons for children to present to emergency departments (EDs) in Australia and New Zealand and worldwide. For more than 10 years the Australian and New Zealand paediatric ED research network, PREDICT (Paediatric Research in Emergency Departments International Collaborative), has focused on improving care for children with head injuries through research. The identification of an optimal clinical decision rule for head injury management and the development of the PREDICT *Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children* (PREDICT Guideline) have been priority topics for PREDICT.

Clinicians need to make key management decisions quickly and accurately with respect to triage, diagnostic imaging, admission or observation, and appropriate discharge and follow-up. Not only are head injuries frequent in children, but identifying intracranial injuries in seemingly mild injuries can be difficult. Intracranial injuries, although most concerning, are in fact uncommon. Based on Australian and New Zealand data of children with head injuries of all severities presenting to EDs, approximately 5 in 1000 children require neurosurgery and 20 in 1000 have abnormal computed tomography (CT) scans of the head (7).

The focus of the PREDICT Guideline is mild to moderate head injuries. Definitions of mild to moderate head injuries are heterogeneous and are not consistent in the literature. Most are based on the initial assessment of a Glasgow Coma Scale (GCS) score, with some definitions of mild or moderate head injury including children with a GCS score of 9 and above, whereas others have higher GCS score cut-offs (8). Within Australia and New Zealand, 98.3% of children who present to EDs with a head injury have a GCS score of 14 or 15 on initial clinician assessment (7). It is these children that the Guideline is predominantly written for. However, a number of children who present with a GCS of 13 or less have a normal head CT scan, return to normal baseline neurological function within a few hours of hospital presentation and are often then suitable for discharge (9). Such children are also included in the management algorithm that accompanies this Guideline. The PREDICT Guideline does not address the management and follow-up care of more severe head injuries, including children with intracranial abnormalities identified on a head CT scan or those undergoing neurosurgery.

There is some debate about terminology between head injury, the degrees of severity of traumatic brain injury and concussion, and how these terms relate to each other. Various organisations use one or another term in preference over others, or offer variable definitions to distinguish the terms. Based on common ED practice in Australia and New Zealand and for the purposes of this document, the PREDICT Guideline uses the term 'head injury' as an overarching term for injuries of any severity to the head and brain due to direct or indirect force.

At the centre of the initial decision-making process in the acute care setting is the question "which children should undergo a head CT scan?". While a head CT scan provides definitive and rapid diagnosis to confirm or exclude intracranial injuries, there is concern about radiation-induced cancer, particularly in younger patients (10-12). Furthermore, CT scans are resource intensive and sedation may be required to facilitate a CT scan (13, 14). Clinical decision rules have been developed to identify children at higher risk of intracranial injuries, assisting clinicians to minimise CT scans while still identifying all relevant injuries (15, 16). In 2017, PREDICT assessed three high-quality clinical prediction rules in 20,000 children with head injuries in Australia and New Zealand (7): (i) the prediction rule for the identification of children at very low risk of clinically important traumatic brain injury, developed by the Pediatric Emergency Care Applied Research Network (PECARN, United States of America [USA]) (17); (ii) the Canadian Assessment of Tomography for Childhood Head Injury (CATCH) rule (18); and (iii) the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE, United Kingdom [UK]) (19). We found that the PECARN clinical decision rule was the most accurate in identifying children with clinically-important traumatic brain injury, traumatic brain injury on CT and neurosurgery. Therefore, we mainly used the risk factors identified in the PECARN rule to help in risk stratifying the PREDICT Guideline recommendations and the accompanying PREDICT Guideline Algorithm for the initial management of children with mild and moderate head injuries (*Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*) (20), available at www.predict.org.au.

Based on a secondary analysis of the same data set, we found that delayed presentation greater than 24 hours after head injury in children, although infrequent, may be significantly associated with traumatic brain injury (21). Therefore, we developed the PREDICT Guideline recommendations for children presenting up to 72 hours after head injury.

In Australia and New Zealand, the head CT rate is generally lower than in North America, but to some degree this lower rate is compensated for by a higher rate of structured observation in the ED or in hospital before discharge (22). Nevertheless, the evidence for who should be observed, for how long and how observation should be structured is limited. Our Guideline recommendations in terms of structured observation are therefore mainly consensus based. However, they reflect the current practice at 31 hospitals that participated in multicentre PREDICT studies, which favoured observation over a head CT scan in select patients. In the Australian and New Zealand context, this has been shown to have sensitivity similar to that of the PECARN rule (23).

In relation to pre-hospital triage prior to ED arrival, we sought to address the impact of geography with possible transfers over large distances and the focus of specialty services, especially neurosurgery, at mainly the tertiary centres located in capital cities in the medical systems in Australia and New Zealand. In particular, we tried to identify evidence on how to identify children with head injuries outside the easy reach of tertiary paediatric centres that require transfer for head CT scans or possible neurosurgery. We also sought to address related triaging decisions in terms of consultation or transfer. Owing to a lack of applicable evidence, pre-hospital guidance was mainly based on a consensus of the Guideline Working Group (GWG).

Guideline recommendations on discharge management and follow-up drew on the recommendations from the Consensus Statement on Concussion in Sports (24). However, based on the consensus of the GWG, we amended much of the guidance to be consistent with the available resources for children in the medical systems in Australia and New Zealand outside the elite sports system.

1.2 Guideline objectives

The overall objective was to develop an evidence-based clinical practice guideline for the acute management of mild to moderate head injury (including concussion) in children.

Specific objectives of this Guideline were to:

- improve outcomes for children who present with mild to moderate head injury
- identify all paediatric patients who have a clinically important intracranial injury in need of intervention, such as neurosurgery and/or intensive care
- promote consistency of management (i.e. standardisation of observation criteria and duration of ED stay), and in doing so reduce unnecessary interventions, including inappropriate use of head CT scans in children at very low risk of intracranial injury
- improve guidance for discharge and follow-up.

1.3 Target audience of the Guideline

The target audience was clinicians involved in the assessment and management of paediatric acute mild to moderate head injury in hospitals in Australia and New Zealand. While targeted to hospital-based clinicians who have access to CT scanners, the Guideline will also be relevant to those clinicians, pre-hospital or at sites without CT scanners, who may refer into hospitals with CT scanning facilities.

1.4 Scope of the Guideline

The scope of the Guideline was the diagnosis and acute management of mild to moderate head injury (including concussion) in children presenting to hospital in Australia and New Zealand within 72 hours of injury. The Guideline addresses aspects of diagnosis and management: assessment, imaging, discharge disposition and discharge advice for those discharged home.

Target population
Children less than 18 years of age.

Healthcare setting
Emergency departments and acute assessment areas of rural, regional and tertiary hospitals in Australia and New Zealand.

Exclusions

1. Neurosurgical management of children identified with an intracranial injury.
2. Management in the intensive care unit of children identified with an intracranial injury.
3. Management of children with severe intracranial injury.
4. Management of concussion in the community*.
5. Long-term rehabilitation.

Summary

	Inclusion	**Exclusion**
Population	Children and infants (aged <18 years of age) Mild to moderate head injuries (including concussion)	Adults 18 years and over Acquired brain injury (ABI) Penetrating trauma Moderate to severe head injuries Abnormal head CT scan
Time of presentation	Initial and repeat presentations (< 72 hours after injury)	Initial and repeat presentation (> 72 hours after injury)
Setting	Pre-hospital Emergency department and acute assessment areas of rural, regional and tertiary hospitals in Australia and New Zealand	Intensive care unit (ICU Rehabilitation services* General practice* Community (including home and sports field)*
Management	Initial triage/diagnosis (including biomarkers) Neuroimaging (including head CT, X-ray and MRI) Observation criteria and time Discharge information including concussion and return to school/play Discharge disposition Conditions requiring special consideration (suspected AHT, bleeding disorders, ventricular shunts)	Pre-hospital management ICU management Neurosurgical management Rehabilitation including post-concussion syndrome

ABI: acquired brain injury; AHT: abusive head trauma; CT: computed tomography; ICU: intensive care unit; MRI: magnetic resonance imaging;
* The Guideline recommendations may also be valid for these settings. Further, there may be instances where Guideline recommendations inform settings that flow from acute management (e.g. discharge advice on follow-up or school concussion policies).

1.5 Funding source for the Guideline

The development, publication and dissemination of this Guideline was made possible with funding support from the National Health and Medical Research Council (NHMRC) Centre of Research Excellence grants for Paediatric Emergency Medicine (GNT 1058560/GNT1171228) Canberra, Australia, administered by the Murdoch Children's Research Institute, and from the Royal Children's Hospital Foundation, Melbourne, Australia. The views and interests of the funding bodies did not influence the final recommendations.

1.6 Structure of this Guideline

The evidence tables are presented by clinical question, grouped under three topics, to match the Guideline sections:

- triage
- imaging
- discharge.

For each question, seven elements are presented, in the order shown below.

1. PREDICT question

The clinical question developed by the GWG for the PREDICT Guideline is presented first.

2. Source question

The source guideline clinical question that most closely aligns with the PREDICT question is presented immediately after the PREDICT question, to allow for a comparison of the two questions.

3. Source recommendation

The recommendation(s) associated with the source guideline clinical question is listed and is highlighted with green shading.

4. Source evidence

The evidence supporting the source guideline recommendations is presented and is referred to as source evidence.

5. New evidence

Citations for the new evidence are listed. Those studies deemed key to answering the PREDICT question are highlighted, along with a rationale for their selection. Data extracted from the key studies are included in tables.

6. Key considerations for assessing the evidence

Key elements of the decision-making by the GWG in relation to the evidence are presented.

7. Guideline Working Group recommendation deliberations

A clinical judgement form was completed by the GWG for each question, to assist in the steps to be undertaken to consider the appropriateness of adopting, adapting or creating new recommendations.

The four source guidelines are discussed in Section 2. One of those four guidelines (NICE CG176, referred to as NICE 2014) underwent surveillance searches in 2016, and a surveillance report was published in 2017 (referred to as NICE 2017). Where subsequent evidence was identified for a question but was not incorporated into the original 2014 body of evidence, the narrative synopses provided within the surveillance report for each study were reviewed and data were extracted from these synopses, as well as from full text articles where necessary, to ensure that the relevant information was available to the Guideline developers.

2 Methodology – approach to Guideline development

2.1 Governance of the Guideline development process

At the commencement of the development of this Guideline, a Guideline Steering Committee (GSC) was formed. The GSC comprised 7 members, including representatives from the following speciality groups: paediatric emergency physicians, paediatricians, and researchers (including an implementation scientist). The GSC developed governance processes, including terms of reference (Appendix B) and conflict of interest management processes (Appendix C). The Committee also formulated the draft scope of the Guideline based on committee expertise and qualitative and quantitative input. The GSC advised on the formation of the multidisciplinary GWG, which comprised 25 representatives from key stakeholder groups, including emergency physicians, paediatricians, neurosurgeons, paediatric neurologists, sports medicine doctors, retrieval specialists, radiologists, nurse/nurse practitioners, neuropsychologists, general practitioners, ambulance staff, implementation scientists and consumers. All members of the GSC joined the GWG. Members were from a mixture of metropolitan and non-metropolitan centres, and included representatives from across states of Australia (New South Wales, South Australia, Northern Territory, Queensland, Victoria and Western Australia) and New Zealand. The GWG provided expert guidance, contextual information and interpretation of evidence syntheses; also members participated in two face-to-face GWG meetings and various remote follow-up meetings as required. Disclosures of conflict of interests were declared by each member and were updated as required at each meeting and following completion of the Guideline.

2.2 Guideline development process

Several existing evidence-based guidelines developed outside of Australia and New Zealand on the acute management of mild to moderate head injuries in children were available. Therefore, it was proposed that the content in the Australian and New Zealand Guideline be drawn from one or more of these existing evidence-based guidelines. Although we had initially envisaged using a standard GRADE (Grading of Recommendations, Assessment, Development and Evaluations)-ADOLOPMENT process (4), it became evident that the existing evidence-based guidelines were themselves either not developed using GRADE or did not provide sufficient information to apply the GRADE-ADOLOPMENT process. Furthermore, not all clinical questions were addressed in the existing evidence-based Guidelines, to cover the required scope of the proposed PREDICT Guideline. We therefore subsequently developed the PREDICT Guideline following a process modified from steps in the GRADE-ADOLOPMENT (4) and ADAPTE Guideline development (27) frameworks, whereby some recommendations were adopted or adapted from relevant sections of the existing evidence-based guidelines (with or without contextualisation), and some were developed de novo, based on a systematic review of the literature or consensus. The choice on whether to adopt, adapt or develop new recommendations was influenced by the quality and suitability of the source clinical practice guidelines and the questions posed for this Guideline.

2.3 Search for existing evidence-based guidelines

An online and database search was conducted for national and international guidelines relevant to the acute management of mild to moderate head injuries in children. In addition, we consulted with head injury experts worldwide to identify any relevant guidelines that may not have been captured by the online and database search. The detailed guideline search terms are available in Appendix D. The initial purpose of reviewing existing evidence-based guidelines was to identify potential questions, recommendations or evidence to inform the PREDICT Guideline.

The following guideline inclusion criteria were discussed and agreed upon:

- Scope: to include mild to moderate head injuries in children. Guidelines solely focused on severe head injury or adult only head injury were excluded.
- Setting: developed countries with established trauma systems. Pre-hospital, community, sports field, rehabilitation or intensive care management only were excluded.
- Relevance: published in the past 5 years (January 2013 onwards) and published in English.

This initial search in October 2018 identified 1,331 citations. Seven guidelines met the inclusion criteria: *Scandinavian Guidelines for Initial Management of Minor and Moderate Head Trauma in Children* (Scandinavian Guideline) (28), Consensus Statement on Concussion in Sport – the 5th International Conference on Concussion in Sport held in Berlin, October 2016 (Berlin Guideline) (24, 29), *Head Injury Triage, Assessment and Early Management of Head Injury in Children, Young People and Adults* (NICE Guideline) (30), *Italian Guidelines on the Assessment and Management of Pediatric Head Injury in the Emergency Department* (Italian Guideline) (31), *Guidelines for Diagnosing and Managing Pediatric Concussion* (ONF Guideline) (32), *Centers for Disease Control and Prevention Guideline on the Diagnosis and Management of Mild Traumatic Brain Injury among Children* (CDC Guideline) (33) and the American College of Radiography (ACR) *ACR Appropriateness Criteria Head Trauma-Child* (ACR Guideline) (34). None of the guidelines were specifically developed for the Australian and New Zealand setting. The search was re-run in February 2019, resulting in an additional 1803 citations, although no further guidelines were identified.

2.4 Quality assessment of existing evidence-based guidelines

A screen of the existing evidence-based guidelines was conducted (by two appraisers) to assess the quality of identified guidelines, using screening questions 7 and 12 from the Appraisal of Guidelines for Research & Evaluation II (AGREE II) tool (with adjudication between 2 appraisers when necessary) (35). The AGREE II tool assesses the methodological rigour and transparency with which a guideline is developed; it does not assess the quality or suitability of the recommendations. Using the AGREE II tool, the seven candidate guidelines listed in Section 2.3 were narrowed down to four possible guidelines from which to draw evidence or recommendations: the Berlin Guideline, Italian Guideline, CDC Guideline and NICE Guideline (24, 29-31, 33). Selection of these existing evidence-based guidelines was based on the quality of the guideline methodology, appropriateness of the questions in the source guidelines to the scope of the proposed PREDICT Guideline, currency of the literature and relevance of the context of the existing guideline to Australia and New Zealand.

2.5 Question generation

The GWG conducted a face-to-face meeting in February 2019, to confirm the Guideline scope and the clinical questions that would be included in the Guideline. Three sub-groups were formed; Working Group 1 (WG1) focused on triage, Working Group 2 (WG2) focused on imaging and Working Group 3 (WG3) focused on discharge and concussion. Recommendations from existing guidelines were mapped to broad topic areas and questions were generated during the Working Group meetings. The Working Groups formulated 33 questions, in PICO (patient/population, intervention/indicator, comparison and outcome) format, regarding the management of mild to moderate head injury in children presenting to hospital in Australia and New Zealand: 2 questions for triage, 17 questions for imaging and 14 questions for discharge and concussion.

2.6 Data extraction from existing guidelines

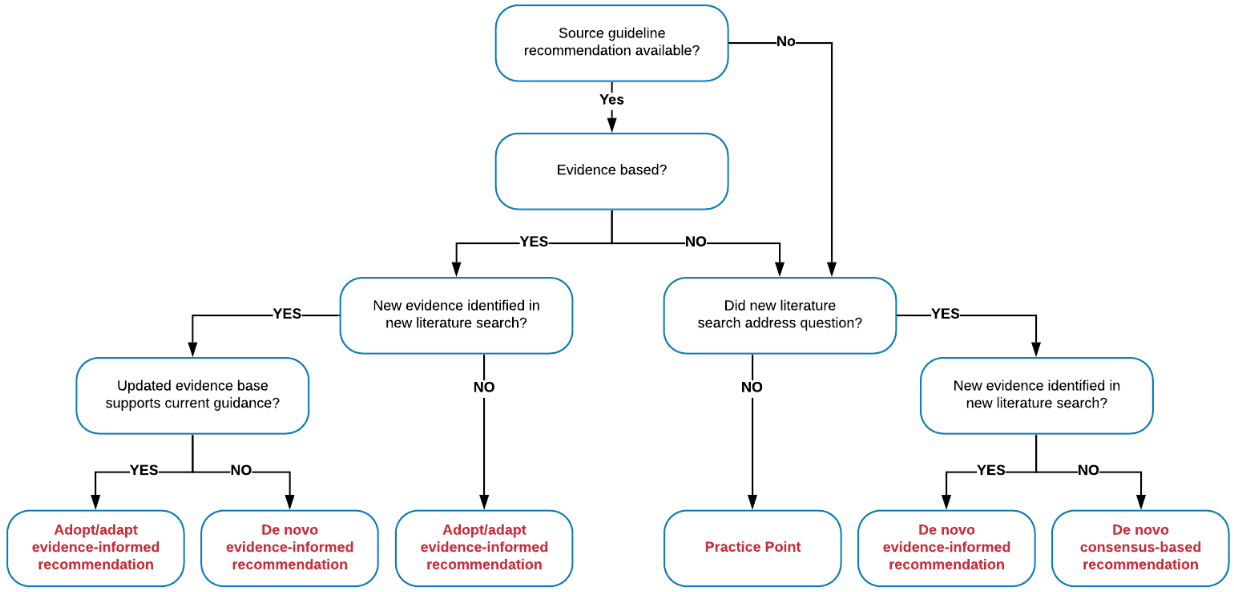
Information was collated about the scope of each of the four existing evidence-based guidelines (24, 29-31, 33) in terms of topics (and sub-topics) that were included, and topics that were not covered. This information was assessed and summarised, along with mapping of relevant guideline recommendations to the 33 questions developed by the GWG based on the appropriateness of the guideline to the individual questions, currency of the literature, access to evidence tables, context and relevance to Australia and New Zealand. On a guideline-specific basis, information about the development process was also taken into consideration, including the methods used to assess the evidence and to develop and grade the recommendations when assessing the suitability of source guidelines and recommendations for adoption or adaptation.

Recommendations and consensus statements from existing evidence-based guidelines were also mapped according to broad topic areas and according to special populations or settings. For each of the existing evidence-based guidelines, explicit evidence gaps with respect to the 33 questions developed by the GWG and research recommendations were also collated.

2.7 Consideration of evidence supporting existing guideline recommendations

The next step in the Guideline development process involved consideration of the evidence supporting the recommendations within existing evidence-based guidelines. The Working Groups assessed whether the existing evidence was appropriate to address the 33 questions posed in the PREDICT Guideline. There were several components of the existing evidence-based guidelines, in addition to recommendations, that were considered when deciding whether to adopt or adapt source (existing) recommendations. This included whether any supporting evidence was summarised, appraised or synthesised, the overall certainty of the evidence of effects, transparency of clinical judgements of the guideline development group on the body of evidence, and documentation of the decision-making process.

A flow chart of the process used to develop recommendations in the PREDICT Guideline is provided in the diagram below and is also described in the text below.



2.8 Updated literature search

The literature search date for the four-existing evidence-based guidelines was out of date by 3 to 4 years (24, 29-31, 33). An updated literature search was therefore conducted in May 2019 to review any new publications relevant to head injury in children. The search strategy was deliberately kept broad in order to capture all relevant head injury publications addressing any of the 33 guideline questions for the PREDICT Guideline. The search was conducted in the following electronic databases – MEDLINE, Embase, PsycInfo, Pubmed, Cochrane Library – which were searched for relevant articles published between 01 Jan 2015 and 28 May 2019 (the full search strategy is available in Appendix E).

The search identified 23,701 records. After removal of duplicates, the title and abstract of each record was reviewed in duplicate by GSC members to identify possible relevance. A total of 1,027 records were subsequently selected for full text review, and these were reviewed in duplicate by two GSC members. The reviewers focused in particular on relevance to the 33 questions, with adjudication by a third member when necessary in cases of non-agreement. Upon completion of this process, 440 new studies met the inclusion criteria for the PREDICT Guideline and, of these, 295 studies were specifically relevant to the Guideline questions: 29 were relevant to the questions in WG1, 169 to the questions in WG2, and 97 to the questions in WG3 (some studies were relevant to more than one Working Group).

2.9 Selection of key new evidence

The new evidence was appraised by the respective WGs in light of the existing evidence. WG appraisers decided to include new evidence to support a recommendation in the PREDICT Guideline, depending upon the relevance of the new evidence to the overall evidence from the existing evidence-based guidelines, and the Australian and New Zealand clinical setting. For example, if there was an existing strong recommendation supported by high quality evidence, the new evidence would need to inform the question, address the primary outcome and be high quality to be included in the overall body of evidence. However, if the evidence supporting an existing recommendation was weak, or there was uncertainty, or the existing evidence did not address the primary outcome, then the appraisers could decide to rely entirely on the new evidence to address the question.

Once a decision was made to include a new study, data were extracted and tabulated for each key new study. Evidence tables and grouped summaries of evidence were prepared of the key included new studies. The new evidence was then appraised and considered in light of the current body of evidence supporting the source recommendations.

2.10 Adoption or adaptation of recommendations, or development of de novo recommendations

Recommendations were developed through either adoption or adaptation of existing recommendations, or the development of entirely new recommendations. The source recommendations were adopted or adapted depending upon agreement of the GWG with the evidence synthesis from the relevant existing evidence-based guideline and the new evidence tables and summaries. The distinction between an adopted and an adapted recommendation is not always obvious in the literature. The NHMRC advises that minor editorial changes may be made to adopted recommendations to ensure they are consistent with the rest of the guideline (3). This process of distinction between adoption and adaption was followed. The decision to adapt a recommendation rather than adopt it verbatim was often related to its transferability to the Australian and New Zealand clinical setting. Although there is some flexibility to amend the wording of an adopted recommendation to reflect local issues, needs and context, adopted recommendations must stay true to the evidence on the balance of benefits and harms in the relevant existing evidence-based guideline to be valid. It was therefore critical that the source recommendations from the existing evidence-based guidelines were not considered in isolation of the underlying evidence base.

If no evidence or recommendations were available from the four existing evidence-based guidelines, a new recommendation was developed involving a process of consensus. New recommendations were drafted based on the Working Groups' interpretation of the available evidence, considering the balance of benefits and harms between different courses of action. The net benefit over harm (clinical effectiveness) was considered. The assessment of net benefit was moderated by the importance placed on the outcomes (the group's values and preferences) and the confidence the Working Group had in the evidence (evidence quality).

When evidence was of poor quality, conflicting or absent, the Working Group drafted recommendations based on information available and their consensus expert opinion. The considerations for making consensus-based recommendations included the balance between potential harms and benefits, current practices, recommendations made in other relevant guidelines despite the lack of high-quality evidence, patient preferences and equity issues. The group also considered the potential harm of failing to make a clear recommendation. In a few circumstances (2 of the 33 questions) other sources (Austroads/National Transport Commission, Australia, and American Academy of Pediatrics) were referred to in the final evidence summaries, and informed the final recommendations, even if they were outside of the scope of the search methodology.

A rationale explaining the development of each recommendation was developed by the Working Groups, detailing the existing relevant evidence, and giving a description and rationale for the inclusion of key evidence.

International and local subject matter experts were consulted on the recommendations, rationale and key evidence selection to ensure there was no key missing evidence. In September 2019, the Working Groups became aware of an update of the *ONF Guidelines for Diagnosing and Managing Pediatric Concussion* (36). In the interests of currency, that guideline was reviewed for suitability and quality. The ONF Guideline was assessed as high quality and the wording of the recommendations and supporting evidence were checked for any potential discrepancies. It was deemed that the recommendations and supporting evidence of the ONF Guideline were aligned with this Guideline. In the process of developing recommendations on children with bleeding disorders, the GWG consulted with haematology experts. The Italian SIMEUP position statement on head injury in children with coagulation disorders was recommended as a source of information (37).

2.11 Grading of recommendations

The wording of final recommendations was agreed upon by the GWG and reflected the 'strength' of the evidence behind the final recommendation. As with the GRADE approach, the criteria for determining the strength of a recommendation used by the GWG was based on a consideration of the balance of desirable and undesirable consequences, quality of evidence, values and preferences of those affected, and resource use. A 'strong' recommendation applied to situations where the GWG believed that the benefits clearly outweigh the harms for most people and was supported by high quality evidence. Similarly, a negative recommendation may have been appropriate if the harms clearly outweigh the benefits for most people. A second face-to-face meeting was held in November 2019 where all GWG members had opportunity to review and contribute to wording of the draft recommendations.

2.12 Formulation and classification of recommendations

The types of guidance are classified as either:

- evidence-informed recommendations (based on evidence);

- consensus-based recommendations (based on consensus where evidence was limited or did not exist); or
- practice points (based on consensus where evidence was not sought).

Rather than applying a recommendation grading system, the strength of recommendations was captured in the wording as advised in NICE's *The Guidelines Manual* (see Section 9.3.3 *Reflect the strength of the recommendation*) (38).

2.13 Consultation and finalisation

The draft Guideline was sent to key stakeholders (relevant colleges, learned bodies, clinicians, consumers, policy makers) within Australia and New Zealand. Feedback was incorporated into the final Guideline.

3 PREDICT Guideline questions

3.1 Questions listed by research area

Table 3.1.1 Research questions by research area

Question	Research question
Triage	
Triage Q1	In infants and children with mild to moderate head injury presenting within 72 hours of injury, are there pre-hospital clinical criteria to determine which children should be assessed in a hospital setting?
Triage Q2	In infants and children presenting with mild to moderate head injury within 72 hours of injury and a radiologically proven traumatic intracranial lesion, which patients require (i) a neurosurgical consultation and/or (ii) transfer?
Imaging	
Imaging Q1	In infants and children with mild to moderate head injury presenting i) within 24 hours, or ii) between 24 and 72 hours, of injury what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/ does not need a cranial CT?
Imaging Q2	In infants and children with a ventricular shunt and mild to moderate head injury presenting within 72 hours of injury, which should undergo i) a cranial CT and/or ii) a shunt series and/or iii) a period of observation?
Imaging Q3	In infants and children on anticoagulant or antiplatelet therapy, or with a known bleeding disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?
Imaging Q4	In infants and children with a neurodevelopmental disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?
Imaging Q5	In children with mild to moderate head injury who are drug or alcohol intoxicated presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?
Imaging Q6 (a)	In infants and children with mild to moderate head injury presenting within 72 hours of injury who does/does not require an initial cranial CT, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?
Imaging Q6 (b)	In infants and children with mild to moderate head injury presenting within 72 hours of injury who do not receive an initial cranial CT, but received a period of observation, what is the optimal frequency of reassessment and duration of observation?
Imaging Q7 (a)	In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for radiologically proven traumatic intracranial lesion, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?
Imaging Q7 (b)	In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for a radiologically proven traumatic intracranial lesion, who received a period of observation, what is the optimal frequency of reassessment and duration of observation?
Imaging Q8	In infants and children with mild to moderate head injury and a negative initial cranial CT or MRI for an intracranial injury with persistent symptoms, who should undergo repeat neuroimaging?
Imaging Q9	In infants and children with mild to moderate head injury, presenting within 72 hours of injury with suspected NAI, i) who should undergo cranial imaging and ii) which modality should be used for initial imaging?
Imaging Q10	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a skull x-ray prior to, or in lieu of a cranial CT?
Imaging Q11	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo ultrasound of the skull in the ED prior to, or in lieu of, a cranial CT?
Imaging Q12	In infants with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a transfontanelle cerebral ultrasound in the ED prior to, or in lieu of a cranial CT?
Imaging Q13	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo MRI in lieu of a cranial CT?
Imaging Q14	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo biomarker testing prior to a cranial CT?
Imaging Q15	In infants and children with mild to moderate head injury presenting within 72 hours of injury who undergo a cranial CT scan, what are the i) appropriate CT protocols/techniques and/or ii) to what extent should the cervical spine be included in the imaging?
Discharge	
Discharge Q1	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and pragmatic considerations (distance/time to travel, capacity to contact hospital) required for safe discharge from the ED or hospital?

Question	Research question
Discharge 2(a)	In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning an acute intracranial injury?
Discharge 2(b)	In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning possible post concussive symptoms?
Discharge Q3	In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital without evidence of radiologically proven traumatic intracranial lesion, which require follow-up for an acute intracranial injury?
Discharge Q4 (a)	In In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, which require follow-up for post concussive symptoms?
Discharge Q4 (b)	In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post concussive symptoms, what type of follow-up should it be?
Discharge Q4 (c)	In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post concussive symptoms, when should they be followed-up?
Discharge Q5 (a)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to sport should be provided to children and their caregivers?
Discharge Q5 (b)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning physical activity or play should be provided to children and their caregivers?
Discharge Q5 (c)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to school and cognitive activity should be provided to children and their caregivers?
Discharge Q5 (d)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning screen time should be provided to children and their caregivers?
Discharge Q5 (e)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to driving/operating machinery should be provided to children and their caregivers?
Discharge Q5 (f)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child’s school?
Discharge Q5 (g)	In children diagnosed with repeat concussion who are discharged from the ED or hospital, what distinct discharge advice should be provided to children and their caregivers?

4 Triage (Working Group 1)

4.1 Triage Q1 – In infants and children with mild to moderate head injury, presenting within 72 hours of injury, are there pre-hospital clinical criteria to determine which children should be assessed in a hospital setting?

4.1.1 PREDICT question

PREDICT Guideline triage Q1

In infants and children with mild to moderate head injury, presenting within 72 hours of injury, are there pre-hospital clinical criteria to determine which children should be assessed in a hospital setting?

4.1.2 Source question

NICE CG176 Section 6.7

What is the effectiveness of pre-hospital assessment tools for selecting adults, infants and children with head injury, for transport direct to specialist neuroscience care or a major trauma centre with neuroscience if the nearest hospital does not provide these?

4.1.3 Source recommendations

NICE CG176 Recommendation 25

Transport patients who have sustained a head injury directly to a hospital that has the resources to further resuscitate them and to investigate and initially manage multiple injuries (a trauma unit or major trauma centre). All acute hospitals receiving patients with head injury directly from an incident should have these resources, which should be appropriate for a patient's age.

Developed: 2014

4.1.4 Source evidence

The reviewers for the NICE CG176 Guideline searched for 'any cohort studies investigating the diagnostic accuracy of decision rules or triage tools in selecting which people with suspected head injury should be directly transported to a centre with neuroscience facilities.' They reported that no direct evidence was identified, but that details of excluded indirect evidence can be found in the exclusion list and in the linking evidence to recommendation section of NICE CG176.

4.1.5 New evidence

Six studies relevant to this question were identified in the PREDICT Guideline literature search (Table 4.1.1). Of these, three are key studies.

Table 4.1.1 New evidence identified for triage Q1

Ref #	Citation
1.	Ament JD, Greenan KN, Tertulien P, Galante JM, Nishijima DK, Zwienenberg M. Medical necessity of routine admission of children with mild traumatic brain injury to the intensive care unit. Journal of Neurosurgery Pediatrics. 2017;19(6):668–74.
2.	Fishe JN, Luberti AA, Master CL, Robinson RL, Grady MF, Arbogast KB, et al. After-Hours Call Center Triage of Pediatric Head Injury: Outcomes After a Concussion Initiative. Pediatric Emergency Care. 2016;32(3):149–53.
3.	Ohbuchi H, Hagiwara S, Hirota K, Koseki H, Kuroi Y, Arai N, et al. Clinical Predictors of Intracranial Injuries in Infants with Minor Head Trauma. World Neurosurgery. 2017;98:479–83.
4.	Parameswaran A, Heitner S, Thosar D, Fowler A, Marks S, O'Leary F. Trial of life: Well infants presenting more than 24 h after head injury with a scalp haematoma: A 10-year review. Journal of Paediatrics & Child Health. 2018;54(11):1193–8.
5.	Snyder CW, Danielson PD, Gonzalez R, Chandler NM. Computed tomography scans prior to transfer to a pediatric trauma center: transfer time effects, neurosurgical interventions, and practice variability. The Journal of Trauma and Acute Care Surgery. 2019.
6.	Yengo-Kahn AM, Hale AT, Zalneraitis BH, Zuckerman SL, Sills AK, Solomon GS. The Sport Concussion Assessment Tool: a systematic review. Neurosurgical Focus. 2016;40(4):E6.

Shaded rows indicate key studies.

4.1.5.1 Rationale for selection of key evidence

Three of the six new studies were selected as key evidence for this question based on the rationale that they addressed predictive factors in the pre-hospital setting or factors influencing transfer to a specialist trauma centre. One was a systematic review of Sports Concussion Assessment Tools (39) and two were retrospective chart review studies (40, 41).

Yengo-Kan's systematic review of Sports Concussion Tools identified 36 studies in children, the majority of which were prospective cohort studies or retrospective cross-sectional studies. The diagnostic value of sports related concussion tools specifically for determination of need for hospital assessment has not been studied.

Parameswaran et al (40) retrospectively studied 157 infants who presented more than 24 hours after head injury with scalp haematoma and found that, although there was a high prevalence of infants with radiological confirmed skull fracture, there were none that required neurosurgical intervention. Infants with mild head injury and scalp haematoma presenting later need not be managed differently from patients presenting earlier.

Snyder et al (41) retrospectively studied 2,947 patients aged 3 to 12 years with head injury who were transferred from a non-trauma centre to a single paediatric trauma centre for neurosurgical review. The risk of neurosurgical intervention was low for patients with a GCS score 15 and transfer times were delayed for those in whom a pre-transfer CT scan was performed.

4.1.5.2 Key evidence data extraction

Table 4.1.2 Data from key evidence for triage Q1

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Parameswaran, A, 2018 Trial of life: Well infants presenting more than 24 h after head injury with a scalp haematoma: A 10-year review. Journal of Paediatrics & Child Health. 2018;54(11):1193–8. **Country** Sydney, Australia **Study Type** Retrospective chart review **Aim of the study** To review the investigation, patterns of injury and short-term outcomes of infants younger than 12 months of age who presented more than 24 h after head injury with an isolated scalp haematoma.	**Sample:** Source: 2433 records 2006–2016 N= 157 met criteria **Characteristics** Infants <12mths with head injury, presenting to ED > 24hrs after injury, were well and had scalp haematoma. Mean age 7.5 mths	Nil – intervention epidemiological study	Data were abstracted from medical records using standardised tool 2433 records reviewed.	14 had a palpable skull fracture; 3 patients had a skull X-ray reported as a fracture; 13 patients had cranial ultrasounds with 3 reported as having a fracture; 124 patients had computed tomography head imaging, with 112 demonstrating a fracture; and 52 patients had acute intracranial abnormalities. There were nine unplanned representations (5.7%). No patients required any neurosurgical intervention.	Infants presenting after 24 h with isolated scalp haematomas had good short-term outcomes despite a high prevalence of underlying injury on imaging. Expectant management, rather than imaging, may be a valid approach.
Snyder 2019 Computed tomography scans prior to transfer to a pediatric trauma center: transfer time effects, neurosurgical interventions, and practice variability. The Journal of Trauma and Acute Care Surgery. 2019. **Country** Florida, USA **Study Type** Retrospective chart review, epidemiological **Aim of the study** This study evaluated the association of pre-transfer CT with transfer delays, the likelihood of emergent neurosurgical intervention among patients who underwent pre-transfer head CT, and the effects of transfer distance on prevalence and regional variability of pre-transfer CT.	**Sample**: Source records: 2009–2017 N= 2947 transfer pts. **Characteristics** Children 3 – 12yrs transferred from outlying non-trauma centres to a single paediatric trauma centre.	Nil – epidemiological	Data were abstracted from medical records. Patients were categorized by undergoing pretransfer CT head alone, CT of multiple/other areas, or no CT. Transfer time (referring hospital arrival to PTC arrival) was compared between CT groups, using multivariable modelling to adjust for covariates. Neurosurgical interventions were compared between patients with normal and abnormal Glasgow Coma Scale (GCS) scores.	1,225 /2,947 (42%) underwent pre-transfer CT transfer, (29% head CT alone, 13% other/multiple CT). Transfer times were significantly longer for patients who underwent pre-transfer head CT or multiple CT (287 or 298 vs. 260 minutes, p<0.0001). Patients with normal pre-transfer GCS who received a pre-transfer head CT, the likelihood of urgent neurosurgical intervention was 1.3%. Prevalence rates of pre-transfer CT by referring centre varied from 15 -94%.	Pre-transfer CT, is associated with delays in transfer to definitive care. For patients with pre-transfer GCS 15, the risk of urgent neurosurgical intervention is very low. There is wide variability in pre-transfer CT use.

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Yengo-Kahn, 2016 The Sport Concussion Assessment Tool: a systematic review. Neurosurgical Focus. 2016;40(4):E6. **Country** Nashville, USA **Study Type** Systematic Review of SCAT studies **Aim of the study** To better understand the SCAT concussion assessment tool and evidence supporting it.	**Sample:** Search 1995-October 2015 **Characteristics:** Papers that used SCAT or, Balance Error Scoring System (mBESS) in athletes > 13years	Review of literature	Systematic Review of literature using PRISMA 36 papers met criteria 19 studies SAC 1 mBESS 16 full SCAT 0 studies able to be included in quantitative synthesis	The majority of these studies (56%) were prospective cohort studies, or retrospective cross-sectional studies. Male football players were the most common athletes studied. An analysis of the studies focused on baseline differences associated with age, sex, concussion history, and the ability to detect an SRC.	Based on this systematic review, the authors propose further, in-depth study of an already comprehensive concussion test, with acute, diagnostic, as well as long-term use.

4.1.6 Key considerations for assessing the evidence

None.

4.1.7 Working Group recommendation deliberations

Table 4.1.3 Clinical judgement form for triage Q1

PREDICT Guideline triage Q1	**In infants and children with mild to moderate head injury, presenting within 72 hours of injury, are there pre-hospital clinical criteria to determine which children should be assessed in a hospital setting?**
Source recommendation/s	
NICE CG176 (2014) UK 1 recommendation: Rec 25	**NICE CG176 Recommendation 25** Transport patients who have sustained a head injury directly to a hospital that has the resources to further resuscitate them and to investigate and initially manage multiple injuries (a trauma unit or major trauma centre). All acute hospitals receiving patients with head injury directly from an incident should have these resources, which should be appropriate for a patient's age.
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☒ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☒ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☐ Yes ☒ No ☐ Unsure ☐ N/A	
Comment: Transport to trauma unit or major trauma centre not broadly applicable in the Australian and New Zealand setting.	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? NICE CG176 Recommendation 25 ☐ Adopt source guidance ☐ Adapt source guidance ☒ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☐ Evidence-informed recommendation/s ☒ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	

PREDICT Guideline triage Q1	In infants and children with mild to moderate head injury, presenting within 72 hours of injury, are there pre-hospital clinical criteria to determine which children should be assessed in a hospital setting?
PREDICT guidance	
PREDICT consensus-based Recommendation 1	Children with head injury should be assessed in a hospital setting if the mechanism of injury was severe[18] or if they develop the following signs or symptoms within 72 hours of injury: • seizure or convulsion • double vision, ataxia, clumsiness, or gait abnormality • loss of consciousness • deteriorating level of consciousness • weakness and tingling in arms or legs • presumed skull fracture (palpable fracture, racoon eyes or Battle's sign) • vomiting[19] • severe headache • not acting normally including abnormal drowsiness, increasing agitation, restlessness or combativeness (in children aged less than 2 years, not acting normally as deemed by a parent) • occipital or parietal or temporal scalp haematoma (in children aged less than 2 years only).[20]
PREDICT consensus-based recommendation 2	Children with trivial head injury[21] do not need to attend hospital for assessment; they can be safely managed at home.[20]

Rationale

The PREDICT GWG developed **new consensus-based recommendations**. The source recommendations for the NICE CG176 Guideline were not adopted as they do not apply to the Australian and New Zealand setting due to geographic distribution of major paediatric trauma centres and feasibility of transfer to these centres for all children with mild to moderate head injuries.

The PREDICT literature search identified 6 new studies, 3 were selected as key evidence for this question based on the rationale that they addressed predictive factors in the pre-hospital setting or factors influencing transfer to a specialist trauma centre (39-41). Yengo-Kan's systematic review of Sports Concussion Tools identified 36 studies in children, the majority of which were prospective cohort studies or retrospective cross-sectional studies. The diagnostic value of sports related concussion tools specifically for determination of need for hospital assessment has not been studied.

Parameswaran 2018 (40) retrospectively studied 157 infants who presented more than 24 hours after head injury with scalp haematoma and found that although there was a high prevalence of infants with radiological confirmed skull fracture, there was none that required neurosurgical intervention. Infants with mild head injury and scalp haematoma presenting later need not be managed differently from patients presenting earlier. Snyder 2019 (41) retrospectively studied 2947 patients aged 3 to 12 years with head injury who were transferred from a non-trauma centre to a single paediatric trauma centre for neurosurgical review. The risk of neurosurgical intervention was low for patients with GCS 15 and transfer times were delayed for those in whom a pre-transfer CT scan was performed.

Limited evidence supports that the presence of scalp haematoma in infants and children with GCS 15 with mild to moderate head injury can be managed safely in the nearest hospital and not require transfer to a specialist paediatric trauma centre.

In light of the lack of evidence of pre-hospital tools to specifically determine which children with mild to moderate head injury should be seen in the acute hospital setting, PREDICT consensus-based recommendations were informed by the red flags from the SCAT5 (42) and Child SCAT5 tools (43) (recommendation 1) and PECARN study (1) definition of trivial head injuries (recommendation 2).

FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

[18] Severe mechanism of injury: motor vehicle accident with patient ejection, death of another passenger or rollover; pedestrian or bicyclist without helmet struck by motorised vehicle; falls of 1 m or more for children aged less than 2 years, and more than 1.5 m for children aged 2 years or older; or head struck by a high-impact object.

[19] A case of a single isolated vomit can be assessed in general practice.

[20] In children aged less than 2 years the signs of intracranial injury may not be apparent in the first hour.

[21] Trivial head injury includes ground-level falls, and walking or running into stationary objects, with no loss of consciousness, a GCS score of 15 and no signs or symptoms of head trauma other than abrasions.

4.2 Triage Q2 – In infants and children presenting with mild to moderate head injury within 72 hours of injury and a radiologically proven traumatic intracranial lesion, which patients require (i) a neurosurgical consultation and/or (ii) transfer?

4.2.1 PREDICT question

PREDICT Guideline triage Q2

In infants and children presenting with mild to moderate head injury within 72 hours of injury and a radiologically proven traumatic intracranial lesion, which patients require (i) a neurosurgical consultation and/or (ii) transfer?

4.2.2 Source question

The NICE CG176 (2014) Guideline does not include a clinical question addressing this issue.

4.2.3 Source recommendations

Expert opinion[22]

NICE CG176 Recommendation 62

Discuss with a neurosurgeon the care of all patients with new, surgically significant abnormalities on imaging. The definition of 'surgically significant' should be developed by local neurosurgical centres and agreed with referring hospitals, along with referral procedures.

Developed: 2003

Amended: 2014

Other associated NICE recommendations are not relevant (Recommendations 63–75) or relate to transfer process (Recommendations 77–80).

4.2.4 Source evidence

Not applicable.

4.2.5 New evidence

Twenty-five studies relevant to this question were identified in the PREDICT Guideline literature search (Table 4.2.1). Of these, 12 are key studies.

Table 4.2.1 New evidence identified for triage Q2

Ref #	Citation	Topic
1.	Arrey EN, Kerr ML, Fletcher S, Cox CS, Jr., Sandberg DI. Linear nondisplaced skull fractures in children: who should be observed or admitted? Journal of Neurosurgery Pediatrics. 2015;16(6):703–8.	Neurosurgical consultation
2.	Asan Z, Caliskan HM, Sahin Y, Sahin C, Durna F. Linear fractures of the cranium: Follow-up and management results of 442 cases. Journal of Clinical and Analytical Medicine. 2018;9(5):425–9.	Neurosurgical consultation
3.	Azim A, Jehan FS, Rhee P, O'Keeffe T, Tang A, Vercruysse G, et al. Big for small: Validating brain injury guidelines in pediatric traumatic brain injury. The Journal of Trauma and Acute Care Surgery. 2017;83(6):1200–4.	Contusions
4.	Badawy MK, Dayan PS, Tunik MG, Nadel FM, Lillis KA, Miskin M, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605.	Contusions

[22] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Ref #	Citation	Topic
5.	Blanchard A, Cabrera KI, Kuppermann N, Dayan PS. Acute Outcomes of Isolated Pneumocephali in Children After Minor Blunt Head Trauma. Pediatric Emergency Care. 2018;34(9):656–60.	Neurosurgical consultation
6.	Bonow RH, Quistberg A, Rivara FP, Vavilala MS. Intensive Care Unit Admission Patterns for Mild Traumatic Brain Injury in the USA. Neurocritical Care. 2019;30(1):157–70.	
7.	Bressan S, Marchetto L, Lyons TW, Monuteaux MC, Freedman SB, Da Dalt L, et al. A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Annals of Emergency Medicine. 2018;71(6):714–7.24E+04.	Neurosurgical consultation
8.	Burns EC, Burns B, Newgard CD, Laurie A, Fu R, Graif T, et al. Pediatric Minor Traumatic Brain Injury with Intracranial Hemorrhage: Identifying Low-Risk Patients Who May Not Benefit from ICU Admission. Pediatric Emergency Care. 2019;35(3):161–9.	Contusions
9.	Flaherty BF, Moore HE, Riva-Cambrin J, Bratton SL. Pediatric patients with traumatic epidural hematoma at low risk for deterioration and need for surgical treatment. Journal of Pediatric Surgery. 2017;52(2):334–9.	
10.	Flaherty BF, Moore HE, Riva-Cambrin J, Bratton SL. Repeat Head CT for Expectant Management of Traumatic Epidural Hematoma. Pediatrics. 2018;142(3):9.	
11.	Greenberg JK, Yan Y, Carpenter CR, Lumba-Brown A, Keller MS, Pineda JA, et al. Development and Internal Validation of a Clinical Risk Score for Treating Children with Mild Head Trauma and Intracranial Injury. JAMA Pediatrics. 2017;171(4):342–9.	
12.	Hassan S, Alarhayema AQ, Cohn SM, Wiersch JC, Price MR. Natural History of Isolated Skull Fractures in Children. Cureus. 2018;10(7):e3078.	Neurosurgical consultation
13.	Hu GW, Lang HL, Guo H, Wu L, Zhang P, Kuang W, et al. A risk score based on admission characteristics to predict progressive hemorrhagic injury from traumatic brain injury in children. European Journal of Pediatrics. 2017;176(6):689–96.	
14.	Idil H, Kirimli G, Korol G, Unluer EE. Are emergency physicians competent to interpret the cranial CT of patients younger than the age of 2 years with mild head trauma? American Journal of Emergency Medicine. 2015;33(9):1175–7.	
15.	Kommaraju K, Haynes JH, Ritter AM. Evaluating the Role of a Neurosurgery Consultation in Management of Pediatric Isolated Linear Skull Fractures. Pediatric Neurosurgery. 2019;54(1):21–7.	Neurosurgical consultation
16.	Lefort R, Hunter JV, Cruz AT, Caviness AC, Luerssen TG, Adekunle-Ojo A. Utility of Emergency Department Observation Units for Neurologically Intact Children with Head CT Abnormalities Secondary to Acute Closed Head Injury. Pediatric Emergency Care. 2017;33(3):161–5.	
17.	Lyons TW, Stack AM, Monuteaux MC, Parver SL, Gordon CR, Gordon CD, et al. A QI Initiative to Reduce Hospitalization for Children with Isolated Skull Fractures. Pediatrics. 2016;137(6):6.	Neurosurgical consultation
18.	Mackel CE, Morel BC, Winer JL, Park HG, Sweeney M, Heller RS, et al. Secondary overtriage of pediatric neurosurgical trauma at a Level I pediatric trauma center. Journal of Neurosurgery Pediatrics. 2018;22(4):375–83.	
19.	Marincowitz C, Lecky FE, Townend W, Borakati A, Fabbri A, Sheldon TA. The risk of deterioration in GCS13–15 patients with traumatic brain injury identified by computed tomography imaging: A systematic review and meta-analysis. Journal of Neurotrauma. 2018;35(5):703–18.	Neurosurgical consultation
20.	Patel SK, Gozal YM, Krueger BM, Bayley JC, Moody S, Andaluz N, et al. Routine surveillance imaging following mild traumatic brain injury with intracranial hemorrhage may not be necessary. Journal of Pediatric Surgery. 2018;53(10):2048–54.	
21.	Rai B, McCartan F, Kaninde A, Sharif F. Infants with head injuries-do all need hospital admission? Irish Journal of Medical Science. 2018;187(1):141–3.	
22.	Tallapragada K, Peddada RS, Dexter M. Paediatric mild head injury: is routine admission to a tertiary trauma hospital necessary? ANZ Journal of Surgery. 2018;88(3):202–6.	Contusions, transfer
23.	Tavor O, Boddu S, Kulkarni AV. Presenting characteristics of children who required neurosurgical intervention for head injury. Childs Nervous System. 2016;32(5):827–31.	
24.	Varano P, Cabrera KI, Kuppermann N, Dayan PS. Acute outcomes of isolated cerebral contusions in children with Glasgow Coma Scale scores of 14 to 15 after blunt head trauma. The Journal of Trauma and Acute Care Surgery. 2015;78(5):1039–43.	Contusions
25.	Yoon SY, Choi YJ, Park SH, Hwang JH, Hwang SK. Traumatic Brain Injury in Children under Age 24 Months: Analysis of Demographic Data, Risk Factors, and Outcomes of Post-traumatic Seizure. Journal of Korean Neurosurgical Society. 2017;60(5):584–90.	

Shaded rows indicate key studies.

4.2.5.1 Rationale for selection of key evidence

Twelve of the 25 new studies were selected as key evidence for this question based on the following: original research, including patients younger than 18, with a traumatic isolated linear non-displaced skull fracture, contusions and intracranial haemorrhages diagnosed by CT or MRI and the clinical outcomes were described. Studies were then selected that examined which injuries required neurosurgical consultation and which required transfer to a tertiary hospital.

4.2.5.2 Key evidence data extraction

Table 4.2.2 Data from key evidence for triage Q2

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Arrey 2015 Linear nondisplaced skull fractures in children: who should be observed or admitted? Journal of Neurosurgery Pediatrics. 2015;16(6):703–8. **Country** Houston, USA **Study design:** Retrospective record review **Study aim:** In this study the authors reviewed clinical management and outcomes in a large series of children with isolated linear nondisplaced skull fractures (NDSFs). Factors associated with hospitalization of these patients and costs of management were also reviewed.	**Source**: 2009 – 2013, single centre Children 0–16yrs who were evaluated for NDSFs Patients were excluded if the fracture was open or comminuted. Additional exclusion criteria included intracranial hemorrhage, more than 1 skull fracture, or pneumocephalus. N= 326 met criteria	Nil – epidemiological review	Data extraction from clinical records.	The median patient age was 19 months (range 2 weeks to 15 years). 193 (59%) male 133 (41%) female. One hundred eighty-four patients (56%) were placed under 23-hour observation, 87 (27%) were admitted to the hospital, and 55 patients (17%) were discharged from the emergency department. 257 fifty-seven patients (79%) were transferred from another institution. The mean hospital stay for patients admitted to the hospital was 46 hours (range 7–395 hours). No patient had any neurological deficits on examination, and none required neurosurgical intervention.	Hospitalisation is not necessary for many children with NDSFs. Patients with mental status changes, additional injuries, or possible nonaccidental injury may require observation.
Azim 2017 Big for small: Validating brain injury guidelines in pediatric traumatic brain injury. The Journal of Trauma and Acute Care Surgery. 2017;83(6):1200–4. **Country** Arizona, USA **Study Type** Prospective observational **Aim of the study** The aim of this study was to evaluate the established brain injury guidelines (BIG-1 category) for managing pediatric traumatic brain injury (TBI) patients with intracranial haemorrhage (ICH) without neurosurgical consultation.	Children <= 21yrs (normal neurologic examination, Intracranial haemorrhage<= 4mm in one location; no skull fracture) to be managed with no neurosurgery. N= 405 160 propensity score matched. (80 neurosurgical consultation; 80 no neurosurgical consultation).	Application of BIG-1 guidelines to paediatric population to determine if neurosurgical consultation required or not in participant group.	Data collected prospectively.	Primary outcome was need for neurosurgery. Mean age 9.03, 62.1% male, median GCS 15; median Abbrev. Injury scale score was 2. A subanalysis based on stratifying patients by age groups showed a decreased in the use of repeat head CT ($p = 0.02$) in the no-neurosurgical consultation (NC) group, with no difference in progression ($p = 0.34$) and the need for neurosurgical intervention ($p = 0.9$) compared with the NC group.	The BIG can be safely and effectively implemented in paediatric TBI patients. Reducing repeat head CT in paediatric patients has long-term sequelae. Likewise, adhering to the guidelines helps in reducing radiation exposure across all age groups.

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Blanchard 2018 Acute Outcomes of Isolated Pneumocephali in Children After Minor Blunt Head Trauma. Pediatric Emergency Care. 2018;34(9):656–60. **Country** Columbia USA **Study design:** A secondary analysis of a public use dataset from a multicenter prospective study of pediatric minor head trauma. **Study aim:** We aimed to determine the prevalence of, and adverse outcomes caused by pneumocephali in children with minor blunt head trauma who had no other intracranial injuries (i.e., isolated pneumocephali).	**Source**: 2004–2006 25 sites, PECARN Children <18 yrs with GCS scores of 14 or 15 and non-trivial mechanisms of injury who had cranial computed tomographies obtained. N= 14983 148 had pneumocephali	Epidemiological study	Patients with isolated pneumocephali were those without other traumatic brain injuries (TBIs) but could have non-depressed or basilar skull fractures (BSFs). We defined adverse outcomes as death, need for neurosurgery, or intubation more than 24 hours for TBI.	54 (36.5%) of 148 pneumocephali cases were isolated. Of these 54 patients, 42 (77.8%) had associated BSFs (7 of whom also had linear skull fractures) and 8 (14.8%) had associated linear skull fractures without BSFs; 4 patients (7.4%) had no fractures. Thirty-three patients (61.1%) had both GCS scores of 15 and no other signs of altered mental status. All patients with isolated pneumocephali and available descriptive data (n = 26) had small-sized pneumocephali. There were no deaths, neurosurgical interventions, or intubations for more than 24 hours for TBI (95% confidence interval for any of the outcomes, 0%–7.9%) in the 54 patients with isolated pneumocephali.	Children with isolated pneumocephali and GCS scores of 14 or 15 after minor blunt head trauma are unlikely to have adverse clinical outcomes.
Bressan 2018 A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Annals of Emergency Medicine. 2018;71(6):714–7.24. **Country** Padua, Italy **Study design** Systematic Review **Study Aim:** Our aim is to quantify the frequency of short-term adverse outcomes of children with isolated skull fractures.	PubMed, EMBASE, the Cochrane Library, Scopus, Web of Science, and grey literature 587 studies screened, the 21 that met our inclusion criteria included 6,646 children with isolated skull fractures	N/A	Two investigators independently reviewed identified articles for inclusion, assessed quality, and extracted relevant data. Our primary outcome was emergency neurosurgery or death. Secondary outcomes were hospitalization and new intracranial haemorrhage on repeated neuroimaging. Meta-analyses of pooled estimate of each outcome were conducted with random-effects models, and heterogeneity across studies was assessed.	One child needed emergency neurosurgery and no children died (pooled estimate 0.0%; 95% confidence interval [CI] 0.0% to 0.0%; I2= 0%). Of the 6,280 children with known emergency department disposition, 4,914 (83%; 95% CI 71% to 92%; I2= 99%) were hospitalized. Of the 569 children who underwent repeated neuroimaging, 6 had new evidence of intracranial haemorrhage (0.0%; 95% CI 0.0% to 9.0%; I2= 77%); none required operative intervention.	Children with isolated skull fractures were at extremely low risk for emergency neurosurgery or death but were frequently hospitalised. Clinically stable children with an isolated skull fracture may be considered for outpatient management in the absence of other clinical concerns.

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Burns 2019 Pediatric Minor Traumatic Brain Injury with Intracranial Hemorrhage: Identifying Low-Risk Patients Who May Not Benefit from ICU Admission. Pediatric Emergency Care. 2019;35(3):161–9. **Country**: Portland, USA **Study design:** Retrospective review of records Study Aim: To quantify tICH frequency and describe disposition and to identify patients at low risk of inpatient critical care intervention (CCI).	**Source**; 2008–2013 Single site level 1 trauma centre Children 0 – 17 yrs with traumatic intracranial haemorrhage (tICH). N= 296 tICH Admissions	Testing of a model for clinical decision instrument classifying patients as low risk for CCI.	The Critical Care Intervention included mechanical ventilation, invasive monitoring, blood product transfusion, hyperosmolar therapy, and neurosurgery. Binary recursive partitioning analysis led to a clinical decision instrument classifying patients as low risk for CCI. The decision instrument classified patients as low risk for CCI when patients had absence of the following: midline shift, depressed skull fracture, unwitnessed/unknown mechanism, and other nonextremity injuries.	Of 296 tICH admissions without prior CCI in the field or emergency department, 29 had an inpatient CCI. This clinical decision instrument produced a high likelihood of excluding patients with CCI (sensitivity, 96.6%; 95% confidence interval, 82.2%–99.9%) from the low-risk group, with a negative likelihood ratio of 0.056 (95% confidence interval, −0.053 to 0.166). The decision instrument misclassified 1 patient with CCI into the low-risk group, but would have impacted disposition of 164 pediatric ICU admissions through 5 years (55% of the sample).	A subset of low-risk patients may not require ICU admission. The proposed decision rule identified low-risk children with tICH who may be observable outside an ICU, although this rule requires external validation before implementation.
Flaherty, 2017 Pediatric patients with traumatic epidural hematoma at low risk for deterioration and need for surgical treatment. Journal of Pediatric Surgery. 2017;52(2):334–9. **Country** Utah, USA **Study type** Retrospective review. **Aim of study** Create a prediction rule to identify patients with Epidural haematoma (EDH) unlikely to fail hospital observation.	**Source**: 2003–2014 Single site, level 1 trauma centre N= 222 Children 0–18yrs diagnosed with Epidural Hematoma (EDH).	Application of a prediction rule	Data extraction from medical records.	196/222 (88%) were successfully observed. The group failing observation was more likely to present with altered mental status (RR 18.8; 95% CI 8.7–49.6), has larger median bleed thickness (observed= 5.6 mm versus failed observation = 10.9 mm, p < 0.01), median bleed volume (observed= 2.1 ml versus failed observation = 15.7 ml, p < 0.01), and mass effect (RR 3.7; 95%CI 1.8–7.7). No mass effect, EDH volume <15ml, and no neurologic deficits predicted patients at low risk of failing observation with a positive predictive value of 98% (95% CI 93–99%).	Patients with no mass effect and EDH volume <15ml on initial CT scan and no neurologic deficit are at low risk of failing observation.

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Hassan S 2018 Natural History of Isolated Skull Fractures in Children. Cureus. 2018;10(7):e3078. **Country** Texas, USA **Study type** Retrospective review. **Aim of study** To determine risk of requiring neurosurgery in children with isolated skull fractures.	**Source1**: 2006–2014 Single centre N= 197 **Source 2**: National Trauma Data Bank (NTDB) research data set for the years 2012–2014 N= 5194 Children 6 – 16yrs presenting to level 1 trauma centre with traumatic brain injuries, normal neurological presentation, isolated skull fractures	Nil / descriptive	Data extraction from medical records / NDTB During this study period, centre admitted 575 children with skull fractures, 197 of which were isolated	Of the 197 patients with isolated SFs, 155 had a normal neurological examination at presentation. In these patients, there were no fatalities and only three (1.9%) required surgery, all for the elevation of the depressed skull fracture. Analysing the NTDB yielded similar results. In 5,194 children with isolated SFs and a normal neurological examination on presentation, there were no fatalities and 249 (4.8%) required neurosurgical intervention, almost all involving craniotomy/ craniectomy and/or elevation of the SF segments.	In conclusion, children with non-depressed isolated skull fractures and a normal Glasgow Coma Scale (GCS) at the time of initial presentation are at extremely low risk of death or needing neurosurgical intervention.
Kommaraju, 2019 Evaluating the Role of a Neurosurgery Consultation in Management of Pediatric Isolated Linear Skull Fractures. Pediatric Neurosurgery. 2019;54(1):21–7. **Country** Richmond, USA **Study type** Retrospective chart review. **Aim of study** The purpose of this study was to determine if a pediatric neurosurgical consultation for isolated linear skull fractures (ILSF) in pediatric patients with Glasgow Coma Scale (GCS) scores of ≥14 changed their management.	Source: 10 yrs of presentations Single site N= 127 Children < 18yrs presenting to level 1 pediatric trauma centre Exclusion criteria were age > 18 years, open, depressed, or skull base fractures, pneumocephalus, poly-trauma, any haemorrhage (intraparenchymal, epidural, subdural, subarachnoid), cervical spine fractures, penetrating head trauma, and initial GCS scores ≤13	Nil – epidemiological	Data extraction from medical records Phone follow up of patients	**Primary outcomes:** • Recommendations to change level of care • Recommendations to order additional imaging studies • Neurosurgical intervention There were 127 cases of ILSF meeting study criteria with an average age of 2.36 years. Unilateral parietal bone fracture was the most common injury (46.5%). Falls were the most common mechanism (81.1%). All patients received pediatric neurosurgical consultations within 24 h of hospital arrival. There were no neurosurgical recommendations to obtain additional imaging studies, change acuity of care, or perform invasive procedures.	Routine neurosurgical consultation in children with ILSF and GCS 14–15 does not appear to alter clinical management.

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Lyons, T, 2016 A QI Initiative to Reduce Hospitalization for Children with Isolated Skull Fractures. Pediatrics. 2016;137(6):6. **Country**: Boston, USA **Study type** Single centre, retrospective chart review, phone follow up and pre/post comparison. **Aim of study** Our aim was to safely decrease the hospitalization rate for children with isolated skull fractures.	**Source**: Level 1 trauma centre, Single centre January 2008 and July 2015 Children ≤21 years, presented to the ED with minor blunt head trauma and an arrival Glasgow Coma Score ≥14 N= 321 with isolated skull fracture	QI initiative of: • Development and implementation of an evidence-based Guideline. • Dissemination of a provider survey designed to reinforce Guideline awareness and adherence.	Aim was to reduce hospital admissions for isolated skull fractures by at least 20% over a 2-year period	Primary outcome was hospitalization rate and our balancing measure was hospital readmission within 72 hours. Identified 321 children with an isolated skull fracture with a median age of 11 months (interquartile range 5–16 months). The baseline admission rate was 71% (179/249, 95% confidence interval, 66%–77%) and decreased to 46% (34/72, 95% confidence interval, 35%–60%) after implementation of our QI initiative. No child was readmitted after discharge. The admission rate in our secular trend control group remained unchanged at 78%.	The hospitalization rate for children with isolated skull fractures was reduced without an increase in the readmissions.
Marincovitz 2018 The risk of deterioration in GCS 13–15 patients with traumatic brain injury identified by computed tomography imaging: A systematic review and meta-analysis. Journal of Neurotrauma. 2018;35(5):703–18. **Country:** United Kingdom **Study design:** Systematic Review and meta-analysis using PRISMA **Study Aim:** The objective of our review and meta-analysis was to estimate the risk of death, neurosurgical intervention, and clinical deterioration in mild TBI patients with injuries identified by CT brain scan, and assess which patient factors affect the risk of these outcomes.	49 papers 5 reviews	N/A	The estimated pooled risk for the outcomes of interest were: clinical deterioration 11.7% (95% confidence interval [CI]: 8.16%–15.8%), neurosurgical intervention 3.5% (95% CI: 2.2%–4.9%), and death 1.4% (95% CI: 0.8%–2.2%)	Twenty-one studies presented within-study estimates of the effect of patient factors. Meta-regression of study characteristics and pooling of within-study estimates of risk factor effect found the following factors significantly affected the risk for adverse outcomes: age, initial Glasgow Coma Scale (GCS), type of injury, and anti-coagulation. The generalizability of many studies was limited due to population selection. Mild TBI patients with injuries identified by CT brain scan have a small but clinically important risk for serious adverse outcomes.	Research is needed to derive and validate a usable clinical decision rule so that low-risk patients can be safely discharged from the ED.

Study design	Participants	Interventions	Methods	Outcomes/results	Comments
Tallapragada 2018 Paediatric mild head injury: is routine admission to a tertiary trauma hospital necessary? ANZ Journal of Surgery. 2018;88(3):202–6. **Country**: Sydney, Australia **Study type**: Retrospective record review. **Aim of study:** To identify other injury patterns (other than isolated linear skull fractures) within the spectrum of paediatric mild head injury, which need only conservative management.	**Source:** 2009–2014. Single site N= 410 Children – 3 days to 16 years, with mild head injury (i.e. admission Glasgow Coma Score 13–15) and skull fracture or haematoma on a head computed tomography scan	Nil – epidemiological	Extraction of data from medical records. Data were collected regarding demographics, clinical findings, mechanism of injury, head computed tomography scan findings, neurosurgical intervention, outcome and length of admission.	381/410 were managed conservatively. Only 17 of 214 children transferred from peripheral hospitals needed neurosurgery. Overall outcomes: zero deaths, one needed brain injury rehabilitation and 63 needed child protection unit intervention. Seventy-five percent of children with non-surgical lesions were discharged within 2 days.	Children with small intracranial haematomas and/or skull fractures who don't need surgery and only require brief inpatient symptomatic treatment and could be safely managed in primary hospitals.
Varano, 2015 Acute outcomes of isolated cerebral contusions in children with Glasgow Coma Scale scores of 14 to 15 after blunt head trauma. The Journal of Trauma and Acute Care Surgery. 2015;78(5):1039–43. **Country**: New York, USA **Study design:** Cross sectional analysis of public dataset, prospective data, 25 sites. **Study aim:** We aimed to determine the risk of acute adverse outcomes in children with minor blunt head trauma who had cerebral contusions and no other traumatic brain injuries on computed tomography.	**Source**: PECARN public dataset Children < 18 yrs with blunt head trauma resulting from nontrivial injury mechanisms and with Glasgow Coma Scale (GCS) scores of 14 or 15. N= 54 with isolated cerebral contusions	Nil – epidemiological	Secondary analysis of prospective dataset.	The median age of those with isolated cerebral contusions was 9 years (interquartile range, 1Y13); 31 (57.4%) had a normal mental status. Of 36 patients with available data on isolated cerebral contusion size, 34 (94.4%) were described as small. 43 (79.6%) of 54 patients with isolated cerebral contusions were hospitalized, including 16 (29.6%) of 54 to an intensive care unit. No patients with isolated cerebral contusions died, were intubated longer than 24 hours for head trauma, or required neurosurgery (95% confidence interval for all outcomes, 0–6.6%).	Children with small isolated cerebral contusions after minor blunt head trauma are unlikely to require further acute intervention, including neurosurgery, suggesting that neither intensive care unit admission nor prolonged hospitalization is generally required.

4.2.6 Key considerations for assessing the evidence

None.

4.2.7 Working Group recommendation deliberations

Table 4.2.3 Clinical judgement form for triage Q2

PREDICT Guideline triage Q2	**In infants and children with mild to moderate head injury within 72 hours of injury and a radiologically proven traumatic intracranial lesion, which patients require (i) a neurosurgical consultation and/or (ii) transfer?**
Source recommendation/s	
NICE CG176 (2014) UK 1 recommendation: Rec 62	**NICE CG176 Recommendation 62** [Expert opinion] Discuss with a neurosurgeon the care of all patients with new, surgically significant abnormalities on imaging. The definition of 'surgically significant' should be developed by local neurosurgical centres and agreed with referring hospitals, along with referral procedures.
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☒ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☒ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☐ Yes ☒ No ☐ Unsure ☐ N/A	
Comment: Transport to trauma unit or major trauma centre not broadly applicable in the Australian and New Zealand setting.	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? NICE CG176 Recommendation 62 ☐ Adopt source guidance ☒ Adapt source guidance ☒ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 3	Consultation with a neurosurgical service may not be routinely required for infants and children with an isolated, non-displaced, linear skull fracture on a head CT scan without intracranial injury and a GCS score of 15.[23]
PREDICT practice point A	Children aged less than 2 years with a suspected or identified isolated, non-displaced, linear skull fracture should have a medical follow-up within 1–2 months to assess for a growing skull fracture.[24]
PREDICT practice point B	In all children presenting with mild to moderate head injury, the possibility of abusive head trauma should be considered.
PREDICT consensus-based recommendation 4	Consultation with a neurosurgical service should occur in all cases of intracranial injury or skull fracture shown on a head CT scan, other than in infants and children with an isolated, non-displaced, linear skull fracture on a head CT scan without intracranial injury and a GCS score of 15.[23]

[23] Measured using an age-appropriate GCS.

[24] A growing skull fracture is a rare complication of linear skull fractures. It tends to occur in children aged less than 2 years with a skull bone fracture, and it represents the diastatic enlargement of the fracture due to a dural tear, with herniating brain tissue or a cystic cerebrospinal fluid-filled mass underneath. In the setting of a known skull fracture, a growing fracture is indicated by any of the following: persistent boggy swelling along a fracture line; palpable diastasis; an enlarging, asymmetrical head circumference; or delayed onset neurological symptoms. This can be assessed by a neurosurgeon, paediatrician or GP who is able to assess for a growing skull fracture.

PREDICT Guideline triage Q2	In infants and children with mild to moderate head injury within 72 hours of injury and a radiologically proven traumatic intracranial lesion, which patients require (i) a neurosurgical consultation and/or (ii) transfer?

Rationale

The PREDICT GWG **adapted expert opinion recommendation 62 of the NICE CG176 Guideline** and **created a new evidence-informed recommendation.** The PREDICT literature search identified 25 new studies, 12 were selected as key evidence for this question based on the following rationale: original research, including patients younger than 18, with a traumatic isolated, nondisplaced, linear skull fracture, contusions and intracranial haemorrhages diagnosed by CT or MRI and the clinical outcomes were described. Studies were then selected that examined which injuries required neurosurgical consultation (n= 11) and which required transfer to a tertiary hospital (n= 1).

i) Neurosurgical consultation

Isolated, non-displaced, linear skull fractures. A systematic review with meta-analysis found a very low risk of adverse outcomes in this population (21 studies, 6,646 patients, mostly retrospective studies) (44).Consistent findings were reported in a further four retrospective studies (45-48). One study reported decreasing hospitalisation rates in this population of patients (49). Based on this evidence we adapted the NICE Guideline to exclude isolated, non-displaced, linear skull fracture from requiring a routine neurosurgical consultation.

Traumatic intracranial haemorrhages. A number of studies of paediatric patients with traumatic intracranial haemorrhages or contusions identified low risk patients, but were heterogeneous in nature (50-54). A systematic review and meta-analysis of 49 studies, limited to patients > 12 years of age, did not identify sufficient high quality studies to assess the level of risk for adverse outcomes in patients with traumatic brain injury (GCS 13–15) identified by head CT scan (55). No evidence-informed recommendation could be made for paediatric patients with traumatic intracranial haemorrhages or contusions, and this population is covered by Consensus-Based Recommendation 4.

Hentzen 2015 (56) and Plackett 2015 (57) (reviewed for IMAGING Q7) support this question and the recommendations.

ii) Transfer

Only one retrospective study was identified that directly addressed the need for transfer to a tertiary centre (53) and thus no evidence-based recommendation can be made. Other studies indirectly implied that no transfer was required but this was not the main objective.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☒ Yes ☐ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☐ No ☒ Unsure

Comment: Potentially there will be less patients transferred to a neurosurgical service. Local policy may be a barrier to implementation.

5 Imaging (Working Group 2)

5.1 Imaging Q1 – In infants and children with mild to moderate head injury presenting i) within 24 hours, or ii) between 24 and 72 hours, of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/ does not need a cranial CT?

5.1.1 PREDICT question

PREDICT Guideline imaging Q1

In infants and children with mild to moderate head injury presenting i) within 24 hours, or ii) between 24 and 72 hours, of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/ does not need a cranial CT?

5.1.2 Source question

NICE CG176 Section 7.3

What is the best clinical decision rule for selecting adults, infants and children with head injury for CT head scan?

5.1.3 Source recommendations

5.1.3.1 Recommendations for children and infants

NICE CG176 Recommendation 29

For children who have sustained a head injury and have any of the following risk factors, perform a CT head scan within 1 hour of the risk factor being identified:

- *Suspicion of non-accidental injury.*
- *Post-traumatic seizure but no history of epilepsy.*
- *On initial emergency department assessment, GCS less than 14, or for children under 1 year GCS (paediatric) less than 15.*
- *At 2 hours after the injury, GCS less than 15.*
- *Suspected open or depressed skull fracture or tense fontanelle.*
- *Any sign of basal skull fracture (haemotympanum, 'panda' eyes, and cerebrospinal fluid leakage from the ear or nose, Battle's sign).*
- *Focal neurological deficit.*
- *For children under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head.*

A provisional written radiology report should be made available within 1 hour of the scan being performed.

Developed: 2014

NICE CG176 Recommendation 30

For children who have sustained a head injury and have more than one of the following risk factors (and none of those in recommendation 29), perform a CT head scan within 1 hour of the risk factors being identified:

- *Loss of consciousness lasting more than 5 minutes (witnessed).*
- *Abnormal drowsiness.*
- *Three or more discrete episodes of vomiting.*
- *Dangerous mechanism of injury (high-speed road traffic accident either as pedestrian, cyclist or vehicle occupant, fall from a height of greater than 3 metres, high-speed injury from a projectile or other object).*
- *Amnesia (antegrade or retrograde) lasting more than 5 minutes.*

A provisional written radiology report should be made available within 1 hour of the scan being performed.

Developed: 2014

NICE CG176 Recommendation 31

Children who have sustained a head injury and have only 1 of the risk factors in recommendation 30 (and none of those in recommendation 29) should be observed for a minimum of 4 hours after the head injury. If during observation any of the risk factors below are identified, perform a CT head scan within 1 hour.

- *GCS less than 15.*
- *Further vomiting.*
- *A further episode of abnormal drowsiness.*

A provisional written radiology report should be made available within 1 hour of the scan being performed. If none of these risk factors occur during observation, use clinical judgement to determine whether a longer period of observation is needed.

Developed: 2014

5.1.3.2 General recommendations

Only those recommendations relevant to children and infants are shown.

5.1.4 Source evidence

5.1.4.1 NICE CG176 (2014)

Table 5.1.1 NICE CG176 (2014) clinical evidence for diagnostic accuracy of CT decision rules for children

Decision rule	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (i)	Specificity % (i)	PPV %	NPV %	Quality
Outcome: Intracranial Injury																
NEXUS II[196]	1	Diagnostic cohort	1666	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	136	1298	2	230	99	15	9	99	High
CHALICE[74]	1	Diagnostic cohort	22579	Serious limitations[(b, c)]	No serious inconsistency	No serious indirectness	No serious imprecision	164	2853	4	19558	98	87	5	100	Moderate
Pilot PECARN [201,262]	2	Diagnostic cohort	3709	Serious limitations[(a)]	No serious inconsistency	No serious indirectness	No serious imprecision	230	1987	13	1479	91–100	43	13–86	98–100	Moderate
PECARN > 2 years; < 18 years[151,92]	2 [(d)]	Diagnostic cohort	42109	Serious limitations[(b)]	No serious inconsistency	No serious indirectness	No serious imprecision	503	15506	21	26079	95–97	58–75	2–8	100	Moderate
Atabaki 2008[12]	1	Diagnostic cohort	1000	Serious limitations[(e)]	No serious inconsistency	No serious indirectness	No serious imprecision	62	478	3	457	95	49	11	99	Moderate
CATCH rule[199,200]	1 [(d)]	Diagnostic cohort	7647	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	323	3653	6	3665	98	50	7–8	99–100	High
CATCH rule[198]	1	Diagnostic cohort	4060	Serious limitations[(i)]	No serious inconsistency	No serious indirectness	No serious imprecision	193	1331	4	2520	98	65	13	99	Moderate
Da Dalt 2006[55]	1	Diagnostic cohort	3798	Serious limitations[(f)]	No serious inconsistency	No serious indirectness	No serious imprecision	22	478	0	3298	100	87	4	100	Moderate
Dietrich 1993[67]	1	Diagnostic cohort	156	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	16	150	0	0	100	0	10	0	High
Guzel 2009[104]	1	Diagnostic cohort	337	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	46	154	21	116	69	43	23	85	High
NOC[118]	1	Diagnostic cohort	175	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	14	120	0	41	100	25	10	100	High
Quayle 1997[214]	1	Diagnostic cohort	321	No serious limitations	No serious inconsistency	No serious indirectness	Serious imprecision [(g)]	12	43	15	251	44	85	22	94	Moderate
RCS Guidelines[74]	1	Diagnostic cohort	22772	Serious limitations[(b, c)]	No serious inconsistency	No serious indirectness	No serious imprecision	242	1219	39	21272	86	95	17	99	Moderate

Decision rule	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (i)	Specificity % (i)	PPV %	NPV %	Quality
Outcome: Neurosurgery																
Atabaki 2008[12]	1	Diagnostic cohort	1000	Serious limitations[(e)]	No serious inconsistency	No serious indirectness	Serious imprecision [(g)]	6	534	0	460	100	46	1	100	Low
CATCH rule[199,200]	1 [(d)]	Diagnostic cohort	7646	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	50	2255	0	5341	100	70	2	100	High
CATCH rule[198]	1	Diagnostic cohort	4060	Serious limitations[(i)]	No serious inconsistency	No serious indirectness	No serious imprecision	20	538	3	3487	87	87	4	100	Moderate
CHALICE[74]	1	Diagnostic cohort	22772	Serious limitations[(b)]	No serious inconsistency	No serious indirectness	No serious imprecision	134	3076	3	19559	98	86	4	100	Moderate
NOC[118]	1	Diagnostic cohort	175	No serious limitations	No serious inconsistency	No serious indirectness	Serious imprecision [(g)]	6	128	0	41	100	24	4	100	Moderate
Pilot PECARN [201]	1	Diagnostic cohort	2043	Serious limitations[(a)]	No serious inconsistency	No serious indirectness	No serious imprecision	29	719	0	1295	100	64	4	100	Moderate
PECARN > 2 years, < 18 years[151]	1	Diagnostic cohort	6411	Serious limitations[(b)]	No serious inconsistency	No serious indirectness	Serious imprecision [(g)]	11	2600	0	3800	100	59	0.4	100	Low

(a) Unclear reference standard – length of follow-up not specified. CT or performance of intervention (62.2%).
(b) Method of patient selection is not reported. Unclear if patients were selected consecutively or randomly, therefore there is potential patient selection bias.
(c) Unclear reference standard – length of follow-up not specified. All patients treated according to RCS Guidelines. This recommends admission for those at high risk and CT scan for those at highest risk (3%). Follow-up: all patients who were documented as having had a skull radiograph, admission to hospital, CT scan or neurosurgery were followed up.
(d) Study reports both derivation and validation in different patients.
(e) Patients selected using a convenience sample rather than included consecutively or randomly, therefore there is potential patient selection bias.
(f) Inadequate reference standard. CT scan obtained at discretion of treating physician (2%). All children discharged immediately from ER or after short observation received a follow-up. Telephone interview approximately 10 days later. Hospital records were checked for readmissions for 1 month after conclusion of study.
(g) The wide range of confidence intervals around the point estimate of the sensitivity in the study increases the uncertainty of the actual diagnostic accuracy.
(h) Study is an abstract only.
(i) Relates to a sensitivity or specificity for a single study or a range of sensitivities or specificities when more than 1 study.

Source: NICE CG176 (2014) Table 9 (pp99–101)
Note: Study reference numbers refer to reference list in NICE CG176 (2014).

Table 5.1.2 NICE CG176 (2014) clinical evidence for diagnostic accuracy of CT decision rules for infants

Decision rule	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (h)	Specificity % (h)	PPV %	NPV %	Quality
Outcome: Intracranial Injury																
Pilot PECARN [201,262]	2	Diagnostic cohort	402	Serious limitations[(c)]	No serious indirectness	Serious imprecision [(d)]	Serious imprecision [(d)]	22	298	0	82	100	11–34	4–11	100	Low

Decision rule	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (h)	Specificity % (h)	PPV %	NPV %	Quality
PECARN [151,92]	2 [(a)]	Diagnostic cohort	15435	Serious limitations[(b)]	No serious indirectness	No serious imprecision	No serious imprecision	114	6666	1	8654	99–100	54–63	2–63	100	Moderate
Buchanich 2007[38]	1	Diagnostic cohort	97	Serious limitations[(e)]	No serious indirectness	No serious imprecision	No serious imprecision	22	45	0	30	100	40	33	100	Moderate
Dietrich 1993[67]	1	Diagnostic cohort	19	No serious limitations	No serious indirectness	Serious imprecision [(d)]	Serious imprecision [(d)]	1	15	0	3	100	17	6	100	Moderate
Greenes and Schutzman 1999[99]	1	Diagnostic cohort	608	Serious limitations[(f)]	No serious indirectness	Serious imprecision [(d)]	Serious imprecision [(d)]	16	161	14	417	53	72	9	97	Low
Greenes and Schutzman 2001[100]	1	Diagnostic cohort	172	Serious limitations[(f)]	No serious indirectness	No serious imprecision	No serious imprecision	13	96	0	63	100	40	12	100	Moderate
NEXUS II[84,196]	2	Diagnostic cohort	2741	Serious limitations[(g)]	No serious indirectness	No serious imprecision	No serious imprecision	41	1273	2	1425	89–100	5–59	2–9	99–100	Moderate
Fabbri 2011[84]	1	Diagnostic cohort	239	Serious limitations[(g)]	No serious indirectness	No serious imprecision	No serious imprecision	18	566	0	1807	100	76	3	100	Moderate
Outcome: Neurosurgery																
PECARN > 2 years; <18 years[151]	1 [(a)]	Diagnostic cohort	2216	Serious limitations[(b)]	No serious inconsistency	No serious indirectness	Serious imprecision [(d)]	5	1035	0	1176	100	53	0.5	100	Low

(a) Study reports both derivation and validation in different patients.
(b) Method of patient selection is not reported. Unclear if patients were selected consecutively or randomly, therefore there is potential patient selection bias.
(c) Unclear reference standard – length of follow-up not specified. CT or performance of intervention (62.2%).
(d) The wide range of confidence intervals around the point estimate of the sensitivity in the study increases the uncertainty of the actual diagnostic accuracy.
(e) Unclear reference standard – length of follow-up not specified. CT scan (97%). Follow-up questionnaire/telephone interview.
(f) Unclear reference standard. CT scan (31%), follow-up calls, review of medical records.
(g) Inadequate reference standard. CT scan within 7 days (52.8%), or re-evaluation within 7 days.
(h) Relates to a sensitivity or specificity for a single study or a range of sensitivities or specificities when more than 1 study.

Source: NICE CG176 (2014) Table 9 (pp101–102)
Note: Study reference numbers refer to reference list in NICE CG176 (2014).

5.1.4.2 NICE surveillance (2017)

The NICE surveillance (2017) report provided the following synopses of relevant studies in either children or adults (Table 5.1.3), but guidance was not changed.

The Easter 2014 validation study of the CATCH, CHALICE and PECARN decision rules is the only subsequent study identified during surveillance that reports diagnostic accuracy data for CT decision rules. The outcome reported, however, was clinically important TBI, which is not one of the two outcomes extracted in the NICE 2014 data tables (Table 5.1.1 and Table 5.1.2 in the prior section). This study is also relatively small and diagnostic statistics cannot be regarded as conclusive.

Table 5.1.3 Subsequent evidence from NICE surveillance (2017) for diagnostic accuracy of CT decision rules for children and infants

Ref#	Study ID	Decision rule	Country	Population	N	Outcome	Diagnostic accuracy reported?	Results	Comment by authors of current review
31	Borgialli 2016	Paediatric GCS – not a decision rule study	US – PECARN Working Group	TBI in children and infants <2 years (reported separately)	10,499	• TBI on CT • ciTBI	AUC only – no threshold (rules) so no sensitivity or specificity statistics reported.	-	Curve is sensitivity plotted against 1-specificity across varying cut-offs. AUC is a measure of the inherent ability of the test to discriminate between patients with/without condition across a range of thresholds (association between the GCS score and TBI). No single threshold was chosen in this study, so it is not actually a decision rule yet.
32	Daymont 2015	Physician judgement – not a defined decision rule	Canada	-	3,771	-	-	-	-
33	Easter 2014	CATCH; CHALICE; PECARN	US (not PECARN Working Group)	minor head injury in children <18 years	1,009	• ciTBI	Yes – sensitivity and specificity	PECARN had sensitivity of 100% and specificity of 62%; CATCH had sensitivity of 91% and specificity of 44%; CHALICE had sensitivity of 84% and specificity of 85%.	Important study to consider adding to body of evidence for the PREDICT Guideline as it is the only validation study for CHALICE (basis for current NICE recommendation). Outcome (ciTBI) is not in PICO for PREDICT. Study authors note this is the only head to head comparison of the three decision rules, and that limitations include less precision than derivation studies due to smaller size, so diagnostic statistics cannot be regarded as conclusive.
34	Gravel 2015	Skull fracture rule	Canada	head trauma in children <2 years (not in need of CT)	Derivation: 811 Validation: 856	• radiologically confirmed skull fracture	Yes, but wrong population	-	Aim of this study was to develop and validate a clinical decision rule to identify skull fracture in young children with head trauma and no immediate need for head tomography, so it is not in scope for this question.
35	Kocyigit 2014	Exploratory analysis, not a decision rule	Turkey	mild head trauma in children 2–15 years	806	• TBI on CT	No	-	-
38	Lee 2014	Single criterion analysis – ISOLATED loss of conscious-ness	US – PECARN Working Group	blunt head trauma in children [both under and over 2, with separate definitions of LoC]	6,286	• ciTBI • TBI on CT	No	-	Relevant to US setting where CT rates are higher. The study authors note that 'Of the clinical factors that strongly influence the use of CT after blunt head trauma, a history of loss of consciousness (LoC) is among the most frequent.' This study shows that children with ISOLATED LoC are at very low risk for ciTBI, and so CT is not routinely required for this population. It should be noted these patients do not fulfil the PECARN criteria, or any other decision rule, but observation is warranted to assess for progression of signs and symptoms. This observation is not necessarily relevant to the Australian setting where CT rates are lower and may be influenced less often by isolated criteria.

Ref#	Study ID	Decision rule	Country	Population	N	Outcome	Diagnostic accuracy reported?	Results	Comment by authors of current review
37	Dayan 2015	Single criterion analysis – ISOLATED headache	US – PECARN Working Group	minor blunt head trauma in children aged 2–18 years	12,675	• TBI on CT	No	-	Headache is a common complaint after minor blunt head trauma, but when headaches are ISOLATED, ciTBIs are rare and TBIs on CT are very uncommon. It should be noted these patients do not fulfil the PECARN criteria, or any other decision rule. The authors note that very few of these patients received a CT, so US clinicians appear not to be using ISOLATED headache as a criterion for requesting CT.
36	Dayan 2014	Single criterion analysis – ISOLATED vomiting	US – PECARN Working Group	minor blunt head trauma in children (not further defined here)	5,392	• TBI on CT; ciTBI	No	-	Vomiting is a common complaint after minor blunt head trauma, but when vomiting is ISOLATED, ciTBIs are rare and TBIs on CT are very uncommon. It should be noted these patients do not fulfil the PECARN criteria, or any other decision rule, but observation is warranted to assess for progression of signs and symptoms.
39	Nishijima 2015	Single criterion analysis – ISOLATED abnormal behaviour	US – PECARN Working Group	minor blunt head trauma in children <2 years	1,297	• ciTBI • TBI on CT	No	-	In children < 2 years old with ISOLATED abnormal behaviour the risk of ciTBI is exceedingly low (lower than lifetime risk of cancer from single CT at age 1 year) and the risk of ciTBI 'remains sufficiently low so that observation before CT decision making is justified, and routine CT scanning is not needed'. It should be noted these patients do not fulfil the PECARN criteria, or any other decision rule, but observation is warranted to assess for progression of signs and symptoms.

Abbreviations: AUC: area under the curve; ciTBI, clinically-important traumatic brain injury; LoC, loss of consciousness

Source: NICE surveillance (2017) report, Appendix A (pp17–18)

5.1.4.3 Evidence missing from source guidelines

No evidence for presentation after 24 hours was reported in the source evidence.

5.1.5 New evidence

Sixty-six studies relevant to this question were identified in the PREDICT Guideline literature search (Table 5.1.4). Of these, five are key studies (7, 21, 58-60).

Table 5.1.4 New evidence identified for imaging Q1

Ref #	Citation
23.	Alharthy N, Al Queflie S, Alyousef K, Yunus F. Clinical manifestations that predict abnormal brain computed tomography (CT) in children with minor head injury. Journal of Emergencies Trauma & Shock. 2015;8(2):88–93.
24.	Ali S, Zarif P, Sajid S. Vomiting as a predictor of fracture skull in head injury patients. Pakistan Journal of Medical and Health Sciences. 2017;11(3):959–62.
25.	Andrade FP, Montoro RN, Oliveira R, Loures G, Flessak L, Gross R, et al. Pediatric minor head trauma: do cranial CT scans change the therapeutic approach? Clinics (Sao Paulo, Brazil). 2016;71(10):606–10.
26.	Arneitz C, Sinzig M, Achatz E, Fasching G. Can a CT be Omitted in Pediatric Minor Head Trauma? Journal of Pediatric Neurology. 2018;16(1):43647.
27.	Atabaki SM, Jacobs BR, Brown KM, Shahzeidi S, Heard-Garris NJ, Chamberlain MB, et al. Quality Improvement in Pediatric Head Trauma with PECARN Rules Implementation as Computerized Decision Support. Pediatric Quality & Safety. 2017;2(3):e019.
1.	Atabaki SM, Hoyle JD, Jr., Schunk JE, Monroe DJ, Alpern ER, Quayle KS, et al. Comparison of Prediction Rules and Clinician Suspicion for Identifying Children with Clinically Important Brain Injuries After Blunt Head Trauma. Academic Emergency Medicine. 2016;23(5):566–75.
28.	Azim A, Jehan FS, Rhee P, O'Keeffe T, Tang A, Vercruysse G, et al. Big for small: Validating brain injury Guidelines in pediatric traumatic brain injury. The Journal of Trauma and Acute Care Surgery. 2017;83(6):1200–4.
29.	Babl FE, Oakley E, Dalziel SR, Borland ML, Phillips N, Kochar A, et al. Accuracy of NEXUS II head injury decision rule in children: a prospective PREDICT cohort study. Emergency Medicine Journal. 2019;36(1):43773.
3.	Babl FE, Oakley E, Dalziel SR, Borland ML, Phillips N, Kochar A, et al. Accuracy of Clinician Practice Compared with Three Head Injury Decision Rules in Children: A Prospective Cohort Study. Annals of Emergency Medicine. 2018;71(6):703–10.
2.	Babl FE, Borland ML, Phillips N, Kochar A, Dalton S, McCaskill M, et al. Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. Lancet. 2017;389(10087):2393–402.
4.	Badawy MK, Dayan PS, Tunik MG, Nadel FM, Lillis KA, Miskin M, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605.
30.	Ballard DW, Kuppermann N, Vinson DR, Tham E, Hoffman JM, Swietlik M, et al. Implementation of a Clinical Decision Support System for Children with Minor Blunt Head Trauma Who Are at Nonnegligible Risk for Traumatic Brain Injuries. Annals of Emergency Medicine. 2019;73(5):440–51.
5.	Bandte A, Puschel K, Krajewski K. Traumatic brain injury in high versus low falls in young children and adolescents: a retrospective analysis. Journal of Neurosurgery Pediatrics. 2018;22(3):233–7.
31.	Bertsimas D, Dunn J, Steele DW, Trikalinos TA, Wang Y. Comparison of Machine Learning Optimal Classification Trees with the Pediatric Emergency Care Applied Research Network Head Trauma Decision Rules. JAMA Pediatrics. 2019;13:13.
33.	Borland ML, Dalziel SR, Phillips N, Lyttle MD, Bressan S, Oakley E, et al. Delayed Presentations to Emergency Departments of Children with Head Injury: A PREDICT Study. Annals of Emergency Medicine. 2019;14:14.
32.	Borland ML, Dalziel SR, Phillips N, Dalton S, Lyttle MD, Bressan S, et al. Vomiting with Head Trauma and Risk of Traumatic Brain Injury. Pediatrics. 2018;141(4):4.
34.	Bozan O, Aksel G, Kahraman HA, Giritli O, Eroglu SE. Comparison of PECARN and CATCH clinical decision rules in children with minor blunt head trauma. European Journal of Trauma & Emergency Surgery. 2017;25:25.
35.	Bressan S, Kochar A, Oakley E, Borland M, Phillips N, Dalton S, et al. Traumatic brain injury in young children with isolated scalp haematoma. Archives of Disease in Childhood. 2019;4:4.
6.	Bressan S, Steiner IP, Mion T, Berlese P, Romanato S, Da Dalt L. The Pediatric Emergency Care Applied Research Network intermediate-risk predictors were not associated with scanning decisions for minor head injuries. Acta Paediatrica. 2015;104(1):47–52.
7.	Burns EC, Grool AM, Klassen TP, Correll R, Jarvis A, Joubert G, et al. Scalp Hematoma Characteristics Associated with Intracranial Injury in Pediatric Minor Head Injury. Academic Emergency Medicine. 2016;23(5):576–83.
8.	Burrows P, Trefan L, Houston R, Hughes J, Pearson G, Edwards RJ, et al. Head injury from falls in children younger than 6 years of age. Archives of Disease in Childhood. 2015;100(11):1032–7.
9.	Cellina M, Panzeri M, Floridi C, Martinenghi CMA, Clesceri G, Oliva G. Overuse of computed tomography for minor head injury in young patients: an analysis of promoting factors. Radiologia Medica. 2018;123(7):507–14.
36.	Cheng CY, Pan HY, Li CJ, Chen YC, Chen CC, Huang YS, et al. Physicians' Risk Tolerance and Head Computed Tomography Use for Pediatric Patients with Minor Head Injury. Pediatric Emergency Care. 2018;25:25.

Ref #	Citation
37.	Chong SL, Barbier S, Liu N, Ong GY, Ng KC, Ong ME. Predictors for moderate to severe paediatric head injury derived from a surveillance registry in the emergency department. Injury. 2015;46(7):1270–4.
10.	Daymont C, Klassen TP, Osmond MH. Accuracy of physician-estimated probability of brain injury in children with minor head trauma. CJEM Canadian Journal of Emergency Medical Care. 2015;17(4):387–94.
38.	Dalziel K, Cheek JA, Fanning L, Borland ML, Phillips N, Kochar A, et al. A Cost-Effectiveness Analysis Comparing Clinical Decision Rules PECARN, CATCH, and CHALICE with Usual Care for the Management of Pediatric Head Injury. Annals of Emergency Medicine. 2019;73(5):429–39.
39.	Dayan PS, Ballard DW, Tham E, Hoffman JM, Swietlik M, Deakyne SJ, et al. Use of Traumatic Brain Injury Prediction Rules with Clinical Decision Support. Pediatrics. 2017;139(4):e20162709. doi:10.1542/peds.2016–2709.
--	Dayan PS, Holmes JF, Schutzman S, Schunk J, Lichenstein R, Foerster LA, Hoyle Jr J, Atabaki S, Miskin M, Wisner D, Zuspan S. Risk of traumatic brain injuries in children younger than 24 months with isolated scalp hematomas. Annals of Emergency Medicine. 2014 Aug 1;64(2):153
11.	Di G, Liu H, Hu X, Chen S, Wang Z, Liu H. Clinical predictors of intracranial injuries on CT in infants younger than 2 years old with mild traumatic brain injury. Oncotarget. 2017;8(54):92615–20.
40.	Dufek JS, Ryan-Wenger NA, Eggleston JD, Mefferd KC. A novel approach to assessing head injury severity in pediatric patient falls. Journal of Pediatric Health Care. 2018;32(2):e59-e66.
41.	Eisenmenger LB, Anzai Y. Computed Tomography in Pediatric Traumatic Brain Injury: Who Needs It and How Is It Scored? Journal of Pediatric Neuroradiology. 2016;5(1):13–9.
42.	Engineer RS, Podolsky SR, Fertel BS, Grover P, Jimenez H, Simon EL, et al. A Pilot Study to Reduce Computed Tomography Utilization for Pediatric Mild Head Injury in the Emergency Department Using a Clinical Decision Support Tool and a Structured Parent Discussion Tool. Pediatric Emergency Care. 2018;15:15.
43.	Ferrara P, Basile MC, Dell'Aquila L, Vena F, Coppo E, Chiaretti A, et al. Traumatic Brain Injury in Children: Role of CDRs-PECARN as a Clinical Predictive Resource for Evaluation of Intracranial Lesions and Neuropsychiatric Outcomes. Pediatric Neurosurgery. 2016;51(5):249–52.
44.	Gelernter R, Weiser G, Kozer E. Computed tomography findings in young children with minor head injury presenting to the emergency department greater than 24h post injury. Injury. 2018;49(1):82–5.
12.	Gerber N, Sookraj K, Munnangi S, Angus LDG, Lamba V, Kumar K, et al. Impact of the Pediatric Emergency Care Applied Research Network (PECARN) Guidelines on emergency department use of head computed tomography at a level I safety-net trauma center. Emergency Radiology. 2019;26(1):45–52.
13.	Gerritsen H, Samim M, Peters H, Schers H, van de Laar FA. Incidence, course and risk factors of head injury: a retrospective cohort study. BMJ Open. 2018;8(5):e020364.
45.	Glass T, Ruddy RM, Alpern ER, Gorelick M, Callahan J, Lee L, et al. Traumatic brain injuries and computed tomography use in pediatric sports participants. American Journal of Emergency Medicine. 2015;33(10):1458–64.
46.	Gokharman FD, Aydin S, Fatihoglu E, Kosar PN. Pediatric Emergency Care Applied Research Network head injury prediction rules: on the basis of cost and effectiveness. Turkish Journal of Medical Sciences. 2017;47(6):1770–7.
14.	Gravel J, Gouin S, Chalut D, Crevier L, Decarie JC, Elazhary N, et al. Derivation and validation of a clinical decision rule to identify young children with skull fracture following isolated head trauma. CMAJ Canadian Medical Association Journal. 2015;187(16):1202–8.
15.	Gravel J, Spenard S, Beaudin M, Gouin S. Validation of the Sainte-Justine head trauma pathway for children younger than 2 years of age. Canadian Journal of Emergency Medicine. 2016;18:S95-S6.
47.	Harvell BJ, Helmer SD, Ward JG, Ablah E, Grundmeyer R, Haan JM. Head CT Guidelines Following Concussion among the Youngest Trauma Patients: Can We Limit Radiation Exposure Following Traumatic Brain Injury? Kansas Journal of Medicine. 2018;11(2):42736.
16.	Heitz C, Morgenstern J, Bond C, Milne WK. Hot Off the Press: Validation of the Pediatric NEXUS II Head Computed Tomography Decision Instrument for Selective Imaging of Pediatric Patients with Blunt Head Trauma. Academic Emergency Medicine. 2019;26(2):246–9.
17.	Hess EP, Homme JL, Kharbanda AB, Tzimenatos L, Louie JP, Cohen DM, et al. Effect of the Head Computed Tomography Choice Decision Aid in Parents of Children with Minor Head Trauma: A Cluster Randomized Trial. JAMA Network Open. 2018;1(5):e182430.
39	Ide K, Uematsu S, Hayano S, Hagiwara Y, Tetsuhara K, Ito T, Nakazawa T, Sekine I, Mikami M, Kobayashi T. Validation of the PECARN head trauma prediction rules in Japan: A multicenter prospective study. American Journal of Emergency Medicine. 2019 Sep 10. pii: S0735–6757(19)30588–1. doi: 10.1016/j.ajem.2019.158439. [Epub ahead of print]
48.	Ide K, Uematsu S, Tetsuhara K, Yoshimura S, Kato T, Kobayashi T. External Validation of the PECARN Head Trauma Prediction Rules in Japan. Academic Emergency Medicine. 2017;24(3):308–14.
49.	Jennings RM, Burtner JJ, Pellicer JF, Nair DK, Bradford MC, Shaffer M, et al. Reducing Head CT Use for Children with Head Injuries in a Community Emergency Department. Pediatrics. 2017;139(4).
50.	Jeong JH, Lee JH, Kim K, Rhee JE, Kim TY, Jo YH, et al. Change in guardians' preference for computed tomography after explanation by emergency physicians in pediatric head injury. Clinical & Experimental Emergency Medicine. 2015;2(4):226–35.
51.	Kauffman JD, Litz CN, Thiel SA, Nguyen ATH, Carey A, Danielson PD, et al. To Scan or Not to Scan: Overutilization of Computed Tomography for Minor Head Injury at a Pediatric Trauma Center. Journal of Surgical Research. 2018;232:164–70.
18.	Kemp A, Nickerson E, Trefan L, Houston R, Hyde P, Pearson G, et al. Selecting children for head CT following head injury. Archives of Disease in Childhood. 2016;101(10):929–34.
52.	Kobe IO, Qureshi MM, Hassan S, Oluoch-Olunya DL. The impact of the introduction of PECARN head CT rules on the utilisation of head CT scans in a private tertiary hospital in Sub-Saharan Africa. Childs Nervous System. 2017;33(12):2147–52.

Ref #	Citation
53.	Mastrangelo M, Midulla F. Minor Head Trauma in the Pediatric Emergency Department: Decision Making Nodes. Current Pediatric Review. 2017;13(2):92–9.
54.	Nakhjavan-Shahraki B, Yousefifard M, Hajighanbari MJ, Oraii A, Safari S, Hosseini M. Pediatric Emergency Care Applied Research Network (PECARN) prediction rules in identifying high risk children with mild traumatic brain injury. European Journal of Trauma & Emergency Surgery. 2017;43(6):755–62.
19.	Nishijima DK, Yang Z, Urbich M, Holmes JF, Zwienenberg-Lee M, Melnikow J, et al. Cost-effectiveness of the PECARN rules in children with minor head trauma. Annals of Emergency Medicine. 2015;65(1):72–8.00E+7.
20.	Oakley E, May R, Hoeppner T, Sinn K, Furyk J, Craig S, et al. Computed tomography for head injuries in children: Change in Australian usage rates over time. Emergency Medicine Australasia. 2017;29(2):192–7.
55.	Ohbuchi H, Hagiwara S, Hirota K, Koseki H, Kuroi Y, Arai N, et al. Clinical Predictors of Intracranial Injuries in Infants with Minor Head Trauma. World Neurosurgery. 2017;98: 479–83.
--	Osmond MH, Klassen TP, Wells GA, Davidson J, Correll R, Boutis K, et al. Validation and refinement of a clinical decision rule for the use of computed tomography in children with minor head injury in the emergency department. CMAJ. 2018 Jul 9;190(27):E816-E822. doi: 10.1503/cmaj.170406.
56.	Parameswaran A, Heitner S, Thosar D, Fowler A, Marks S, O'Leary F. Trial of life: Well infants presenting more than 24 h after head injury with a scalp haematoma: A 10-year review. Journal of Paediatrics & Child Health. 2018;54(11):1193–8.
57.	Pikstra ARA, Metting Z, Fock JM, van der Naalt J. The juvenile head trauma syndrome – Deterioration after mild TBI: Diagnosis and clinical presentation at the Emergency Department. European Journal of Paediatric Neurology. 2017;21(2):344–9.
58.	Puffenbarger MS, Ahmad FA, Argent M, Gu H, Samson C, Quayle KS, et al. Reduction of Computed Tomography Use for Pediatric Closed Head Injury Evaluation at a Nonpediatric Community Emergency Department. Academic Emergency Medicine. 2019.
59.	Rothman SM, Alander SW. Neuroimaging Rates for Closed Head Trauma in a Community Hospital. Pediatric Emergency Care. 2018;34(2):102–5.
60.	Sellin JN, Moreno A, Ryan SL, Lam SK, Donaruma-Kwoh M, Luerssen TG, et al. Children presenting in delayed fashion after minor head trauma with scalp swelling: do they require further workup? Childs Nervous System. 2017;33(4):647–52.
61.	Song CH, Ahmad MZ, Siti-Azrin AH, Wan-Nor-Asyikeen WA. The identification of key factors predictive of traumatic brain injury in paediatric patients with a minor blunt head injury. Hong Kong Journal of Emergency Medicine. 2019.
62.	Spenard S, Gouin S, Beaudin M, Gravel J. Validation of the Sainte-Justine Head Trauma Pathway for children younger than two years of age. Canadian Journal of Surgery. 2018;61(4):283–7.
63.	Tavor O, Boddu S, Kulkarni AV. Presenting characteristics of children who required neurosurgical intervention for head injury. Childs Nervous System. 2016;32(5):827–31.
21.	Thiam DW, Yap SH, Chong SL. Clinical Decision Rules for Paediatric Minor Head Injury: Are CT Scans a Necessary Evil? Annals of the Academy of Medicine, Singapore. 2015;44(9):335–41.
22.	Unden J, Dalziel SR, Borland ML, Phillips N, Kochar A, Lyttle MD, et al. External validation of the Scandinavian Guidelines for management of minimal, mild and moderate head injuries in children. BMC Medicine. 2018;16(1):176.

Shaded rows indicate key studies.

5.1.5.1 Rationale for selection of key evidence

Six of the 66 new studies were selected as key evidence for this question based on the following rationale: relevant to the question and prospective multicentre studies. New evidence added to three sections – risk factors for clinically-important traumatic brain injury (7, 68), issues of delayed presentations (21) and decision-making for infants up to 3 months of age (58-60).

5.1.5.2 Key evidence data extraction

Table 5.1.5 Data from key evidence for imaging Q1

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Babl FE**, Borland ML, Phillips N et al. Accuracy of PECARN, CATCH and CHALICE head injury decision rules in children. Lancet 2017; 389(10087):2393–2402 **Aim** Validate 3 clinical decisions rules (PECARN, CATCH and CHALICE) **Setting** 10 EDs in Australia and New Zealand **Type** Prospective observational study	**Sample Size** 20137 children and adolescents (aged <18 years) with head injuries **Characteristics** 95% presented within 24h of injury. Mean age 5.7 (4.7) years. Boys 63.7%. **Inclusion** PECARN[1] CATCH[2] CHALICE[3] **Exclusion** PECARN[4] CATCH[5] CHALICE[6]	Rule specific predictor variables for standardised outcome of clinically important traumatic brain injuries.	Predictor variables: mechanism of injury History: LOC, vomiting, headache, amnesia, suspected NAI, seizure Examination: GCS score, other signs of altered mental status, skull fracture, occipital, parietal or temporal scalp haematoma, presence of bruise, swelling. Demographic and epidemiological data	**Primary outcome:** PECARN: Clinically important TBI -280 (1%) CATCH 185 (1%) had need for neurological intervention CHALICE 403 (2%) had clinically significant intracranial injury. **Rule sensitivity:** PECARN < 2yrs: 100.0% (95% CI 90.7–100.0) PECARN ≥2: 99.0%, 94.4–100.0) CATCH (high risk predictors): 95.2%; 76.2–99.9 CHALICE: (92.3%, 89.2–94.7)	**Limitations** CT scans not obtained on all patients. 10% patients lost to telephone follow up and excluded. **Study conclusion:** The sensitivities of three clinical decision rules for head injuries in children were high when used as designed. The findings are an important starting point for clinicians considering the introduction of one of the rules.
Citation **Badawy MK**, Dayan PS, Tunik MG, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605. **Aim:** Describe outcomes of head injured children with post traumatic seizures (PTS) **Setting** 25 paediatric EDs in North America **Type** Prospective observational 2004–2006	**Sample Size** 42,424 Children <18 years 536 had PTS **Characteristics** Median Age 4.9 (IQR 2.2–12.7) **Inclusion** Children < 18 with head trauma w/in 24 hours. GCS <14 included. **Exclusion** 1) presence of a pre-existing neurological disease, 2) history of ventricular shunt placement, 3) presence of a coagulopathy, 4) transfer from another facility with neuroimaging already performed and 5) patients with known seizure disorders.	Planned secondary descriptive analysis of patients with PTS within the PECARN head injury cohort.	Descriptive rates of CT, TBI on CT, neurosurgical intervention and recurrent PTS within one week.	**CT Proportion** 466/536 (86.9%, CI, 83.8%–89.7%) **TBI on CT** 72 (15.5%, CI = 12.3%–19.1%) **Neurosurgical intervention** 20 (27.8%, CI 17.9%–39.6%) **No TBI on CT**: n= 394 None of these required neurosurgery. • 282 were discharged, none had recurrent seizures • 112 admitted, 4.7% (CI 1.5, 10.6%) had recurrent seizures.	**Limitations** Parent study not designed to risk-stratify patients with PTS. Dataset included patients with GCS <14 **Study Conclusion** Children with PTS, but without TBI on CT very infrequently had short-term seizure recurrence, and none required neurosurgical intervention. **Comment** Some children with PTS and normal CT may be safe for discharge from ED without repeat imaging

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Bertisma D**, Dunn J, Steele DW et al. Comparison of Machine Learning Optimal Classification Trees with the Pediatric Emergency Care applied Research Network Head Trauma Decision Rules. JAMA Pediatrics. 2019;13:13 **Aim** To examine whether optimal classification trees improve on PECARN rules' predictive accuracy **Setting** 25 EDs in North America **Type** Secondary Analysis of prospective study	**Sample Size** 42412 children **Characteristics** Children < 2 years, mean age 11.6 mths, for children > 2years mean age 9.1 [SD:4.9] years **Inclusion** PECARN[1] **Exclusion** PECARN[4]	Compared predictive performance of derived OCT-based prediction rules for ciTBI in a validation cohort of children <2 years and > 2 years.	Analysed PECARN data set and developed OCT.	**Primary outcome: ciTBI** **Predictive performance of OCT in younger cohort:** specificity: 69.3%; 95% CI, 67.4%-71.2% vs 52.8%; 95% CI, 50.8%-54.9% **Older cohort specificity:** 65.6%; 95% CI, 64.5%-66.8% vs 57.6%; 95% CI, 56.4%-58.8% **PPV: odds ratios,** 1.54; 95% CI, 1.36–1.74 and 1.23; 95% CI, 1.17–1.30, in younger and older children, respectively **Positive likelihood ratio: risk ratios,** 1.54; 95% CI, 1.36–1.74 and 1.23; 95% CI, 1.17–1.30, in younger and older children, respectively	**Limitations** OCTs have not validated their predictive performance outside of PECARN. **Study conclusions** If implemented, OCTs may help reduce the number of unnecessary CT scans, without missing more patients with ciTBI than the PECARN rules.
Citation **Borland ML**, Dalziel SR, Phillips N. Delayed Presentations to Emergency Departments of Children with Head Injury: A PREDICT Study. Annals of Emergency Medicine. 2019;14:14 **Aim** Determine prevalence of traumatic brain injuries for patients presenting to EDs > 24hrs after injury to identify symptoms and signs to guide management **Setting** Original study: 10 EDs in Australia and NZ **Type** Secondary analysis of prospective observational study (Babl 2017 Lancet)	**Sample Size** 20137 children and adults with head injuries **Characteristics** 95% presented within 24h of injury. Mean age 5.7 (4.7) years. Boys 63.7%. **Inclusion** PECARN[1] CATCH[2] CHALICE[3] **Exclusion** PECARN[4] CATCH[5] CHALICE[6]	Compared children who presented > 24hrs after head injury and those who presented within 24hrs.	Secondary analysis testing associations b/w predictors of TBI on CT and clinically-important traumatic brain injury on CT.	**Features associated significantly with presentation > 24hrs vs <24hrs:** **Nonfrontal haematoma** 20.8% vs. 18.1% **Headache** (31.6% versus 19.9%), **Vomiting** (30.0% versus 16.3%), **Assault with nonaccidental injury** concerns (1.4% versus 0.4%). CT scan 203 (20.6%) vs. 7.9% TBI on CT occurred in 37 patients (3.8%), ciTBI occurred in 8 pts (0.8%) with 2 (0.2%) requiring neurosurgery with no deaths.	**Limitations** CT scans were obtained in minority of patients in original study. **Study conclusions** Delayed presentation after head injury, although infrequent, is significantly associated with traumatic brain injury. Evaluation of delayed presentations must consider identified factors associated with this increased risk.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Dayan PS**, Holmes JF, Schutzman S et al. Risk of traumatic brain injuries in children younger than 24 months with isolated scalp hematomas. Ann Emerg Med. 2014 Aug;64(2):153–62. **Aim** Determine association between children with isolated scalp haematoma and traumatic brain injuries **Setting** 25 EDs **Type** Prospective study	**Sample Size** 2,998 head injured children with isolated scalp haematomas of 43,904 **Characteristics** 4.7% had more than 1 scalp haematoma location 123 had temporal/ parietal region **Inclusion** Head-injured children aged <24 months GCS 14 or 15 Presented within 24hrs of injury **Exclusion**[7]	Compared head injured children with isolated scalp haematomas to head injured children without isolated skull haematomas.	Secondary analysis. In parent study standardized history and physical exam. Cranial CT at clinician discretion.	**2 outcomes:** **(1) Clinically important traumatic brain injury:** 12 patients (0.4%; 95% confidence interval [CI] 0.2% to 0.7%); none underwent neurosurgery (95% CI 0% to 0.1%) **(2) Traumatic brain injury on CT** 50 (8.8%; 95% CI 6.6% to 11.4%) had traumatic brain injuries on CT	**Limitations** CT scans obtained in minority of patients; selection bias toward more severe findings. **Study conclusion:** Minority of patients with isolated scalp haematomas received CT scans; ciTBI is rare. Clinicians should use patient age, scalp hematoma location and size, and injury mechanism to help determine which otherwise asymptomatic children should undergo neuroimaging.
Citation **Ide K**, Uematsu S, Hayano S et al. Validation of the PECARN head trauma prediction rules in Japan: A multicenter prospective study. Am J Emerg Med. 2019 Sep 10. pii: S0735–6757(19)30588–1. doi: 10.1016/j.ajem.2019.158439 [Epub ahead of print] **Aim** Investigate if PECARN rules can be applied to Japanese children **Setting** 6 EDs **Type** Prospective	**Sample Size** 6585 head injured children **Characteristics** 2237 patients <2 years old 4348 patients ≥ 2 years old **Inclusion** Children aged <16 years with minor head injury defined as GCS ≥ 14. Presented within 24 h **Exclusion**[8]	Applied PECARN to Japanese cohort	Standardised history and exam. CT was at clinician discretion.	**PECARN rule:** NPV: 99.96% (95%CI: 99.86–100.00; p = 0.019) ciTBI rate: 0.35% (n= 23) CT scan rate: 7% (n= 463)	**Limitations** Did not exclude trivial injury mechanisms. Excluded children with nonaccidental injury who have a high incidence of ciTBI. **Study conclusion:** PECARN head trauma prediction rules seemed to be safely applicable to Japanese children.

[1]**PECARN inclusion:** Age <18 years; presenting within 24 hours of head injury

[2]**CATCH inclusion:** Age <17 years. All of the following: presenting with blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (two or more distinct episodes 15 minutes apart), persistent irritability in the ED (in children <2 years), initial GCS score in ED ≥13, as determined by treating physician, injury within the past 24 hours.

[3]**CHALICE inclusion:** Age <16 years; any history or signs of injury to the head

[4]**PECARN exclusion:** Trivial mechanism of injury, defined by ground-level fall or walking or running into stationary objects and no signs or symptoms of head trauma other than scalp abrasions and lacerations; penetrating trauma; known brain tumours; pre-existing neurological disorder complicating assessment; neuroimaging at an outside hospital before transfer; patient with ventricular shunt; patient with bleeding disorder GCS score <14

[5]**CATCH exclusion**: Obvious penetrating skull injury; obviously depressed fracture; acute focal neurological deficit; chronic generalised developmental delay; head injury secondary to suspected child abuse; returning for reassessment of previously treated head injury. Patients who were pregnant.

[6]**CHALICE exclusion:** refusal to consent

[7]**Exclusion**: Patients with trivial head trauma mechanisms (e.g., ground-level falls or running into stationary objects) and who had either no signs of head trauma or only a scalp laceration or abrasion were excluded. We also excluded children with penetrating trauma, known brain tumours, pre-existing neurologic disorders complicating the clinical assessment, ventricular shunts, bleeding disorders, or previous neuroimaging.

5.1.6 Key considerations for assessing the evidence

5.1.6.1 NICE Guideline Development Group considerations

The following is a selection of the considerations made by the NICE CG176 (2014) Guideline Development Group (GDG) during recommendation development. These were considered relevant to the consideration of new evidence that might be added to the body of evidence during the production of the PREDICT Guideline.

> <u>Relative values of different outcomes</u>*: Diagnostic accuracy in predicting intracranial injury and need for neurosurgery were the outcomes prioritised for this review. Sensitivity was considered the most important outcome by the GDG for this review question as a clinical decision rule should select all patients with intracranial injury for CT head scan. The consequence of missing a patient with intracranial injury would have serious implications, including death and long-term neurological sequelae.*
>
> <u>Trade-off between clinical benefits and harms</u>*: The GDG noted that the NICE 2007 head injury Guideline (CG56) is based on the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) clinical decision rule. During this update, additional clinical decision rules including the Canadian Assessment of Tomography for Childhood Head Injury (CATCH) and the Prediction Rule for identification of children at very low risk of Clinically-important Traumatic Brain Injury (referred to herein as PECARN) were identified. The CATCH and PECARN clinical decision rules have undergone internal (but not external) validation and neither has been validated in our UK population. The GDG noted that the CHALICE clinical decision rule has not undergone validation in any population, but there have been a small number of studies assessing its performance retrospectively. Overall, the GDG felt that the evidence was not strong enough to recommend a change from current practice to another clinical decision rule at this time. The GDG would want to see a large increase in specificity to warrant such a substantial change in practice to implement a new decision rule.*

No change was made to the 2014 guidance as a result of the 2017 surveillance of the literature.

5.1.6.2 Current NICE Guideline review author observations

As reported above, the CHALICE tool, which forms the basis of recommended practice in the UK, has not been validated. The diagnostic statistics in the evidence tables are from the derivation study but, compared to those from validation sets, diagnostic statistics from derivation sets tend to overestimate accuracy due to at least some degree of over-fitting the model. Therefore, the true diagnostic accuracy of CHALICE in the clinical setting is likely to be less than that suggested in the evidence tables. The NICE GDG noted a large increase in specificity is warranted before a new decision rule could be implemented. This statement is presumably based on the very high sensitivity of CHALICE (98%) leaving little room to improve this most important outcome. However, should a validation study be conducted, and the true sensitivity be found to be less than 98%, other decision tools may become viable alternatives in need of consideration on the basis of sensitivity alone.

It seems likely that the derivation of CHALICE in a UK population would have been a strong factor in deeming it applicable to the UK clinical setting. This consideration, however, is not as pertinent to the choice of a decision tool in the Australian and New Zealand setting.

5.1.7 GWG recommendation deliberations

Table 5.1.6 Clinical judgement form for imaging Q1

<table>
<tr><td>PREDICT Guideline imaging Q1</td><td colspan="2">In infants and children with mild to moderate head injury presenting within 24 hours, or between 24 and 72 hours, of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/ does not need a cranial CT?</td></tr>
<tr><td colspan="3">Source recommendation/s</td></tr>
<tr><td>NICE CG176 (2014)
UK
3 recommendations:
Recs 29, 30 and 31</td><td colspan="2">NICE CG176 Recommendation 29 [Developed: 2014]
For children who have sustained a head injury and have any of the following risk factors, perform a CT head scan within 1 hour of the risk factor being identified:
• Suspicion of non-accidental injury.
• Post-traumatic seizure but no history of epilepsy.
• On initial emergency department assessment, GCS less than 14, or for children under 1 year GCS (paediatric) less than 15.
• At 2 hours after the injury, GCS less than 15.
• Suspected open or depressed skull fracture or tense fontanelle.
• Any sign of basal skull fracture (haemotympanum, 'panda' eyes, and cerebrospinal fluid leakage from the ear or nose, Battle's sign).
• Focal neurological deficit.
• For children under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head.
A provisional written radiology report should be made available within 1 hour of the scan being performed.

NICE CG176 Recommendation 30 [Developed: 2014]
For children who have sustained a head injury and have more than one of the following risk factors (and none of those in recommendation 29), perform a CT head scan within 1 hour of the risk factors being identified:
• Loss of consciousness lasting more than 5 minutes (witnessed).
• Abnormal drowsiness.
• Three or more discrete episodes of vomiting.
• Dangerous mechanism of injury (high-speed road traffic accident either as pedestrian, cyclist or vehicle occupant, fall from a height of greater than 3 metres, high-speed injury from a projectile or other object).
• Amnesia (antegrade or retrograde) lasting more than 5 minutes.
A provisional written radiology report should be made available within 1 hour of the scan being performed.

NICE CG176 Recommendation 31 [Developed: 2014]
Children who have sustained a head injury and have only 1 of the risk factors in recommendation 30 (and none of those in recommendation 29) should be observed for a minimum of 4 hours after the head injury. If during observation any of the risk factors below are identified, perform a CT head scan within 1 hour.
• GCS less than 15.
• Further vomiting.
• A further episode of abnormal drowsiness.
A provisional written radiology report should be made available within 1 hour of the scan being performed. If none of these risk factors occur during observation, use clinical judgement to determine whether a longer period of observation is needed.</td></tr>
<tr><td colspan="3">Notes on wording changes</td></tr>
<tr><td colspan="3">GENERALISABILITY of the source recommendation/s</td></tr>
<tr><td colspan="2">Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?
☒ Yes ☐ No ☐ Unsure ☐ N/A</td><td>If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☐ Yes ☐ No ☐ Unsure ☐ N/A</td></tr>
<tr><td colspan="3">Comment:</td></tr>
<tr><td colspan="3">APPLICABILITY of the source recommendation/s</td></tr>
<tr><td colspan="3">Is the recommendation relevant to the Australian health care setting?
☐ Yes ☒ No ☐ Unsure ☐ N/A</td></tr>
<tr><td colspan="3">Comment:</td></tr>
<tr><td colspan="3">Adapt, adopt or new guidance</td></tr>
<tr><td colspan="3">Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?</td></tr>
<tr><td><u>NICE CG176 Recommendation 29</u>
☐ Adopt source guidance
☐ Adapt source guidance
☒ Create new guidance</td><td><u>NICE CG176 Recommendation 30</u>
☐ Adopt source guidance
☐ Adapt source guidance
☒ Create new guidance</td><td><u>NICE CG176 Recommendation 31</u>
☐ Adopt source guidance
☐ Adapt source guidance
☒ Create new guidance</td></tr>
<tr><td colspan="3">Comment:</td></tr>
<tr><td colspan="3">If new guidance needs to be developed, what type of guidance is appropriate?</td></tr>
</table>

PREDICT Guideline imaging Q1	**In infants and children with mild to moderate head injury presenting within 24 hours, or between 24 and 72 hours, of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/ does not need a cranial CT?**

☒ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

PREDICT guidance	
PREDICT evidence-informed recommendation 5	In children with mild to moderate head injury and a GCS score of 14–15[25] who have one or more risk factors for a clinically-important traumatic brain injury[26] (see below or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*), clinicians should take into account the number, severity and persistence of signs and symptoms, and family factors (e.g. distance from hospital and social context) when choosing between structured observation and a head CT scan.[27] **Risk factors for clinically-important traumatic brain injury[26]** : – GCS score of 14[25] or other signs of altered mental status[28] – Severe mechanism of injury[29] – Post-traumatic seizure(s) – Abnormal neurological examination **Specific risk factors for children aged less than 2 years**: – Palpable skull fracture[30] – Occipital or parietal or temporal scalp haematoma[31] – History of LOC 5 seconds or more – Not acting normally per parent **Specific risk factors for children aged 2 years and older**: – Signs of base of skull fracture[32] – History of LOC – History of vomiting[33] – Severe headache.
PREDICT evidence-informed recommendation 6	For children presenting to an acute care setting within 24 hours of a head injury and a GCS score of 15,[25] a head CT scan should not be performed without any risk factors for clinically-important traumatic brain injury[26] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*).
PREDICT evidence-informed recommendation 7	Children presenting to an acute care setting within 72 hours of a head injury and a GCS score of 13 or less[25] should undergo an immediate head CT scan.[27]
PREDICT consensus-based recommendation 8	Children with delayed initial presentation (24–72 hours after head injury) and a GCS score of 15[25] should be risk stratified in the same way as children presenting within 24 hours.
PREDICT practice point C	For children with mild to moderate head injury, consider shared decision-making[34] with parents, caregivers, and adolescents (e.g. a head CT scan[27] or structured observation).
PREDICT practice point D	All cases of head injured infants aged 6 months and younger should be discussed with a senior clinician. These infants should be considered at higher risk of intracranial injury, with a lower threshold for observation or imaging.[27]

[25] Measured using an age-appropriate GCS.
[26] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.
[27] Sedation is usually not required in children for non-contrast CT scans as they generally only take seconds to complete. If sedation is required for uncooperative children requiring imaging, local safe sedation practice should be followed.
[28] Agitation, drowsiness, repetitive questioning, slow response to verbal communication.
[29] Severe mechanism of injury: motor vehicle accident with patient ejection, death of another passenger or rollover; pedestrian or bicyclist without helmet struck by motorised vehicle; falls of 1 m or more for children aged less than 2 years, and more than 1.5 m for children aged 2 years or older; or head struck by a high-impact object.
[30] Palpable skull fracture: on palpation or possible on the basis of swelling or distortion of the scalp.
[31] Non-frontal scalp haematoma: occipital, parietal or temporal.
[32] Signs of base of skull fracture: haemotympanum, 'raccoon eyes', cerebrospinal fluid (CSF) otorrhoea or CSF rhinorrhoea, Battle's signs.
[33] Isolated vomiting, without any other risk factors, is an uncommon presentation of clinically-important traumatic brain injury. Vomiting, regardless of the number or persistence of vomiting, in association with other risk factors increases concern for clinically-important traumatic brain injury.
[34] Validated tools should be adapted for shared decision-making with parents, caregivers and adolescents.

PREDICT Guideline imaging Q1	In infants and children with mild to moderate head injury presenting within 24 hours, or between 24 and 72 hours, of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/ does not need a cranial CT?

Rationale

The PREDICT GWG developed **new evidence-informed recommendations**. None of the source guidelines were deemed relevant to inform these recommendations.

The PREDICT literature search identified 66 new studies, of these 5 were selected as key evidence for this question (7, 21, 58-60). The PECARN (Pediatric Emergency Care Applied Research Network) clinical prediction rules (1) were derived and validated in 42,412 children with head trauma with GCS scores of 14–15 aged less than 18 years in the United States. The PECARN rule is age specific and focuses on the identification of clinically-important traumatic brain injuries (ciTBI: death from traumatic brain injury (TBI), neurosurgical intervention for TBI, intubation > 24 h for TBI, or hospital admission of 2 nights or more for the TBI in association with TBI on CTs). In the validation population the rule for 2,216 children younger than 2 years (normal mental status, no scalp haematoma except frontal, no loss of consciousness or loss of consciousness for less than 5 s, non-severe injury mechanism, no palpable skull fracture, and acting normally according to the parents) had a sensitivity of 25/25 (100%, 86.3–100.0). The prediction rule for 6,411 children aged 2 years and older (normal mental status, no loss of consciousness, no vomiting, non-severe injury mechanism, no signs of base of skull fracture, and no severe headache) had a sensitivity of 61/63 (96.8%, 89.0–99.6). This clinical decision rule was externally validated in 20,137 children aged less than 18 years with head trauma of any severity in Australia and New Zealand (7, 25). In a comparison with two other large, prospectively derived paediatric clinical decision rules, the CATCH (Canadian Assessment of Tomography for Childhood Head Injury) and CHALICE (Children's Head Injury Algorithm for the Prediction of Important Clinical Events), the PECARN rule had the highest point sensitivity among the rules. Validation sensitivity for 4,011 children younger than 2 years was 38/38 (100.0%, 95% CI 90.7–100.0) and for 11,152 children aged 2 years and older 97/98 (99.0%, 95% CI 94.4–100.0). While post-traumatic seizures are usually associated with loss of consciousness - and therefore would be captured as a risk factor via the PECARN rule - the guideline working group elected to emphasise post-traumatic seizures as a separately described risk factor. In a secondary analysis of 42,424 children with head trauma of all severities, 536 children had post-traumatic seizures; of these 72 had TBIs on CT (13% overall or 15% of those with CT scan) of whom 20 (3.7%) underwent neurosurgical intervention (68).

There are limited data on presentations more than 24 hours after the injury; PECARN and CATCH rules excluded these patients and CHALICE did not report delayed presentations. In a secondary analysis of delayed presentation of children with head injuries in the Australian and New Zealand data set (21) 981 (5.0%) presented greater than 24 hours after injury. Traumatic brain injury on head CT occurred in 37 patients (3.8%) and ciTBI occurred in 8 patients (0.8%), with 2 (0.2%) requiring neurosurgery.

Children 3 months of age and younger with head injury appear to be at higher risk of intracranial injury (58-60).

FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☐ No ☒ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.2 Imaging Q2 – In infants and children with a ventricular shunt and mild to moderate head injury presenting within 72 hours of injury, which should undergo i) a cranial CT and/or ii) a shunt series and/or iii) a period of observation?

5.2.1 PREDICT question

PREDICT Guideline imaging Q2

In infants and children with a ventricular shunt and mild to moderate head injury presenting within 72 hours of injury, which should undergo i) a cranial CT and/or ii) a shunt series and/or iii) a period of observation?

5.2.2 Source question

Italian Guideline (Da Dalt 2018) ventricular shunt

Is the presence of ventricular shunt a risk factor for ciTBI in children presenting to the ED following minor head trauma? Should thresholds for obtaining head CT scan in these patients be different than for other children even in the absence of signs and symptoms? Is a higher CT use justified in these patients?

5.2.3 Source recommendation

Italian Guideline recommendation – Key action statement 7

In children with ventricular shunt who sustain a minor head trauma and have no PECARN predictors of traumatic brain injury and no other risk factors from history, clinicians should favor initial observation over routine immediate CT scan.

Evidence quality: A
Recommendation strength: Strong recommendation

5.2.4 Source evidence

This recommendation is supported by an overall synopsis of eight studies, which is reproduced here in full, followed by the citations, and then data extraction for one of these studies:

> *The purpose of this statement is to offer guidance on decision-making about whether to order a head CT scan in children with ventricular shunts who present to the ED following a minor blunt head trauma and have no signs or symptoms of traumatic brain injury. The PECARN rule does not apply to this group of patients. These children along with those with known brain tumours, pre-existing neurologic disorders, bleeding disorders, or neuroimaging performed at a transferring hospital were excluded from the PECARN rule study [3].*
>
> *The presence of a ventricular shunt may potentially increase the risk of intracranial haemorrhage following head trauma by stretching the bridging veins or cortical arteries that normally adhere to the inner surface of the dura [105–108]. This potential risk has led to the common practice of ordering a cranial CT scan for most children with VP shunt presenting to the ED following a minor head trauma [109]. However, it must be taken into account that children with ventricular shunt are exposed to repeated CT scans for their underlying condition and additional CT scans following a head trauma contribute to the cumulative risk of repeated radiation exposures [110].*
>
> *A recent a priori-planned secondary analysis [109] of the PECARN dataset [3] is the only prospective study that provides a risk estimate of ciTBI in children with ventricular shunt presenting to the ED following a minor head trauma. The study included 98 patients with ventricular shunt and 39,634 patients without shunt who presented to the ED with a GCS ≥ 14 within 24 h following a blunt head trauma. Patients with and without ventricular shunt were comparable for baseline clinical characteristics. Of the patients with ventricular shunt 14% had signs of altered mental status, 19% had a non-frontal hematoma, while a history of vomiting, loss of consciousness and severe mechanism of injury was present in 16%, 10% and 9% of patients respectively. The prevalence of ciTBI in patients with ventricular shunt was similar to patients without shunt, 1% (1 out of 98 patients) and 0.9% (346 out of 39,619 patients) respectively, with a difference of 0.1% and 95% CI of −0.3–5%. The one child with a ventricular shunt who had a ciTBI was a 10-year-old boy who walked into a stationary object and had no PECARN traumatic brain injury predictors. However, this patient had a known chronic subdural hematoma that was larger after the head trauma compared with previous CT, leading to neurosurgical hematoma evacuation. Even though the small number of patients with ventricular shunt in the study limits the ability to make precise risk estimates, the CIs around the differences between groups were relatively narrow, even after*

use of accepted statistical methods for rare outcomes (low prevalence rates). While 46% of patients with ventricular shunt underwent a cranial CT the remaining 54% received standardized clinical follow up in order to meet the ciTBI patient centered outcome definition. Of the 43,498 patients enrolled in the parent study [3] 2912 (7%) were excluded for missing information about the presence or absence of ventricular shunts. However, selection bias was very unlikely to affect the results of the analysis given the very low prevalence of children with ventricular shunt in the overall enrolled population (0.2%).

Despite the small number of patients, this is to date the largest available cohort and the first study providing a risk estimate of ciTBI in children with ventricular shunt following minor head trauma. Due to the similar risk of ciTBI in children with and without ventricular shunt, clinicians should not base neuroimaging decisions purely on the presence of the shunt. In these children routine immediate cranial CT may not be indicated in the absence of other risk factors for TBI. In addition, the risk of a delayed diagnosis of a ciTBI is further reduced by close observation in the ED [111, 112] (Da Dalt (2018) p18)

Table 5.2.1 Citations for source evidence for Italian Guideline key action statement 7

Reference No	Citation
105	Kraus R, Tracy PT, Hanigan WC. Intracranial hemorrhage following blunt injury to a shunt valve. Childs Nerv Syst. 2004;20:68–70.
106	Davis RL, Mullen N, Makela M, Taylor JA, Cohen W, Rivara FP. Cranial computed tomography scans in children after minimal head injury with loss of consciousness. Ann Emerg Med. 1994;24:640–5.
107	Okazaki T, Oki S, Migita K, Kurisu K. A rare case of shunt malfunction attributable to a broken Codman-hakim programmable shunt valve after a blow to the head. Pediatr Neurosurg. 2005;41:241–3.
108	Aoki N, Mizutani H. Acute subdural hematoma due to minor head trauma in patients with a lumboperitoneal shunt. Surg Neurol. 1988;29:22–6.
109	Nigrovic LE, Lillis K, Atabaki SM, Dayan PS, Hoyle J, Tunik MG, et al. The prevalence of traumatic brain injuries after minor blunt head trauma in children with ventricular shunts. Ann Emerg Med. 2013;61:389–93.
110	Holmedal LJ, Friberg EG, Borretzen I, Olerud H, Laegreid L, Rosendahl K. Radiation doses to children with shunt-treated hydrocephalus. Pediatr Radiol. 2007;37:1209–15.
111	Nigrovic LE, Schunk JE, Foerster A, Cooper A, Miskin M, Atabaki SM, et al. The effect of observation on cranial computed tomography utilization for children after blunt head trauma. Pediatrics. 2011;127:1067–73.
112	Schonfeld D, Fitz BM, Nigrovic LE. Effect of the duration of emergency department observation on computed tomography use in children with minor blunt head trauma. Ann Emerg Med. 2013;62:597–603.

Table 5.2.2 Data extraction for Nigrovic et al 2013 (Ref No 111) from Italian Guideline (2018) key action statement 7

Study ID Study design Setting Population	Sample Length of follow up	Intervention	Confounding variables	Measures Analysis	Results	Leve of evidence Caveat
Nigrovic 2013 Ann Emerg Med Prospective Cohort study A priori planned secondary analysis of a large prospective cohort study PECARN PED network Children with mild head trauma (GCS > = 14) presenting to the ED	• 98 pts with ventricular shunt • 39,634 without ventricular shunt Telephone follow up after 7–90 days following discharge	Comparison of: ciTBI cranial CT rate	Clinical severity Clustering of CT use by hospital	ciTBI (see definition) positive CT (for traumatic findings) CT rate	ciTBI prevalence: 1% pts w shunt vs 0.9% without; difference 0.1%, 95% CI -0.3–5% CT use: 46% pts w shunt vs 35% without; difference 11%, 95%CI 1–21% The one child with a ventricular shunt who had a ciTBI had a known chronic subdural hematoma that was larger after the head trauma compared with previous CT; the child underwent hematoma evacuation.	Level of evidence: B **Caveats** Relatively low number of pts w ventricular shunt, but largest so far available. No CT scan to all pts but clinical follow up→ patient centred outcome (ciTBI). Patients in PECARN very low risk not reported. Not powered to detect differences in injury severity. Missing data on VP shunt (7% of larger cohort) but unlikely to have affected the results as prevalence of VP shunt was 0.2%.

5.2.5 New evidence

Two studies relevant to this question were identified in the PREDICT Guideline literature search. No key studies were selected.

Table 5.2.3 New evidence identified for imaging Q2

Ref #	Citation
64.	Antonucci MC, Zuckerbraun NS, Tyler-Kabara EC, Furtado AD, Murphy ME, Marin JR. The Burden of Ionizing Radiation Studies in Children with Ventricular Shunts. Journal of Pediatrics. 2017; 182:210–2.16E+03
8.	Burrows P, Trefan L, Houston R, Hughes J, Pearson G, Edwards RJ, et al. Head injury from falls in children younger than 6 years of age. Archives of disease in childhood. 2015;100(11):1032–7.

5.2.5.1 Rationale for selection of key evidence

The recommendation was adapted from the Italian Guideline (Da Dalt 2018) in light of evidence supporting this recommendation (61) and the findings from IMAGING question 1 determining that the PECARN clinical decision rule should be used to determine predictors of intracranial injury.

5.2.6 Key considerations for assessing the evidence

5.2.6.1 Excerpt from Italian Guideline (Da Dalt 2018)

For reference, the following table is reproduced from the Italian Guideline (31), which lists considerations made by the Italian Guideline Working Group during development of the recommendation (Table 5.2.4).

Table 5.2.4 Action statement profile for key action statement 7 from Italian Guideline (2018)

Aggregate evidence quality	B
Benefits	Limitation of exposure to risks related to radiation and possible need for sedation, as well as reduction in costs, for children at negligible risk of ciTBI who are already exposed to higher radiation doses due to underlying pathology.
Risk, harm, cost	Negligible risk of missing a ciTBI; Costs of observation over CT scan
Benefit-harm assessment	Benefits outweigh harms
Values judgments	Concern for unnecessary radiation and potentially high accumulated radiation doses in children already exposed to repeated CTs for their underlying condition.
Intentional vagueness	None
Role of patient preference	None
Exclusion	Patients with GCS < 15 or signs and symptoms of traumatic brain injury
Strength	Moderate recommendation
Difference of opinion	None

5.2.7 Working Group recommendation deliberations

Table 5.2.5 Clinical judgement form for imaging Q2

PREDICT Guideline imaging Q2	In infants and children with a ventricular shunt and mild to moderate head injury presenting within 72 hours of injury, which should undergo i) a cranial CT and/or ii) a shunt series and/or iii) a period of observation?
Source recommendation/s	
Italian Guideline (Da Dalt 2018) Italy 1 recommendation: Key action statement 7	**Key action statement 7** In children with ventricular shunt who sustain a minor head trauma and have no PECARN predictors of traumatic brain injury and no other risk factors from history, clinicians should favor initial observation over routine immediate CT scan. Evidence quality: A Recommendation strength: Strong recommendation

PREDICT Guideline imaging Q2	In infants and children with a ventricular shunt and mild to moderate head injury presenting within 72 hours of injury, which should undergo i) a cranial CT and/or ii) a shunt series and/or iii) a period of observation?

GENERALISABILITY of the source recommendation/s

Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?	If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☒ Yes ☐ No ☐ Unsure ☐ N/A	☐ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☒ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

Italian Guideline Da Dalt (2018) KAS 7

☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☒ Not applicable

Comment:

PREDICT guidance

PREDICT evidence-informed recommendation 9	In children with a ventricular shunt (e.g. ventriculoperitoneal shunt) presenting to an acute care setting following mild to moderate head injury, who have no risk factors for clinically-important traumatic brain injury[35] (see PREDICT Recommendation 5 or Box A for risk factors*)*, consider structured observation over an immediate head CT scan.
PREDICT practice point E	In children with a ventricular shunt and mild to moderate head injury, consider obtaining a shunt series, based on consultation with a neurosurgical service, if there are local signs of shunt disconnection, shunt fracture (e.g. palpable disruption or swelling), or signs of shunt malfunction.

Rationale

The PREDICT GWG **adapted an evidence-informed recommendation** (key action statement 7) of the Italian Guideline (31) . The PREDICT literature search identified 2 new studies but were not selected as key evidence for this question. The Italian Guideline recommendations are supported by 8 studies, but are largely based on a secondary analysis of the PECARN data (61) 98 (0.2%) of 39,732 children with blunt head trauma and GCS scores greater than or equal to 14 had ventricular shunts. Children had a similar rate of clinically-important traumatic brain injuries (1/98 [1%] with shunts versus 346/39,619 [0.9%] without; difference 0.1%; 95% confidence interval -0.3% to 5%). The one child with a ventricular shunt who had a clinically-important traumatic brain injury had a known chronic subdural hematoma.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☐ No ☒ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

[35] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

5.3 Imaging Q3 – In infants and children on anticoagulant or antiplatelet therapy, or with a known bleeding disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

5.3.1 PREDICT question

PREDICT Guideline imaging Q3

In infants and children on anticoagulant or antiplatelet therapy, or with a known bleeding disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

5.3.2 Source question

NICE CG176 Section 7.6

What is the best clinical decision rule for selecting adults, infants and children with head injury for CT head scan who have no history of amnesia or loss of consciousness who are on anticoagulant or antiplatelet therapy?

5.3.3 Source recommendations

NICE CG176 Recommendation 28

For patients (adults and children) who have sustained a head injury with no other indications for a CT head scan and who are having warfarin treatment, perform a CT head scan within 8 hours of the injury. A provisional written radiology report should be made available within 1 hour of the scan being performed. (For advice on reversal of warfarin anticoagulation in people with suspected traumatic intracranial haemorrhage, see the NICE Guideline on blood transfusion.)

Developed: 2014

SIMEUP Position Statement (37)[36]

Recommendation 1

Pediatric patients with congenital or acquired bleeding disorders who have sustained a minor head trauma and do not present any signs or symptoms of traumatic brain injury, clinical observation should be preferred over a routine CT, depending on the severity of the coagulation disorder, the mechanism of injury and specific risk factors related to the patient or to the baseline haemorrhagic diathesis (i.e. moderate and severe forms, hemophiliacs with inhibitors, severe deficit of FXIII

Recommendation 2

In patients with coagulation factors deficiency and suspected intracranial haemorrhage, the performance of a CT must not delay the administration of the replacement factor, which is, the gold standard for treatment and must be infused within the shortest time possible

Recommendation 3a

The level of factor should be immediately elevated in the presence of significant trauma or early symptoms and the use of neuroimaging should not delay the infusion of the factor itself

Recommendation 5

In case of head injury in patients with a rare coagulopathy not on prophylaxis treatment, it is necessary to immediately contact the center that is treating the patient or the regional referral center.

Recommendation 6

CT is not necessary in the absence of clinical signs suggestive of intracranial haemorrhage [immune thrombocytopenias)

Recommendation (unnumbered)

In patients on warfarin therapy who undergo a minor head injury, the performance of a routine CT should be considered regardless of the presence or absence of clinical signs and presenting symptoms.

Developed: ***2019***

5.3.4 Source evidence

5.3.4.1 NICE CG176 (2014)

The NICE CG176 (2014) Guideline did not identify evidence for a decision rule for CT in patients of any age with coagulopathy. Therefore, the NICE 2014 GDG noted the following approach in the absence of evidence to meet the PICO:

> *… the technical team revisited the validation studies assessing clinical decision rules, some of which provided data relating to patients with coagulopathy as a risk factor, including some data relating to the populations of interest (NICE CG176 (2014) p110).*

Data from two studies were presented that provided data for adolescents and adults on the association between coagulopathy and intracranial lesions. As no studies were identified that derived or validated clinical decision rules for this question in children or infants, the NICE 2014 GDG felt it appropriate to extrapolate this evidence ‘to the whole population of patients with head injury including children and infants’.

The first, Fabbri et al 2005,(62) was a study that tested the diagnostic performance of the NICE 2003 version of the head injury Guideline in a cohort of adolescent and adult patients who had been managed according to the Neurotraumatology Committee of the World Federation of Neurosurgical Societies (NCWFNS) proposal. The NCWFNS proposal specifies CT for all coagulopathy patients (defined in these studies as patients using warfarin with an international normalised ratio (INR) of greater than 2)[37], while the NICE 2003 Guideline required additional risk factors to indicate CT in coagulopathy patients. The second

[36] Supplement to the Italian Guideline (Da Dalt 2018) to guide CT decision-making in children with congenital or acquired coagulation disorders (in press)

[37] Confirmed by study authors to authors of the NICE CG176 (2014) Guideline.

study, Fabbri 2004 et al,(63) was conducted in the same patient cohort and reported follow up in the subgroup of patients who would not have received CT had they been managed under the NICE 2003 Guideline, including patients with coagulopathy. The authors of these two studies concluded that “the exclusion of coagulopathy as a factor always indicating CT impairs the diagnostic accuracy of NICE guidance.” The data presented from these studies in the NICE CG176 (2014) Guideline are reproduced in Table 5.3.1.

Table 5.3.1 NICE CG176 (2014) clinical evidence for frequency of intracranial lesions in patients with coagulopathy (warfarin and an INR > 2 for these studies)

No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other	Coagulopathy	No coagulopathy	Relative (95% CI)	Absol	Quality	Importance
Univariate analysis of coagulopathy versus non-coagulopathy in patients who would not have been scanned by NICE 2003 Guideline, but were scanned according to NCWFNS proposal (follow-up 7 days)[(g)83]												
1[83]	Observational	Serious risk of bias[(a,b,c)]	No serious inconsistency	No serious indirectness	No serious imprecision	None	16/66 (24.2%)	24/435 (5.5%)	OR 5.48 (2.73 to 11.0)	–	Low	CRITICAL
Univariate analysis of coagulopathy versus non-coagulopathy in patients without loss of consciousness or amnesia (follow-up 7 days) [(g), 81]												
1[81]	Observational	Serious risk of bias[(a,b)]	No serious inconsistency	No serious indirectness	No serious imprecision	None	25/83 (30.1%)	517/7872 (6.6%)	OR 6.1 (3.8 to 9.9)	–	Low	CRITICAL
Univariate analysis of coagulopathy versus non-coagulopathy. (follow-up 7 days) [(g), 81]												
1[81]	Observational	Serious risk of bias[(a,b)]	No serious inconsistency	Serious indirectness[(f)]	No serious imprecision	None	67/265 (25.3%)	474/7690 (6.2%)	OR 5.1 (3.8 to 6.9)	–	Very low	CRITICAL
Multivariate analysis[(d)] of coagulopathy versus non-coagulopathy. (follow-up 7 days) [(g), 81]												
1[81]	Observational	Serious risk of bias[(a)]	No serious inconsistency	Serious indirectness[(f)]	No serious imprecision	None	67/265 (25.3%)	474/7690 (6.2%)	Adjusted OR 8.4 (5.5 to 12.6)	–	Very low	CRITICAL
Univariate analysis of coagulopathy versus non-coagulopathy in patients with loss of consciousness or amnesia. (follow-up 7 days) [(g), 81]												
1[81]	Observational	Serious risk of bias[(a,b)]	No serious inconsistency	Serious indirectness[(f)]	No serious imprecision	None	42/182 (23.1%)	500/7773 (6.4%)	OR 4.4 (3.1 to 6.2)	–	Very low	CRITICAL
Multivariate analysis[(e)] of coagulopathy versus no coagulopathy in patients with loss of consciousness or amnesia. (follow-up 7 days) [(g), 81]												
1[81]	Observational	Serious risk of bias[(a)]	No serious inconsistency	Serious indirectness[(f)]	No serious imprecision	None	42/182 (23.1%)	500/7773 (6.4%)	Adjusted OR 4.8 (2.6 to 8.6)	–	Very low	CRITICAL

a) Post-hoc analysis of prospectively collected data relating to a cohort of 7955 mild head injury patients. Some patients were excluded from the eligible 9464 patients because of unclear history of trauma as the primary event (n= 559), refusal of diagnostic and management procedures (n= 235).Some of these patients may have been anticoagulated patients without loss of consciousness or amnesia.

(b) Univariate analysis.

(c) Also reports a further 1235/7955 patients excluded from the analysis for a variety of reasons (numbers not reported). Some of these patients may have been anticoagulated patients without loss of consciousness or amnesia.

(d) Multivariate stepwise logistic regression analysis. Variables included in analysis are risk factors used in the NCWFNS as indicators for a CT scan.

(e) Multivariate stepwise logistic regression analysis. Variables included in analysis are risk factors used in the NICE Guideline (2003 version) as indicators for a CT scan.

(f) The population is not directly applicable. The effect size is reported to illustrate that all patients using warfarin have a large increased risk of developing intracranial lesions regardless of whether they have loss of consciousness or amnesia.

(g) Patients were followed for 7 days after trauma; later events were not considered in the paper's analysis. The GDG agreed this was a suitable follow-up period for this question. All patients using warfarin were scanned according to the NCWFNS proposal.

Source: NICE CG176 (2014) Table 12 (pp112–113)

Citations for included studies – **81:** Fabbri A, Servadei F, Marchesini G, Dente M, Iervese T, Spada M et al. Clinical performance of NICE recommendations versus NCWFNS proposal in patients with mild head injury. Journal of Neurotrauma. 2005; 22(12):1419–1427; **83**: Fabbri A, Vandelli A, Servadei F, Marchesini G. Coagulopathy and NICE recommendations for patients with mild head injury. Journal of Neurology, Neurosurgery and Psychiatry. 2004; 75(12):1787–1788

Note: The authors were contacted by the NICE 2014 authors to confirm the definition of coagulopathy – in the context of the Fabbri 2005 study [81] it refers to patients using warfarin with an international normalised ratio (INR) of greater than 2.

For patients on antiplatelet therapy, the NICE 2014 GDG noted that one study was identified primarily of patients who were on aspirin and indobufen:

> *Patients who were on ticlopidine may have been included (there is ambiguity on this point in the manuscript), but patients on clopidogrel were excluded from the analysis. Given these factors, the GDG considered the evidence to be of limited relevance.*

5.3.4.2 NICE surveillance (2017)

The NICE surveillance (2017) report did not identify evidence for a decision rule for CT in patients of any age with coagulopathy. Synopses of prognostic analysis studies were provided for studies examining the relationship between coagulopathy and relevant outcomes are reported and reproduced here for patients on antiplatelet or anticoagulant drugs (Table 5.3.2) and patients with any coagulopathy (Table 5.3.3). It should be noted, however, that none of these studies were conducted in children or infants, nor were any child or infant subgroup results included in these synopses, so they may be of limited relevance to the PREDICT GWG. The relevant citations have been added to the synopses in case further investigation of these studies by the GWG is warranted. The NICE surveillance (2017) report evidence did not result in a change of guidance.

Table 5.3.2 Subsequent evidence from NICE surveillance (2017) for patients on antiplatelet or anticoagulant drugs

#	Original study citation	NICE surveillance (2017) evidence for patients on antiplatelet or anticoagulant drugs
	Anticoagulants	
1	Mason S, Kuczawski M, Teare MD et al. (13–1-2017) AHEAD Study: an observational study of the management of anticoagulated patients who suffer head injury. BMJ Open 7:e014324.	The UK-based AHEAD study[43] included 3,566 people with blunt head injury who were taking warfarin at the time of injury. CT was performed in 59.8% of participants and showed significant head injury-related finding in 5.4%; 0.5% underwent neurosurgery; 1.2% patients suffered a head injury-related death. Overall, the rate of adverse outcome was 5.9%. Patients with GCS of 15 and no associated symptoms had lowest risk of adverse outcome (2.7%). Multivariable analysis found risk of adverse outcome to increase when reporting at least one associated symptom (vomiting, amnesia, headache, or loss of consciousness). INR measurement did not predict adverse outcome in patients with GCS of 15. A cost-effectiveness analysis based on the data from AHEAD44 suggested that CT in all people on warfarin presenting with head injury was not cost-effective, with and an incremental cost-effectiveness ratio (ICER) of £94,895.
2	Beynon C, Potzy A, Sakowitz OW et al. (2015) Rivaroxaban and intracranial haemorrhage after mild traumatic brain injury: A dangerous combination? Clinical Neurology & Neurosurgery 136:73–78.	A retrospective study[45] (n= 70) included people with mild traumatic brain injury and traumatic intracranial haemorrhage. Before head injury, 37 had no antithrombotic use, 22 people used antiplatelet agents, and 6 people were on rivaroxaban. Despite the small number of people on rivaroxaban, its use was associated with higher mortality and recurrent haemorrhage. However, no differences in length of hospital stay or GCS at discharge were seen.
3	Chauny JM, Marquis M, Bernard F et al. (2016) Risk of Delayed Intracranial Hemorrhage in Anticoagulated Patients with Mild Traumatic Brain Injury: Systematic Review and Meta-Analysis. Journal of Emergency Medicine 26:26.	A systematic review and meta-analysis[46] assessed 7 studies (n= 1,594) of a second CT after 24 hours in people taking vitamin K antagonists at the time of head trauma whose initial scan was normal. The incidence of haemorrhage on the second scan was 0.6%.
4	Docimo S, Jr, Demin A et al. (2014) Patients with blunt head trauma on anticoagulation and antiplatelet medications: can they be safely discharged after a normal initial cranial computed tomography scan? American Surgeon 80:610–613.	A retrospective analysis[47] included 303 people with blunt head trauma, 168 of whom were taking antiplatelet or anticoagulant drugs. Aspirin was used by 72 people, clopidogrel by 39 people, and warfarin by 18 people. Initial CT showed 'significant findings' in 166 people (98.8%). Delayed intracranial haemorrhage was seen on second CT in 2 people, both of whom were taking warfarin (1.2%) and had INR greater than 2.0.
5	Huynh TK, Costello JL, and Rebuck JA. (2014) Optimizing the dose of three-factor prothrombin complex concentrate in traumatic brain injury patients on warfarin therapy. Pharmacotherapy: The Journal of Human Pharmacology & Drug Therapy 34:260–264.	An analysis[48] included 42 people who had traumatic brain injury, were taking warfarin at the time of injury, had INR of 1.5 or higher, and received at least 1 dose of three-factor prothrombin complex concentrate. A moderate dose of prothrombin complex concentrate (35 IU/kg) was used in 17 people, and 25 people received a low dose (25 IU/kg). The low dose was associated with significantly lower rates of INR reversal at first measurement after administration of prothrombin complex concentrate. The low dose was also associated with significantly longer time to reversal of INR. There were no differences between the groups in stabilisation of brain injury, days in the intensive care unit, total days in hospital, blood product administration, and adverse events.

#	Original study citation	NICE surveillance (2017) evidence for patients on antiplatelet or anticoagulant drugs
6	Lim BL, Manauis C, and Asinas-Tan ML. (2016) Outcomes of warfarinized patients with minor head injury and normal initial CT scan. American Journal of Emergency Medicine 34:75–78.	A retrospective analysis[49] assessed 298 people who had minor head injury with normal CT findings who were on warfarin. Of this group, (3.7%) had a second CT, with 1 (0.3%) abnormality. Fresh frozen plasma was administered to 7 people (2.4%), and 8 (2.7%) received vitamin K. One patient (0.3%) needed neurosurgical intervention. The median hospital length of stay was 3 days. No patients re-attended 2 weeks after discharge.
7	Albrecht JS, Liu X, Baumgarten M et al. (2014) Benefits and risks of anticoagulation resumption following traumatic brain injury. JAMA Internal Medicine 174:1244–1251.	A retrospective cohort study[50] included 10,782 people aged 65 years or older admitted to hospital with traumatic brain injury who were on warfarin in the month before their injury. The study looked at the effects of warfarin use in 30-day periods in the year after brain injury. Warfarin use 'in the prior period' was associated with decreased risk of thrombotic events, and of haemorrhagic or ischemic stroke, but with increased risk of haemorrhagic events.
	Antiplatelet agents	
8	van dB, C L, Tolido T et al. (2016) Systematic Review and Meta-Analysis: Is Pre-Injury Antiplatelet Therapy Associated with Traumatic Intracranial Hemorrhage? Journal of Neurotrauma 9:9.	A systematic review and meta-analysis[51] assessed 10 studies (n= 20,247) investigating the effect of pre-injury antiplatelet therapy in people with traumatic head injury. Antiplatelet therapy was associated with significantly increased risk of traumatic intracranial haemorrhage. The risk was highest for mild traumatic brain injury. Although there was substantial heterogeneity between the studies, the authors noted that most individual results showed the association between antiplatelets and intracranial haemorrhage. However, aspirin monotherapy showed no significant effect on risk of intracranial haemorrhage.
9	Leong LB and David TK. (2015) Is Platelet Transfusion Effective in Patients Taking Antiplatelet Agents Who Suffer an Intracranial Hemorrhage? Journal of Emergency Medicine 49:561–572.	A systematic review[52] assessed 7 retrospective cohort studies of platelet transfusion in people with antiplatelet-agent-associated intracranial haemorrhage. Platelet transfusion was associated with significantly greater mortality, and greater likelihood of 'medical decline' in traumatic antiplatelet-agent-associated intracranial haemorrhage.
10	Joseph B, Pandit V, Aziz H et al. (2014) Clinical outcomes in traumatic brain injury patients on preinjury clopidogrel: a prospective analysis. The Journal of Trauma and Acute Care Surgery 76:817–820.	A prospective analysis[53] included 142 people with CT-confirmed traumatic intracranial haemorrhage, 71 of whom were on clopidogrel at the time of head injury. A matched sample of 71 people were not on clopidogrel. More than half of patients (61%) received a platelet transfusion. Pre-injury clopidogrel was associated with significantly greater likelihood of intracranial haemorrhage progression on repeat CT, needing repeat CT because of clinical deterioration, and neurosurgical intervention.
11	Joseph B, Aziz H, Pandit V et al. (2014) Low-dose aspirin therapy is not a reason for repeating head computed tomographic scans in traumatic brain injury: a prospective study. Journal of Surgical Research 186:287–291.	A prospective analysis[54] included 144 people with CT-confirmed traumatic intracranial haemorrhage, 72 of whom were on aspirin at the time of head injury. A matched sample of 72 people were not on aspirin. There were no significant differences between groups for progression on repeat CT or change in management after repeat CT. CGS at discharge and mortality also did not differ significantly between groups.
12	Joseph B, Pandit V, Meyer D et al. (2014) The significance of platelet count in traumatic brain injury patients on antiplatelet therapy. The Journal of Trauma and Acute Care Surgery 77:417–421.	A prospective analysis[55] included 264 people with CT-confirmed intracranial haemorrhage who were taking aspirin or clopidogrel, or both at the time of head injury. Platelet counts of 135,000 per microliter of blood of less were associated with significantly greater likelihood of progression of intracranial haemorrhage on repeat CT. Platelet counts of 95,000 per microliter of blood of less were associated with significantly greater likelihood of need for neurosurgical intervention.
	Anticoagulants and antiplatelets	
13	Dunham CM, Hoffman DA, Huang GS et al. (2014) Traumatic intracranial hemorrhage correlates with preinjury brain atrophy, but not with antithrombotic agent use: a retrospective study. PLoS ONE [Electronic Resource] 9:e109473.	A retrospective analysis[56] included 198 people older than 60 years with external signs of head trauma. Antithrombotic drugs (defined as warfarin, clopidogrel and aspirin) were used at the time of head injury in 64% of the cohort. The rate of intracranial haemorrhage did not differ significantly with antithrombotic use compared with no antithrombotic use. No differences were seen in neurological complications defined as progression of intracranial haemorrhage, craniotomy, neurological deterioration, or death.
14	Grandhi R, Harrison G, Voronovich Z et al. (2015) Preinjury warfarin, but not antiplatelet medications, increases mortality in elderly traumatic brain injury patients. The Journal of Trauma and Acute Care Surgery 78:614–621.	A retrospective analysis[57] included 1,552 people older than 65 years with closed head injury and evidence of brain haemorrhage on CT. Antithrombotic agent use was: 543 on aspirin only, 97 on clopidogrel only, 218 on warfarin only, 193 on clopidogrel and aspirin, and 501 on no antithrombotic agent. Blood products were administered to reverse coagulopathy in 77.3% of people on antithrombotic medications. Antithrombotics were associated with increased mortality. Warfarin was associated with a borderline significant increase in mortality compared with other oral anticoagulants.
15	Joseph B, Sadoun M, Aziz H et al. (2014) Repeat head computed tomography in anticoagulated traumatic brain injury patients: still warranted. American Surgeon 80:43–47.	A retrospective analysis[58] included 1,606 people with blunt head injury, 508 of whom had CT-confirmed intracranial haemorrhage, and 72 people from this group were taking warfarin, aspirin, or clopidogrel at the time of injury. People on these drugs were significantly older, and presented with worse injury, and had longer stays in intensive care and in hospital. They were also significantly more likely to have progression of intracranial haemorrhage on repeat CT.

#	Original study citation	NICE surveillance (2017) evidence for patients on antiplatelet or anticoagulant drugs
16	McCammack KC, Sadler C, Guo Y et al. (2015) Routine repeat head CT may not be indicated in patients on anticoagulant/antiplatelet therapy following mild traumatic brain injury. The Western Journal of Emergency Medicine 16:43–49.	A retrospective analysis[59] assessed 144 people on anticoagulant and antiplatelet drugs who had head injury and a routine second non-contrast CT 6 hours after the first. Intracranial haemorrhage was detected in 10 people, and 1 person had delayed intracranial haemorrhage, but did not need further intervention.
17	Nishijima DK, Shahlaie K, Sarkar K et al. (2013) Risk of unfavorable long-term outcome in older adults with traumatic intracranial hemorrhage and anticoagulant or antiplatelet use. American Journal of Emergency Medicine 31:1244–1247.	A retrospective study[60] included 77 people with isolated head injury, 27 of whom who were taking clopidogrel or warfarin at the time of injury. People on preinjury clopidogrel or warfarin were significantly older than the control group and were significantly more likely to have an unfavourable outcome at 6 months.
	Ibuprofen	
18	Zangbar B, Pandit V, Rhee P et al. (2015) Clinical outcomes in patients on preinjury ibuprofen with traumatic brain injury. American Journal of Surgery 209:921–926.	An analysis[61] assessed the effect of preinjury ibuprofen use in 195 people with traumatic intracranial haemorrhage. People with preinjury ibuprofen use were matched to 2 non-ibuprofen control patients. There was no evidence of an effect of ibuprofen on haemorrhagic progression on repeat CT or need for neurosurgical intervention.

Topic expert feedback

Topic experts highlighted the AHEAD study,[43] [study #1 in this table; Mason et al 2017] which was noted as ongoing at the time of developing the Guideline.

Topic expert feedback suggested that preinjury clopidogrel use may be associated with increased risk of poor outcomes after head injury.

Impact statements

Warfarin was noted to increase risk of intracranial haemorrhage after head injury, which is consistent with current recommendations to perform CT in people on warfarin in the absence of any signs of brain injury. Additionally, the AHEAD study indicated that the risk of adverse outcomes (neurosurgery or death) was greater when patients had at least 1 symptom. It identified that 2.7% of people on warfarin with no indications for CT had an adverse outcome. This provides some support for the recommendation to do CT in people on warfarin in the absence of other indications for CT. The proportion of people with significant head injuries but no symptoms was lower than the 5.5% found in the evidence considered in Guideline development. However, none of the studies identified in surveillance assessed the risk of significant head injury in people without symptoms in people on warfarin compared with those not on warfarin.

A large systematic review suggested that antiplatelet drugs (other than aspirin) may increase the risk of intracranial haemorrhage after head injury. However, several of the studies included in this review were excluded from consideration during Guideline development.

During surveillance, several studies were identified that reported on both warfarin and antiplatelets. It was not clear from the abstracts whether data for clopidogrel could be extracted separately from such studies.

In developing the Guideline, the Guideline committee considered evidence on clopidogrel, but excluded all identified evidence from the clinical review because it did not meet the protocol '(indirect population, included patients on warfarin or clopidogrel, not all patients were scanned or unknown if they had initial loss of consciousness or amnesia that is, whether they would have been scanned under 2007 NICE recommendations)'.

The studies identified in surveillance also would not have met the criteria for the protocol. They provide evidence that anticlotting drugs may be associated with higher risk of intracranial haemorrhage or poorer outcomes. But we do not know whether significant brain injuries would be missed in this group of patients with the current criteria for CT.

Other considerations

We considered whether the review protocol for this review question needed to change in light of the poor evidence available. However, the AHEAD study of warfarin showed that a small proportion of people on warfarin who would be missed by the general CT criteria do have significant brain injury. This supports the recommendation to undertake CT in people on warfarin. Similar studies evaluating antiplatelets agents and also direct oral anticoagulants are needed. Although the evidence is insufficient to support an update at this time, we will reconsider this decision if suitable new evidence emerges.

The cost-effectiveness study showing CT in all people with head injury on warfarin was considered not to have an impact on current recommendations because:

- it was based on a very small number of people that may not fully represent the target population
- exploration of the uncertainty around the ICER was insufficient.

New evidence is unlikely to change Guideline recommendations.

Source: NICE surveillance (2017) report, Appendix A (pp20–23)

Table 5.3.3 Subsequent evidence from NICE surveillance (2017) for patients with any coagulopathy

#	Original study citation	NICE surveillance (2017) evidence for patients with any coagulopathy
1	Yuan Q, Sun YR, Wu X et al. (2016) Coagulopathy in Traumatic Brain Injury and Its Correlation with Progressive Hemorrhagic Injury: A Systematic Review and Meta-Analysis. Journal of Neurotrauma 33:1279–1291.	A systematic review and meta-analysis[62] assessed 19 studies of traumatic brain injury and coagulopathy. Studies were included if they assessed coagulopathy by comparing isolated traumatic brain injury with a similar severity of injury to other body regions, or compared progressive haemorrhagic injury with non-progressive head injury. Mean fibrinogen was significantly higher in people with isolated traumatic brain injury, compared with traumatic brain injury plus other injuries or other injuries only. However, other coagulation tests were not significantly different between these groups. People with progressive haemorrhagic injury had a lower platelet count and a higher international normalised ratio in people whose injury did not progress, but no differences were seen in the mean activated partial thromboplastin time or prothrombin time.
2	Folkerson LE, Sloan D, Cotton BA et al. (2015) Predicting progressive hemorrhagic injury from isolated traumatic brain injury and coagulation. Surgery 158:655–661.	An analysis[63] included 279 people with isolated traumatic brain injury; 157 of whom had progressive haemorrhagic injury and 122 of whom were stable on repeat CT. Patients with progressive head injury were older, had fewer hospital-free days, and higher mortality. Coagulopathy and age were independent predictors of progression. Controlling for age, CGS and coagulopathy, patients with intraparenchymal contusions were more likely to experience progressive haemorrhagic injury.
3	Raj R, Siironen J, Kivisaari R et al. (2013) External validation of the international mission for prognosis and analysis of clinical trials model and the role of markers of coagulation. Neurosurgery 73:305–311.	A retrospective analysis[64] including 342 people was used for validation of the IMPACT (International Mission for Prognosis and Analysis of Clinical Trials) clinical prediction model. The IMPACT model had an area under the curve (AUC) of 0.85 for predicting mortality, and 0.81 for predicting neurological outcome. People with poor outcomes had significantly lower levels of platelets and higher international normalised ratio (INR) and injury severity scores. These variables were added to the model. However, the only significant improvement in prediction was seen with adding INR to the model which improved prediction of mortality but not neurological outcome.
4	Yuan Q, Wu X, Du ZY et al. (2015) Low-dose recombinant factor VIIa for reversing coagulopathy in patients with isolated traumatic brain injury. Journal of Critical Care 30:116–120.	A prospective analysis[65] included 87 people with isolated traumatic brain injury and coagulopathy, of whom 49 were given blood products to reverse coagulopathy and 38 people also received low-dose (20 micrograms/kg) recombinant factor VIIa. People who received recombinant factor VIIa had significantly greater improvement in INR. Significantly more people who received only blood products developed progressive haemorrhagic injury compared with those receiving recombinant factor VIIa. There was no evidence of an effect on mortality with recombinant factor VIIa.
5	Joseph B, Aziz H, Zangbar B et al. (2014) Acquired coagulopathy of traumatic brain injury defined by routine laboratory tests: which laboratory values matter? The Journal of Trauma and Acute Care Surgery 76:121–125.	A retrospective cohort analysis[66] included 591 people with isolated traumatic brain injury who were not on pre-injury anticoagulant or antiplatelet therapy who had coagulation tests (INR, platelet count, and partial thromboplastin time) on admission. Coagulopathy was defined as an INR of 1.5 or greater, partial thromboplastin time of 35 seconds or greater, or platelet count of 100,000 per microlitre or less. Of the cohort, 13.3% showed coagulopathy at admission. A platelet count of 100,000 per microlitre or lower independently predicted progression on repeat CT, need for neurosurgical intervention, and mortality. INR independently predicted progression on repeat CT.
6	Wu X, Du Z, Yu J et al. (2014) Activity of factor VII in patients with isolated blunt traumatic brain injury: association with coagulopathy and progressive hemorrhagic injury. The Journal of Trauma and Acute Care Surgery 76:114–120.	An analysis[67] included 81 people with isolated brain injury who underwent coagulation tests on admission. Coagulopathy was defined as platelet count less than 120,000 per microlitre, INR greater than 1.2 or prolonged activated partial thromboplastin time greater than 40 seconds. People with coagulopathy had significantly lower factor VII activity than those with no coagulopathy. However, there was no evidence of a difference in mortality by factor VII activity
7	Abdelmalik PA, Boorman DW, Tracy J et al. (2016) Acute Traumatic Coagulopathy Accompanying Isolated Traumatic Brain Injury is Associated with Worse Long-Term Functional and Cognitive Outcomes. Neurocritical Care 24:361–370.	A retrospective analysis[68] of data (n= 647) from the COBRIT trial (Citicoline Brain Injury Treatment) assessed coagulopathy in people with isolated traumatic brain injury. Coagulopathy was defined as INR greater than 1.3, partial thromboplastin time greater than 38 seconds, or platelet count less than 120,000 per microlitre. Coagulation tests were performed at admission and during the first 7 days of hospital admission. Incidence of coagulopathy was highest at admission and on day 2. Of this cohort, 21% had coagulopathy, and these patients were significantly more likely to have GCS less than 8. This group also had higher mortality, poorer functional and cognitive outcomes, and had longer stay in hospital.
8	Epstein DS, Mitra B, Cameron PA et al. (2016) Normalization of coagulopathy is associated with improved outcome after isolated traumatic brain injury. Journal of Clinical Neuroscience 29:64–69.	A retrospective analysis of a trauma registry[69] included 157 people with isolated traumatic brain injury and coagulopathy (defined as INR greater than 1.3). Procoagulant agents (fresh frozen plasma, platelets, cryoprecipitate, prothrombin complex concentrates, tranexamic acid, vitamin K) were used in 68 people. The median time to delivery of first procoagulant was 182.5 minutes, and time to normalisation of INR was 605 minutes. Normalisation of INR was independently associated with significantly lower mortality
Topic expert feedback		
No topic expert feedback was relevant to this evidence.		

#	Original study citation	NICE surveillance (2017) evidence for patients with any coagulopathy
Impact statement		
NICE guidance on blood transfusion (NG24) contains recommendations for reversing anticoagulation for people on warfarin who have suspected traumatic intracranial haemorrhage. NICE NG24 also covers platelet transfusion It was not always clear in the abstracts of the studies of coagulopathy whether patients were on anti-clotting drugs at the time of injury. One study looked specifically at people not taking such drugs and suggested a fairly high incidence of coagulopathy of over 13%. It is also not clear whether coagulopathy occurred for the first time in head injury. People with a previous history of bleeding or clotting disorders would receive CT under current recommendations (see recommendation 1.4.8) Detection and treatment of coagulopathy is not considered in NICE CG176 but may be relevant to acute care because of the long time between starting treatments to correct coagulopathy and seeing an effect. However, the available evidence consists of small observational studies, and do not show a clear need for updated guidance in this area.		
New evidence is unlikely to change Guideline recommendations.		

Source: NICE surveillance (2017) report, Appendix A (pp23–24)

5.3.4.3 SIMEUP Position Statement (2019)

The SIMEUP Position found little evidence concerning the risk of intracranial haemorrhage (ICH)-related trauma in children with bleeding disorders, the majority were retrospective studies and case series of children with a specific coagulation disorder. Only one prospective study was identified that provides an estimate of the risk of ICH in children with various bleeding disorders (64).

Table 5.3.4 Evidence from SIMEUP Position Statement (2019)

#	Original study citation	SIMEUP Position Statement (2019) evidence for children with bleeding disorders
1	Lee LK, Dayan PS, Geraldi MJ et al. (2011) Intracranial hemorrhage after blunt head trauma in children with bleeding disorders. Journal of Pediatrics 158:1003–1008.	PECARN secondary analysis which reported 230 children with bleeding disorders in 43,904 children aged less than 18 years with blunt head trauma and Glasgow Coma Scale (GCS) scores of 14 to 15. Of the children who underwent CT, 2 of 186 children with bleeding disorders had intracranial haemorrhage (1.1%; 95% CI, 0.1 to 3.8) compared with 655 of 14,969 children without bleeding disorders (4.4%; 95% CI, 4.1–4.7; rate ratio, 0.25; 95% CI, 0.06 to 0.98). Both children with bleeding disorders and intracranial haemorrhage had symptoms and none required neurosurgery (64)

5.3.5 New evidence

Four studies relevant to this question were identified in the PREDICT Guideline literature search. No key studies were identified as key for this question.

Table 5.3.5 New evidence identified for imaging Q3

Ref #	Citation
66.	Anderst JD, Carpenter SL, Presley R, Berkoff MC, Wheeler AP, Sidonio RF, Jr., et al. Relevance of Abusive Head Trauma to Intracranial Hemorrhages and Bleeding Disorders. Pediatrics. 2018;141(5):5.
67.	Uccella L, Zoia C, Bongetta D, Gaetani P, Martig F, Candrian C, et al. Are Antiplatelet and Anticoagulants Drugs A Risk Factor for Bleeding in Mild Traumatic Brain Injury? World Neurosurgery. 2018;110:e339-e45.
68.	van den Brand CL, Tolido T, Rambach AH, Hunink MG, Patka P, Jellema K. Systematic review and meta-analysis: Is pre-injury antiplatelet therapy associated with traumatic intracranial hemorrhage? Journal of Neurotrauma. 2017;34(1):43647.
65.	Verschoof M, Zuurbier C, De Beer F, Coutinho J, Van Geel B. 24-hour close observation may not be necessary in patients with mild traumatic brain injury (mTBI) during anticoagulation therapy. European Journal of Neurology Conference: 3rd congress of the European Academy of Neurology Netherlands. 2017;24:100.

Shaded rows indicate key papers.

5.3.5.1 Rationale for selection of key evidence

None of the four new studies were selected as key evidence for this question. The new evidence did not address the question regarding the risk difference between patients with bleeding disorders and not having a bleeding disorder. The key paper informing this recommendation was found prior to the search dates (64). The Guideline recommendation was adapted in response to findings from the key paper (64)with changes to wording for local practice.

5.3.5.2 Key evidence data extraction

N/A

5.3.6 Key considerations for assessing the evidence

5.3.6.1 NICE GDG considerations

The GDG updated the 2007 guidance based on the evidence identified in 2014:

> *…evidence of increased risk of developing a haematoma in all patients using warfarin, not just those with loss of consciousness or amnesia and have modified this recommendation to ensure that all these patients are scanned (see recommendation 28). It is anticipated that this would probably increase the specificity of the NICE Guideline in detecting intracranial haematomas.*

No change was made to the 2014 guidance as a result of the 2017 surveillance of the literature.

5.3.7 Working Group recommendation deliberations

Table 5.3.6 Clinical judgement form for imaging Q3

PREDICT Guideline imaging Q3	**In infants and children on anticoagulant or antiplatelet therapy, or with a known bleeding disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?**
Source recommendation/s	
SIMEUP Position Statement (37) Italy 6 recommendations and one statement not labelled as recommendations Recs 1, 2, 3a, 5, 6, 7	**SIMEUP Recommendation 1** Pediatric patients with congenital or acquired bleeding disorders who have sustained a minor head trauma and do not present any signs or symptoms of traumatic brain injury, clinical observation should be preferred over a routine CT, depending on the severity of the coagulation disorder, the mechanism of injury and specific risk factors related to the patient or to the baseline haemorrhagic diathesis (i.e. moderate and severe forms, hemophiliacs with inhibitors, severe deficit of FXIII). **SIMEUP Recommendation 2** In patients with coagulation factors deficiency and suspected intracranial haemorrhage, the performance of a CT must not delay the administration of the replacement factor, which is, the gold standard for treatment and must be infused within the shortest time possible. **SIMEUP Recommendation 3a** The level of factor should be immediately elevated in the presence of significant trauma or early symptoms and the use of neuroimaging should not delay the infusion of the factor itself. **SIMEUP Recommendation 5** In case of head injury in patients with a rare coagulopathy not on prophylaxis treatment, it is necessary to immediately contact the center that is treating the patient or the regional referral center. **SIMEUP Recommendation 6** CT is not necessary in the absence of clinical signs suggestive of intracranial haemorrhage [immune thrombocytopenias] **SIMEUP Recommendation 7** In case of head injury in patients with platelet counts less than 20,000 / mmc, preventive therapy of intracranial bleeding with IVIG is recommended. **SIMEUP – unlabelled statement** In patients on warfarin therapy who undergo a minor head injury, the performance of a routine CT should be considered regardless of the presence or absence of clinical signs and presenting symptoms.

GENERALISABILITY of the source recommendation/s

Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?

☒ Yes ☐ No ☐ Unsure ☐ N/A

If not, is the recommendation generalisable/ transferable to the settings and patients of interest?

☒ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☒ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

SIMEUP – Recommendation 1
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

SIMEUP – Recommendation 2
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

SIMEUP – Recommendation 3a
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

SIMEUP – Recommendation 5
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

SIMEUP – Recommendation 6
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

SIMEUP – Recommendation 7
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

SIMEUP – unlabelled statement
☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

Comment:

PREDICT Guideline imaging Q3	In infants and children on anticoagulant or antiplatelet therapy, or with a known bleeding disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

If new guidance needs to be developed, what type of guidance is appropriate?

☒ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance	
PREDICT evidence-informed recommendation 10	In children with congenital or acquired bleeding disorders, following a head injury that results in presentation to an acute care setting, where there are no risk factors for clinically-important traumatic brain injury[38] (see PREDICT Recommendation 5 or Box A for risk factors, and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries)*, consider structured observation over an immediate head CT scan. If there is a risk factor for intracranial injury, a head CT should be performed. If there is a deterioration in neurological status, a head CT should be performed urgently.
PREDICT practice point F	In children with coagulation factor deficiency (e.g. haemophilia), following a head injury that results in presentation to an acute care setting, the performance of a head CT scan or the decision to undertake structured observation must not delay the urgent administration of replacement factor.
PREDICT practice point G	In all children with a bleeding disorder or on anticoagulant or antiplatelet therapy, following a head injury that results in presentation to an acute care setting, clinicians should urgently seek advice from the haematology team treating the child in relation to risk of bleeding and management of the coagulopathy.
PREDICT evidence-informed recommendation 11	In children with immune thrombocytopaenias, following a head injury which results in presentation to an acute care setting, where there are no risk factors for clinically-important traumatic brain injury[37] (see PREDICT Recommendation 5 or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*), consider structured observation over an immediate head CT scan. If there is a risk factor for intracranial injury, a head CT should be performed. If there is a deterioration in neurological status, a head CT should be performed urgently. Clinicians should check platelet count in all children with immune thrombocytopaenias, and blood group in all symptomatic patients, if not already available.
PREDICT practice point H	In children with immune thrombocytopaenia with mild to moderate head injury and platelet counts of less than 20×10^9/L, consider empirical treatment after discussion with the haematology team treating the child.
PREDICT consensus-based recommendation 12	In children with mild to moderate head injury on warfarin therapy, other anticoagulants (e.g. direct oral anticoagulants) or antiplatelet therapy, consider a head CT scan regardless of the presence or absence of risk factors for clinically-important traumatic brain injury[38] (see PREDICT Recommendation 5 or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*). Seek senior clinician review to inform timing of the head CT scan. Discuss the patient with the team managing the anticoagulation regarding early consideration of reversal agents. Check the appropriate anticoagulant measure (if available); for example, international normalised ratio (INR), activated partial thromboplastin time (APTT) or anti-Xa assay.
PREDICT practice point I	In adolescents with mild to moderate head injury and taking anticoagulants, including warfarin, consider managing according to adult literature and guidelines.

Rationale:

The PREDICT GWG **adapted evidence-informed recommendations** from the Italian SIMEUP position statement (37) (in press). The GWG also sought input from the haematology group at Royal Children's Hospital, Melbourne. The PREDICT literature search identified 4 new studies, none were selected as key evidence for this question.

Prospective data addressing the risk of important intracranial injuries in children with bleeding disorders compared to those without bleeding disorders are limited; there are likely differences in the risk of intracranial haemorrhage between different types of bleeding disorders and types of anticoagulant or antiplatelet therapy. Key evidence is limited to the PECARN secondary analysis which reported 230 children with bleeding disorders in 43,904 children aged less than 18 years with blunt head trauma and Glasgow Coma Scale (GCS) scores of 14 to 15. Of the children who underwent CT, 2 of 186 children with bleeding disorders had intracranial haemorrhage (1.1%; 95% CI, 0.1 to 3.8) compared with 655 of 14,969 children without bleeding disorders (4.4%; 95% CI, 4.1–4.7; rate ratio, 0.25; 95% CI, 0.06 to 0.98). Both children with bleeding disorders and intracranial haemorrhage had symptoms and none required neurosurgery (64).

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☐ No ☒ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

[38] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

5.4 Imaging Q4 – In infants and children with a neurodevelopmental disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

5.4.1 PREDICT question

PREDICT Guideline imaging Q4

In infants and children with a neurodevelopmental disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

5.4.2 Source question

There is no corresponding clinical question in the source guidelines.

There is a prognostic question in the CDC Guideline that identified neurological and psychiatric problems as premorbid factors associated with poorer post-concussive symptoms, but this does not inform decisions about cranial CT or observation.

5.4.3 Source recommendation

There are no source recommendations that corresponds to the PREDICT Guideline IMAGING Q4 (CT or observation in children with a neurodevelopmental disorder).

5.4.4 Source evidence

N/A

5.4.5 New evidence

No new studies relevant to this question were identified in the PREDICT Guideline literature search.

5.4.6 Key considerations for assessing the evidence

N/A

5.4.7 Working Group recommendation deliberations

Table 5.4.1 Clinical judgement form for imaging Q4

PREDICT Guideline imaging Q4	**In infants and children with a neurodevelopmental disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?**
Source recommendation/s	
None available	
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?	If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☐ Yes ☐ No ☐ Unsure ☒ N/A	☐ Yes ☐ No ☐ Unsure ☒ N/A
Comment:	

PREDICT Guideline imaging Q4	In infants and children with a neurodevelopmental disorder and mild to moderate head injury presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☐ Yes ☐ No ☐ Unsure ☒ N/A

Comment:

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

☐ Adopt source guidance
☐ Adapt source guidance
☒ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☒ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance

PREDICT consensus-based recommendation 13	It is unclear whether children with neurodevelopmental disorders presenting to an acute care setting following mild to moderate head injury have a different background risk for intracranial injury. Consider structured observation or a head CT scan for these children because they may be difficult to assess. For these children, shared decision-making with parents, caregivers and the clinical team that knows the child is particularly important.

Rationale

PREDICT GWG developed a **new consensus-based recommendation**. There were no source guideline recommendations to inform this question and the PREDICT literature search did not identify any new studies.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

5.5 Imaging Q5 – In children with mild to moderate head injury who are drug or alcohol intoxicated presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

5.5.1 PREDICT question

PREDICT Guideline imaging Q5

In children with mild to moderate head injury who are drug or alcohol intoxicated presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?

5.5.2 Source question

There is no corresponding clinical question in the source guidelines.

5.5.3 Source recommendations

No source recommendations are dedicated to this patient population, but drug or alcohol intoxication is listed as a risk factor indicating conservative management for six recommendations in the NICE CG176 (2014) Guideline: two for referral to hospital and four for decisions regarding admission to hospital (Table 5.5.1). All of these recommendations are based on level 5 evidence, which is expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Table 5.5.1 NICE CG176 (2014) differential recommendations for patients who are also drug- or alcohol-affected

Section of NICE CG176 Recommendation no	Expert opinion recommendations (c)	History
Section 5.16 Recommendation 3	**Telephone advice lines** Telephone advice services (for example, NHS 111 or emergency department helplines) should refer patients who have sustained a head injury to a hospital emergency department if they have any of the following risk factors: • Any loss of consciousness ('knocked out') as a result of the injury, from which the person has now recovered. • Amnesia for events before or after the injury ('problems with memory').(a) • Persistent headache since the injury. • Any vomiting episodes since the injury. • Any previous brain surgery. • Any history of bleeding or clotting disorders. • Current anticoagulant therapy such as warfarin. • Current drug or alcohol intoxication. • There are any safeguarding concerns (for example, possible non-accidental injury or a vulnerable person is affected). • Irritability or altered behaviour ('easily distracted', 'not themselves', 'no concentration', 'no interest in things around them') particularly in infants and children aged under 5 years. • Continuing concern by helpline staff about the diagnosis	**Developed** 2003 **Amended** 2014
Section 5.17 Recommendation 4	**Community health services and NHS minor injury clinics** Community health services (GPs, ambulance crews, NHS walk-in centres, dental practitioners) and NHS minor injury clinics should refer patients who have sustained a head injury to a hospital emergency department, using the ambulance service if deemed necessary, if any of the following are present: • Glasgow Coma Scale (GCS) score of less than 15 on initial assessment. • Any loss of consciousness as a result of the injury. • Any focal neurological deficit since the injury. • Any suspicion of a skull fracture or penetrating head injury since the injury. • Amnesia for events before or after the injury.(a) • Persistent headache since the injury. • Any vomiting episodes since the injury (clinical judgement should be used regarding the cause of vomiting in those aged 12 years or younger and the need for referral). • Any seizure since the injury. • Any previous brain surgery. • A high-energy head injury. • Any history of bleeding or clotting disorders. • Current anticoagulant therapy such as warfarin. • Current drug or alcohol intoxication. • There are any safeguarding concerns (for example, possible non-accidental injury or a vulnerable person is affected). • Continuing concern by the professional about the diagnosis	**Developed** 2003 **Amended** 2007 2014
Section 10.3 Recommendation 81	**Discharge of low risk patients with GCS equal to 15** If CT is not indicated on the basis of history and examination the clinician may conclude that the risk of clinically important brain injury to the patient is low enough to warrant transfer to the community, as long as no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).	**Developed** 2003
Section 10.4 Recommendation 82	**Discharge of patients with normal imaging of the head** After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected	**Developed** 2003

Section of NICE CG176 Recommendation no	Expert opinion recommendations (c)	History
	non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).	
Section 10.5 Recommendation 83	**Discharge of patients with normal imaging of the cervical spine** After normal imaging of the cervical spine the clinician may conclude that the risk of injury to the cervical spine is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15 and their clinical examination is normal, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).	**Developed** 2003
Section 10.10 Recommendation 88	**Information at discharge** (b) Offer information and advice on alcohol or drug misuse to patients who presented to the emergency department with drug or alcohol intoxication when they are fit for discharge.	**Developed** 2003
Section 11.2 Recommendation 94	**Admission** Use the criteria below for admitting patients to hospital following a head injury: • Patients with new, clinically significant abnormalities on imaging. • Patients whose GCS has not returned to 15 after imaging, regardless of the imaging results. • When a patient has indications for CT scanning, but this cannot be done within the appropriate period, either because CT is not available or because the patient is not sufficiently cooperative to allow scanning. • Continuing worrying signs (for example, persistent vomiting, severe headaches) of concern to the clinician. • Other sources of concern to the clinician (for example, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak).	**Developed** 2003

Source: NICE CG176 (2014), Sections as indicated.
(a) Assessment of amnesia will not be possible in pre-verbal children and is unlikely to be possible in children aged under 5 years.
(b) Title of this section is 'Recommendations and link to evidence', which forms part of the findings for a clinical question. While new evidence was identified and used to create new recommendations concerning information for patients at discharge, Recommendation 88 is unchanged since 2003. The new recommendations did not refer to patients with drug or alcohol intoxication.
(c) Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

5.5.4 Source evidence

5.5.4.1 NICE CG176 (2014)

As the NICE CG176 (2014) Guideline does not include a clinical question addressing drug or alcohol intoxicated patients with head injury, and the only recommendations specifying this population are based on expert opinion, no evidence is available for this PREDICT Guideline question.

5.5.4.2 NICE surveillance (2017)

No new evidence was found by the NICE surveillance (2017) for head injury patients with drug or alcohol intoxication. The recommendations from the NICE CG176 (2014) Guideline remained unchanged.

5.5.5 New evidence

No new studies relevant to this question were identified in the PREDICT Guideline literature search.

5.5.6 Key considerations for assessing the evidence

5.5.6.1 Excerpt from NICE 2003

The following rationale was reproduced from the 2003 Guideline explaining the differential management of head injury patients who are affected by drugs or alcohol:

Drug or alcohol intoxication (2003) *Drug or alcohol intoxication can result in signs and symptoms which are risk factors for intracranial complications (for example, vomiting, headache, amnesia, impaired consciousness) but have also been identified as independent risk factors following head injury, making a differential diagnosis difficult.[39,40] In addition, alcohol abuse can lead to hypoglycaemia, which can in turn lead to impaired consciousness. This may lead to the incorrect diagnosis of a developing intracranial trauma complication (NICE CG176 (2014) Section 5.10, p77).*

5.5.7 Working Group recommendation deliberations

Table 5.5.2 Clinical judgement form for imaging Q5

PREDICT Guideline imaging Q5	**In children with mild to moderate head injury who are drug or alcohol intoxicated presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?**
Source recommendation/s	
None available	
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☐ No ☐ Unsure ☒ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☐ Yes ☐ No ☐ Unsure ☒ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? ☐ Adopt source guidance ☐ Adapt source guidance ☒ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☐ Evidence-informed recommendation/s ☒ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT consensus-based recommendation 14	In children who are drug or alcohol intoxicated presenting to an acute care setting following mild to moderate head injury, treat as if the neurological findings are due to the head injury. The decision to undertake structured observation or a head CT scan should be informed by the risk factors for clinically-important traumatic brain injury[41] (see PREDICT Recommendation 5 or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*) rather than the child being intoxicated.
Rationale PREDICT GWG developed a **new consensus-based recommendation**. There was no Guideline evidence source to inform this question and the PREDICT literature search did not identify any new studies.	

[39] Cook LS, Levitt MA, Simon B, Williams VL. Identification of ethanol-intoxicated patients with minor head trauma requiring computed tomography scans. Academic Emergency Medicine. 1994; 1(3):227-234

[40] Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PM. Indications for computed tomography in patients with minor head injury. New England Journal of Medicine. 2000; 343(2):100-105

[41] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

PREDICT Guideline imaging Q5	In children with mild to moderate head injury who are drug or alcohol intoxicated presenting within 72 hours of injury, which should undergo a i) cranial CT and/or ii) a period of observation?	
FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.6 Imaging Q6 – In infants and children with mild to moderate head injury presenting within 72 hours of injury who does/does not require an initial cranial CT, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?

5.6.1 PREDICT questions

PREDICT Guideline imaging Q6 (a)

In infants and children with mild to moderate head injury presenting within 72 hours of injury who does/does not require an initial cranial CT, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?

PREDICT Guideline imaging Q6 (b)

In infants and children with mild to moderate head injury presenting within 72 hours of injury who do not receive an initial cranial CT, but received a period of observation, what is the optimal frequency of reassessment and duration of observation?

5.6.2 Source question

There are no clinical questions in NICE CG176 related to IMAGING Q6 (a) in either adult or paediatric populations.

One clinical question for the general population is related to IMAGING Q6 (b).

NICE CG176 Section 7.13

What are the effects on patient outcomes of providing an immediate CT versus observation?

5.6.3 Source recommendations

There are no recommendations in NICE CG176 related to IMAGING Q6 (a) or IMAGING Q6 (b) in either adult or paediatric populations.

Recommendation 31 includes information about the length of time for observation of a subset of the paediatric population, but this is covered in IMAGING Q1 where it forms part of an overall strategy involving three recommendations.[42]

The following five expert opinion recommendations are also related to observation of children, but do not directly address the clinical questions in NICE CG176 or this Guideline (PREDICT). They are reproduced here for reference only.

Expert opinion[43]

NICE CG176 Recommendation 106

Observation of infants and young children (that is, aged under 5 years) is a difficult exercise and therefore should only be performed by units with staff experienced in the observation of infants and young children with a head injury. Infants and young children may be observed in normal paediatric observation settings, as long as staff have the appropriate experience.
Developed: 2003

NICE CG176 Recommendation 109

Specific training is required for the observation of infants and young children.
Developed: 2003

Expert opinion[44]

NICE CG176 Recommendation 81

If CT is not indicated on the basis of history and examination the clinician may conclude that the risk of clinically important brain injury to the patient is low enough to warrant transfer to the community, as long as no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).

Developed: 2003

Expert opinion[45]

NICE CG176 Recommendation 82

After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).

Developed: 2003

[42] No evidence or rationale is presented for the recommended period observation.
[43] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".
[44] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".
[45] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Expert opinion[46]

NICE CG176 Recommendation 100

Perform and record observations on a half-hourly basis until GCS equal to 15 has been achieved. The minimum frequency of observations for patients with GCS equal to 15 should be as follows, starting after the initial assessment in the emergency department:

- *Half-hourly for 2 hours.*
- *Then 1-hourly for 4 hours.*
- *Then 2-hourly thereafter.*

Developed: 2003

5.6.4 Source evidence

5.6.4.1 NICE CG176 (2014)

The NICE CG176 (2014) Guideline identified one study relevant to imaging Q6 (b), an RCT of head CT (n= 1,316) compared with admission to hospital for observation (n= 1,286) in patients 6 years of age or older presenting within 24 hours. The synopsis provided in the NICE Guideline is reproduced in Table 5.6.1. No statistically significant difference was found between the groups for any of the outcomes (proportion of patients with complete recovery at 3 months, severe loss of function or mortality).

Table 5.6.1 NICE CG176 (2014) clinical evidence for CT versus observation

Ref#	Citation	NICE 2014 evidence for CT versus admission to hospital for observation
1	af Geijerstam JL, Oredsson S, Britton M. Medical outcome after immediate computed tomography or admission for observation in patients with mild head injury: randomised controlled trial. BMJ. 2006; 333(7566):465	One study (level 1++ evidence) was identified[4] for this review. This recent large, randomised controlled trial investigated CT compared with admission to hospital for observation. This study included hospital patients aged ≥6 years of age with mild head injury within the past 24hrs who attended emergency departments. The main findings from this trial were that at 3 months, 21.4% (275/1316) of patients in the CT group had not recovered completely compared with 24.2% (300/1286) admitted for observation. The difference was found to be not significant in favour of CT (95%CI: -6.1%-0.6%). The worst outcomes like mortality and severe loss of function were similar between the groups. None of the patients with normal findings on immediate CT had complications later.

Source: NICE CG176 (2014) (p139).

No recommendation was developed based on this evidence.

5.6.4.2 NICE 2017 surveillance

No new studies were identified for this question in the NICE surveillance (2017) report (Appendix A, p28).

5.6.5 New evidence

Nineteen studies relevant to this question were identified in the PREDICT Guideline literature search (Table 10.6.2). Four key studies were selected, one new study (7) and three studies published prior to the search date (61, 65, 66).

Table 5.6.2 New evidence identified for imaging Q6

Ref #	Citation
26.	Arneitz C, Sinzig M, Achatz E, Fasching G. Can a CT be Omitted in Pediatric Minor Head Trauma? Journal of Pediatric Neurology. 2018;16(1):43647.
69.	Arrey EN, Kerr ML, Fletcher S, Cox CS, Jr., Sandberg DI. Linear nondisplaced skull fractures in children: who should be observed or admitted? Journal of Neurosurgery Pediatrics. 2015;16(6):703–8.

[46] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Ref #	Citation
75.	Asan Z, Caliskan HM, Sahin Y, Sahin C, Durna F. Linear fractures of the cranium: Follow-up and management results of 442 cases. Journal of Clinical and Analytical Medicine. 2018;9(5):425–9.
2.	Babl FE, Borland ML, Phillips N, Kochar A, Dalton S, McCaskill M, et al. Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. Lancet. 2017;389(10087):2393–402.
4.	Badawy MK, Dayan PS, Tunik MG, Nadel FM, Lillis KA, Miskin M, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605.
76.	Blanchard A, Cabrera KI, Kuppermann N, Dayan PS. Acute Outcomes of Isolated Pneumocephali in Children After Minor Blunt Head Trauma. Pediatric Emergency Care. 2018;34(9):656–60.
77.	Bressan S, Marchetto L, Lyons TW, Monuteaux MC, Freedman SB, Da Dalt L, et al. A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Annals of Emergency Medicine. 2018;71(6):714–7.24E+04.
78.	Burns EC, Burns B, Newgard CD, Laurie A, Fu R, Graif T, et al. Pediatric Minor Traumatic Brain Injury with Intracranial Hemorrhage: Identifying Low-Risk Patients Who May Not Benefit from ICU Admission. Pediatric Emergency Care. 2019;35(3):161–9.
79.	Flaherty BF, Moore HE, Riva-Cambrin J, Bratton SL. Pediatric patients with traumatic epidural hematoma at low risk for deterioration and need for surgical treatment. Journal of Pediatric Surgery. 2017;52(2):334–9.
80.	Flaherty BF, Moore HE, Riva-Cambrin J, Bratton SL. Repeat Head CT for Expectant Management of Traumatic Epidural Hematoma. Pediatrics. 2018;142(3):9.
81.	Hagiwara Y, Inoue N. The Effect of an Observation Unit on Pediatric Minor Head Injury. Pediatric Emergency Care. 2018;24:24.
82.	Lefort R, Hunter JV, Cruz AT, Caviness AC, Luerssen TG, Adekunle-Ojo A. Utility of Emergency Department Observation Units for Neurologically Intact Children with Head CT Abnormalities Secondary to Acute Closed Head Injury. Pediatric Emergency Care. 2017;33(3):161–5.
70.	Marincowitz C, Lecky FE, Townend W, Borakati A, Fabbri A, Sheldon TA. The risk of deterioration in GCS13–15 patients with traumatic brain injury identified by computed tomography imaging: A systematic review and meta-analysis. Journal of Neurotrauma. 2018;35(5):703–18.
71.	Masoumi B, Heydari F, Hatamabadi H, Azizkhani R, Yoosefian Z, Zamani M. The Relationship between Risk Factors of Head Trauma with CT Scan Findings in Children with Minor Head Trauma Admitted to Hospital. Open Access Macedonian Journal of Medical Sciences. 2017;5(3):319–23.
72.	Ogrenci A, Koban O, Eksi M, Yaman O, Dalbayrak S. The Necessity of Follow-Up Brain Computed-Tomography Scans: Is It the Pathology Itself or Our Fear that We Should Overcome? Open Access Macedonian Journal of Medical Sciences. 2017;5(6):740–3.
83.	Patel SK, Gozal YM, Krueger BM, Bayley JC, Moody S, Andaluz N, et al. Routine surveillance imaging following mild traumatic brain injury with intracranial hemorrhage may not be necessary. Journal of Pediatric Surgery. 2018;53(10):2048–54.
73.	Rai B, McCartan F, Kaninde A, Sharif F. Infants with head injuries-do all need hospital admission? Irish Journal of Medical Science. 2018;187(1):141–3.
74.	Tallapragada K, Peddada RS, Dexter M. Paediatric mild head injury: is routine admission to a tertiary trauma hospital necessary? ANZ Journal of Surgery. 2018;88(3):202–6.
84.	Varano P, Cabrera KI, Kuppermann N, Dayan PS. Acute outcomes of isolated cerebral contusions in children with Glasgow Coma Scale scores of 14 to 15 after blunt head trauma. The Journal of Trauma and Acute Care Surgery. 2015;78(5):1039–43.
Relevant evidence published prior to new evidence search date limit	
--	Hamilton M, Mrazik M, Johnson DW. Incidence of delayed intracranial haemorrhage in children after uncomplicated minor head injuries. Pediatrics. 2010 Jul;126(1):e33–9. doi: 10.1542/peds.2009–0692. Epub 2010 Jun 21. PubMed PMID:20566618.
--	Nigrovic LE, Schunk JE, Foerster A, Cooper A, Miskin M, Atabaki SM, Hoyle J, Dayan PS, Holmes JF, Kuppermann N; Traumatic Brain Injury Group for the Pediatric Emergency Care Applied Research Network. The effect of observation on cranial computed tomography utilization for children after blunt head trauma. Pediatrics. 2011 Jun;127(6):1067–73. doi: 10.1542/peds.2010–3373. Epub 2011 May 9.
--	Schonfeld D, Fitz BM, Nigrovic LE. Effect of the duration of emergency department observation on computed tomography use in children with minor blunt head trauma. Ann Emerg Med. 2013 Dec;62(6):597–603. doi: 10.1016/j.annemergmed.2013.06.020. Epub 2013 Aug 2.

Shading indicates key studies.

5.6.5.1 Rationale for selection of key evidence

One of the 19 new studies was selected as key evidence for this question based on the following rationale: Babl, Borland (7) externally validated the PECARN rule in the Australian and New Zealand setting however it does not provide a similar risk stratification for the non-low risk patients similar to Kuppermann, Holmes (1). An older study (65) reported a very low incidence (0.03%) of delayed ICH in children with uncomplicated minor head injury with none experiencing a deterioration in level of consciousness. However, despite this low risk, there is no new relevant evidence to determine the optimal length of observation. The recommendation regarding the non-low risk patient population and the length of observation has been developed by consensus opinion. There is a need for research to assess the risk stratification for non-low risk patients and optimal length of observation.

5.6.5.2 Key evidence data extraction

Table 5.6.3 Data from key evidence for imaging Q6

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Babl FE**, Borland ML, Phillips N et al. Accuracy of PECARN, CATCH and CHALICE head injury decision rules in children. Lancet 2017; 389(10087):2393–2402 **Aim** Validate 3 clinical decisions rules (PECARN, CATCH and CHALICE) **Setting** 10 EDs in Australia and New Zealand **Type** Prospective observational study.	**Sample Size** 20137 children and adults with head injuries **Characteristics** 95% presented within 24h of injury. Mean age 5.7 (4.7) years. Boys 63.7%. **Inclusion** PECARN[1] CATCH[2] CHALICE[3] **Exclusion** PECARN[4] CATCH[5] CHALICE[6]	Rule specific predictor variables for standardised outcome of clinically important traumatic brain injuries.	**Predictor variables**: mechanism of injury **History**: LOC, vomiting, headache, amnesia, suspected NAI, seizure **Examination**: GCS score, other signs of altered mental status, skull fracture, occipital, parietal or temporal scalp haematoma, presence of bruise, swelling. Demographic and epidemiological data	**Primary outcome:** PECARN: Clinically important TBI -280 (1%) CATCH 185 (1%) had need for neurological intervention CHALICE 403 (2%) had clinically significant intracranial injury. **Rule sensitivity:** PECARN < 2yrs: 100.0% (95% CI 90.7–100.0) PECARN ≥2: 99.0%, 94.4–100.0) CATCH (high risk predictors): 95.2%; 76.2–99.9 CHALICE: (92.3%, 89.2–94.7)	**Limitations** CT scans not obtained on all patients. 10% patients lost to telephone follow up and excluded. **Study conclusion** The sensitivities of three clinical decision rules for head injuries in children were high when used as designed. The findings are an important starting point for clinicians considering the introduction of one of the rules.

[1]**PECARN inclusion:** Age <18 years; presenting within 24 hours of head injury
[2]**CATCH inclusion:** Age <17years. All of the following: presenting with blunt trauma to head resulting in witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (two or more distinct episodes 15 minutes apart), persistent irritability in the ED (in children <2 years), initial GCS score in ED ≥13, as determined by treating physician, injury within the past 24 hours.
[3]**CHALICE inclusion:** Age <16 years; any history or signs of injury to the head
[4]**PECARN exclusion:** Trivial mechanism of injury, defined by ground-level fall or walking or running into stationary objects and no signs or symptoms of head trauma other than scalp abrasions and lacerations; penetrating trauma; known brain tumours; pre-existing neurological disorder complicating assessment; neuroimaging at an outside hospital before transfer; patient with ventricular shunt. Patient with bleeding disorder GCS score <14.
[5]**CATCH exclusion**: Obvious penetrating skull injury; obviously depressed fracture; acute focal neurological deficit; chronic generalised developmental delay; head injury secondary to suspected child abuse; returning for reassessment of previously treated head injury. Patients who were pregnant.
[6]**CHALICE exclusion:** refusal to consent

5.6.6 Key considerations for assessing the evidence

5.6.6.1 NICE GDG considerations

The only recommendation related to this question concerned safeguarding for children and vulnerable adults suspected of abusive head trauma. The recommendation was reached by consensus, with the GDG noting that ‘whilst there are costs to staff time to undertake the appropriate action, safeguarding is a mandatory activity.’

5.6.7 Working Group recommendation deliberations

Table 5.6.4 Clinical judgement form for imaging Q6 (a,b)

PREDICT Guideline imaging Q6 (a,b)	**(a) In infants and children with mild to moderate head injury presenting within 72 hours of injury who does/does not require an initial cranial CT, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?** **(b) In infants and children with mild to moderate head injury presenting within 72 hours of injury who do not receive an initial cranial CT, but received a period of observation, what is the optimal frequency of reassessment and duration of observation?**
Source recommendation/s	
None available	
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☐ No ☐ Unsure ☒ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☐ Yes ☐ No ☐ Unsure ☒ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? ☐ Adopt source guidance ☐ Adapt source guidance ☒ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 15	In children presenting to an acute care setting following mild to moderate head injury, the risk of clinically-important traumatic brain injury[47] requiring hospital care is low enough to warrant discharge home without a head CT scan if the patient has no risk factors for a clinically-important traumatic brain injury[47] (see PREDICT Recommendation 5 or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*), has a normal neurological examination and has no other factors warranting hospital admission (e.g. other injuries, clinician concerns [e.g. persistent vomiting], drug or alcohol intoxication, social factors, underlying medical conditions such as bleeding disorders or possible abusive head trauma).
PREDICT practice point J	In children undertaking structured observation following mild to moderate head injury, consider observation up to 4 hours from the time of injury, with discharge if the patient returns to normal for at least 1 hour. Consider an observation frequency of every half hour for the first 2 hours, then 1-hourly until 4 hours post injury. After 4 hours, continue observation at least 2-hourly for as long as the child remains in hospital.
PREDICT practice point K	The duration of structured observation may be modified based on patient and family variables, including time elapsed since injury or signs and symptoms, and reliability and ability of the child or parent to follow advice on when to return to hospital.

[47] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

PREDICT Guideline imaging Q6 (a,b)	**(a) In infants and children with mild to moderate head injury presenting within 72 hours of injury who does/does not require an initial cranial CT, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?** **(b) In infants and children with mild to moderate head injury presenting within 72 hours of injury who do not receive an initial cranial CT, but received a period of observation, what is the optimal frequency of reassessment and duration of observation?**

Rationale

The PREDICT GWG developed a **new evidence-informed recommendation and two practice points.** One practice point (J) was adapted from the NICE CG176 (2014) Guideline. There was no Guideline evidence source to inform this recommendation. The PREDICT literature search identified 19 new studies, of these 4 studies were deemed key (3 were published prior to the search date).

The PECARN clinical prediction rules (1) were derived and validated in 42,412 children with head trauma with GCS scores of 14–15 aged less than 18 years in the United States. The PECARN rule is age specific and focuses on the identification of clinically-important traumatic brain injuries (ciTBI: death from traumatic brain injury, neurosurgery, intubation > 24 h, or hospital admission > or= 2 nights). The rule identified age specific low risk factors (children younger than 2 years: normal mental status, no scalp haematoma except frontal, no loss of consciousness or loss of consciousness for less than 5 s, non-severe injury mechanism, no palpable skull fracture, and acting normally according to the parents; children aged 2 years and older: normal mental status, no loss of consciousness, no vomiting, non-severe injury mechanism, no signs of base of skull fracture, and no severe headache. The PECARN rule was externally validated in 20,137 children with head injuries in Australia and New Zealand (7). If children are not low risk based on the adapted PECARN rules, they should be considered for head CT imaging or observation (Recommendation 7) based on a risk of ciTBI 4.3% – 4.4% if high risk PECARN criteria (GCS= 14 or other signs of altered mental status or palpable skull fracture in children younger than 2 years or signs of basilar skull fracture in children aged 2 years and older) or a risk of ciTBI of 0.9% with any of the other PECARN risk criteria and no high risk criteria. The PREDICT GWG consensus is that children with any PECARN risk factors who do not undergo head CT imaging should undertake structured observation.

Three key papers published prior to the new literature search date provide evidence that observation of children with mild head injuries reduces head CT use and does not increase the risk of missing a clinically important traumatic brain injury (61, 65, 66) .

There is no evidence to inform the optimal frequency of reassessment and duration of the structured observation period. Existing guidelines and common practice refer to an observation period of 4 hours and expert opinion recommendations were adapted and extended for the paediatric population.

FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.7 Imaging Q7 – In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for radiologically proven traumatic intracranial lesion, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?

5.7.1 PREDICT question

PREDICT Guideline imaging Q7 (a)

In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for radiologically proven traumatic intracranial lesion, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?

PREDICT Guideline imaging Q7 (b)

In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for a radiologically proven traumatic intracranial lesion, who received a period of observation, what is the optimal frequency of reassessment and duration of observation?

5.7.2 Source question

There are no corresponding clinical questions in the NICE CG176 (2014) Guideline.

5.7.3 Source recommendations

NICE CG176 Recommendation 82

After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).

Developed: 2003

There are no recommendations in NICE CG176 related to IMAGING Q7 (b) in paediatric populations, but there is one expert opinion recommendation[48] for the general population.

5.7.4 Source evidence

As there are no clinical questions in NICE CG176 related to these PREDICT questions, no evidence is presented, and no evidence of relevance to the expert opinion recommendation was presented in either NICE CG176 or the subsequent surveillance in 2017.

5.7.5 New evidence

Eight new studies relevant to this question were identified in the PREDICT Guideline literature search, five were selected as key evidence. One additional study was identified as key that was published prior to the new evidence search date limit (67).

Table 5.7.1 New evidence identified for imaging Q7

Ref #	Citation
4.	Badawy MK, Dayan PS, Tunik MG, Nadel FM, Lillis KA, Miskin M, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605.
	Bressan S, Marchetto L, Lyons TW, Monuteaux MC, Freedman SB, Da Dalt L, Nigrovic LE. A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Ann Emerg Med. 2018 Jun;71(6):714–724.e2. doi: 10.1016/j.annemergmed.2017.10.014. Epub 2017 Nov 24.
85.	Farach SM, Danielson PD, Amankwah EK, Chandler NM. Repeat computed tomography scans after pediatric trauma: results of an institutional effort to minimize radiation exposure. Pediatric Surgery International. 2015;31(11):1027–33.
86.	Hentzen AS, Helmer SD, Nold RJ, Grundmeyer RW, 3rd, Haan JM. Necessity of repeat head computed tomography after isolated skull fracture in the pediatric population. American Journal of Surgery. 2015;210(2):322–5.
87.	Idil H, Kirimli G, Korol G, Unluer EE. Are emergency physicians competent to interpret the cranial CT of patients younger than the age of 2 years with mild head trauma? American Journal of Emergency Medicine. 2015;33(9):1175–7.
72.	Ogrenci A, Koban O, Eksi M, Yaman O, Dalbayrak S. The Necessity of Follow-Up Brain Computed-Tomography Scans: Is It the Pathology Itself or Our Fear that We Should Overcome? Open Access Macedonian Journal of Medical Sciences. 2017;5(6):740–3.

[48] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Ref #	Citation
88.	Plackett TP, Asturias S, Tadlock M, Wright F, Ton-That H, Demetriades D, et al. Re-evaluating the need for hospital admission and observation of pediatric traumatic brain injury after a normal head CT. Journal of Pediatric Surgery. 2015;50(10):1758–61.
	Powell EC, Atabaki SM, Wootton-Gorges S, Wisner D, Mahajan P, Glass T, Miskin M, Stanley RM, Jacobs E, Dayan PS, Holmes JF, Kuppermann N. Isolated linear skull fractures in children with blunt head trauma. Pediatrics. 2015 Apr;135(4):e851–7.
Relevant evidence published prior to new evidence search date limit	
	Holmes JF, Borgialli DA, Nadel FM, Quayle KS, Schambam N, Cooper A, Schunk JE, Miskin ML, Atabaki SM, Hoyle JD, Dayan PS, Kuppermann N; TBI Study Group for the Pediatric Emergency Care Applied Research Network. Do children with blunt head trauma and normal cranial computed tomography scan results require hospitalization for neurologic observation? Ann Emerg Med. 2011 Oct;58(4):315–22. doi: 10.1016/j.annemergmed.2011.03.060. Epub 2011 Jun 16

Shading indicates key studies.

5.7.5.1 Rationale for selection of key evidence

Five studies were identified as key evidence for these questions, in addition one was published prior to the new literature search date. One study (67) provided information on the risk of neurosurgical intervention for patients with a normal ED CT scan and GCS ≥14. The other five studies included information on other patient groups such as children with post-traumatic seizure (68) or isolated, non-displaced, linear skull fractures (44, 56, 57, 69). Some of the key new evidence was of low quality due to retrospective design and small sample sizes but supplemented the findings from Holmes by identifying sub-populations (isolated, non-displaced, linear skull fracture and post-traumatic seizure) that may be safe for discharge from ED with a head CT scan negative for intracranial injury and GCS 15.

5.7.5.2 Key evidence data extraction

Table 5.7.2 Data from key evidence for imaging Q7

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Badawy MK**, Dayan PS, Tunik MG, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605. **Aim:** Describe outcomes of head injured children with post traumatic seizures (PTS) **Setting** 25 paediatric EDs in North America **Type** Prospective observational 2004–2006	**Sample Size** 42,424 Children <18 years 536 had PTS **Characteristics** Median Age 4.9 (IQR 2.2–12.7) **Inclusion** Children < 18 with head trauma w/in 24 hours. GCS <14 included. **Exclusion** 1) presence of a pre-existing neurological disease, 2) history of ventricular shunt placement, 3) presence of a coagulopathy, 4) transfer from another facility with neuroimaging already performed and 5) patients with known seizure disorders.	Planned secondary descriptive analysis of patients with PTS within the PECARN head injury cohort.	Descriptive rates of CT, TBI on CT, neurosurgical intervention and recurrent PTS within one week.	**CT Proportion** 466/536 (86.9%, CI, 83.8%–89.7%) **TBI on CT** 72 (15.5%, CI = 12.3%–19.1%) **Neurosurgical intervention** 20 (27.8%, CI 17.9%–39.6%) **No TBI on CT**: n= 394 None of these required neurosurgery. • 282 were discharged, none had recurrent seizures • 112 admitted, 4.7% (CI 1.5, 10.6%) had recurrent seizures.	**Limitations** Parent study not designed to risk-stratify patients with PTS. Dataset included patients with GCS <14 **Study Conclusion** Children with PTS, but without TBI on CT very infrequently had short-term seizure recurrence, and none required neurosurgical intervention. **Comment** Some children with PTS and normal CT may be safe for discharge from ED without repeat imaging
Citation **Bressan S,** Marchetto L, Lyons TW. A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Ann Emerg Med. 2018;71(6):714-724. **Aim:** Quantify the frequency of short-term adverse outcomes of children with isolated skull fractures. **Setting** N/A **Type** Systematic review and meta-analyses	N/A **Inclusion** Patients < 18 years with isolated linear non-displaced skull fractures after head injury; CT or MRI performed **Exclusion** Case reports with fewer than 3 patients, editorials or other narratives; exclusive adult studies; studies including basilar or depressed skull fractures.	N/A	PubMed, EMBASE, the Cochrane Library, Scopus, Web of Science, and grey literature were systematically searched. 587 studies screened, 21 included. Two investigators independently reviewed articles.	**Primary outcome:** (1) emergency neurosurgery or death: one child needed neurosurgery and none died (pooled estimate 0.0%; 95% confidence interval [CI] 0.0% to 0.0%; I2= 0%) **Secondary outcome:** (1) Hospitalisation: 4,914 (83%; 95% CI 71% to 92%; I2= 99%) (2) New intracranial haemorrhage on repeated neuroimaging: 6 (0.0%; 95% CI 0.0% to 9.0%; I2= 77%)	**Limitations** Limited by search indices and methods; unpublished, unreported data and case reports were not included. **Study conclusion:** Children with isolated skull fractures were at extremely low risk for emergency neurosurgery or death, but were frequently hospitalized.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Hentzen AS**, Helmer SD, Nold RJ, Grundmeyer RW, 3rd, Haan JM. Necessity of repeat head computed tomography after isolated skull fracture in the paediatric population. American Journal of Surgery. 2015;210(2):322–325. **Aim:** To quantify the number of Isolated skull fracture (ISF) patients who progressed to a significant intracranial lesion on follow-up CT scan. **Setting** Kansas, USA, Trauma Centre **Type** Retrospective 2001–2011	**Sample Size** 298 patients with skull fracture 65 with ISF **Characteristics** Mean age 4.2 years, ISS 7.2 **Inclusion** Age < 18 with head trauma and skull fracture **Exclusion** Multi-system trauma, ICH on initial CT	Retrospective descriptive study of characteristics of children with ISF.	**Data** Demographics, mechanism of injury, trauma level, initial vitals, Injury Severity Score, abbreviated injury score, GCS score, clinical indicators for CT, admission skull fracture details, presence of ICH on admission, presence of ICH on follow-up CT. Admission & LOS, mechanical ventilation requirements, hospital LOS disposition, and mortality.	**ISF Admission:** 100% **ICU admission:** 63.1% **Average ICU LOS** of 1.2 days (range 1 to 3 days). **Mechanical Ventilation**: 4 (6.2%) One patient developed an ICH after her initial CT evaluation of the head. She had multiple indicators of head injury including a non-frontal scalp hematoma, LOC, GCS < 15, and nausea. Her nausea continued for 72 hours and she developed a headache, which led to repeat CT of the head that revealed a small SDH.	**Limitations** Single centre, retrospective, post-hospital follow-up not available. **Study Conclusion** Based on this data, repeat CT evaluation after identification of ISFs in the paediatric population may not be necessary as long as the patients do not develop clinical indicators associated with head injury during an observational period.
Citation **Plackett TP**, Asturias S, Tadlock M, et al. Re-evaluating the need for hospital admission and observation of paediatric traumatic brain injury after a normal head CT. Journal of Paediatric Surgery. 2015;50(10):1758–1761. **Aim**: Characterize the clinical outcomes of paediatric blunt head patients with a normal initial Head CT. **Setting** Two US Trauma Centres (CA) **Type** Retrospective, 2010–2012	**Sample Size** 631 with Head CT 439 with Normal CT or linear skull fracture (n= 42) **Characteristics** Median age 8 (2–13) **Inclusion** All trauma service patients < 16 undergoing a head CT for suspected traumatic brain injury. **Exclusion** ICH and/or displaced skull fracture. Patients that were evaluated by the emergency department, but not the trauma service were not included in the study.	Descriptive analysis of trauma service patients with an initial Head CT without ICH or depressed skull fracture.	Abstracted Demographics and injury details from medical record. CT scans were performed at the treating provider's discretion. A post hoc assessment of the necessity for imaging based upon the PECARN criteria. Outcomes included admission status, LOS, re-evaluation within 6 months for neurologic complaint not attributed to post-concussive syndrome.	53 (12%) of patients did not have initial CT indicated by PECARN. 132 (30%) did. 129/439 (29%) of patients with **normal head CT or non-displaced skull fracture** were observed and discharged home from ED 310 (71%) were admitted 150 patients (48%) admitted to the **PICU** **Inpatient LOS** mean of 2.4 ± 2.5 days (range 1–16). **PICU LOS** 1.3 ± 1.9 days. No patients went neurosurgical intervention	**Limitations** Retrospective and only included trauma service patients. Criteria for observation vs discharge not known. **Study Conclusion** Paediatric patients with mild traumatic brain injury can be safely discharged to home from the emergency department once their GCS normalizes to 15, unless other clinical or social reasons necessitate admission.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Powell EC**, Atabaki SM, Wootton-Gorges S. Isolated linear skull fractures in children with blunt head trauma. Pediatrics. 2015;135(4):e851-e857. **Aim:** Describe injury circumstances and frequency of clinically important neurologic complications among children with minor blunt head trauma and isolated linear skull fractures. **Setting** 25 EDs **Type** Prospective cohort	**Sample Size** 350 patients **Characteristics** 11,035 [25%] <2 years old Median age 10mths **Inclusion** GCS 14 or 15 All with isolated linear skull fractures on CT Presented within 24hours **Exclusion** Trivial mechanisms Children with GCS<14 Signs of basilar skull fracture Neuroimaging with findings other than isolated linear skull fracture Comorbidities	N/A	Neurologic outcomes through clinical information collected or via telephone or male at least 1 week after ED visit. Imaging was at clinician discretion.	201 hospitalised with 42 repeat CT/MRI/radiograph and 5 traumatic findings, 0 neurosurgery 149 discharged from ED, 20 repeat cranial CT/MRI/radiograph, 0 traumatic findings, 0 neurosurgery	**Limitations** CT imaging was at clinician discretion and many in parent stud were not imaged. Possible missed findings since not all patients had repeat CT. **Study conclusions** Children with minor blunt head trauma, initial ED GCS scores of 14 or 15, and isolated linear skull fractures are at very low risk of clinical deterioration and need for neurosurgical intervention. New findings on follow-up CT or MRI scans are rare. Our data suggest that neurologically normal children with isolated linear skull fractures after minor blunt head trauma do not typically warrant inpatient observation and can safely be discharged from the hospital after ED evaluation to reliable caretakers and a safe environment with strict discharge instructions and return precautions.
Citation **Holmes JF**, Borgialli DA, Nadel FM et al. Do children with blunt head trauma and normal cranial computed tomography scan results require hospitalization for neurologic observation? Ann Emerg Med. 2011 Oct;58(4):315–22. **Aim:** Identify the frequency of neurologic complications in children with minor blunt head trauma and normal ED CT scan results. **Setting** 25 EDs **Type** Prospective multicentre	**Sample Size** 13,543 children <18yrs **Characteristics** **Inclusion** Children < 18 yrs with blunt head trauma **Exclusion** GCS scores less than 14, if they had traumatic findings on their initial ED cranial CT scans, or history of coagulopathy or ventricular shunt.	Descriptive analysis	In children with normal CT and GCS 14 or 15 followed for neurologic outcomes and telephone follow up.	2,485 (18%) were hospitalized (2107/12584 had GCS 15, 378/959 had GCS 14). Of children hospitalized, 137 (6%) received subsequent CT or MRI; 16 (0.6%) had abnormal CT/MRI scan results and none (0%; 95% CI 0% to 0.2%) received a neurosurgical intervention. 2% had subsequent CT or MRI, 5 (0.05%) had abnormal findings No neurosurgical intervention 0%; 95% confidence interval [CI] 0% to 0.03%	**Limitations** Not all pts enrolled underwent CT. Some pts missed at telephone follow up. **Study conclusions** Children with blunt head trauma and initial ED GCS scores of 14 or 15 and normal cranial CT scan results are at very low risk for subsequent traumatic findings on neuroimaging and extremely low risk of needing neurosurgical intervention. Hospitalization of children with minor head trauma after normal CT scan results for neurologic observation is generally unnecessary.

5.7.6 Key considerations for assessing the evidence

None.

5.7.7 Working Group recommendation deliberations

Table 5.7.3 Clinical judgement form for imaging Q7 (a,b)

PREDICT Guideline imaging Q7 (a,b)	**(a) In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for radiologically proven traumatic intracranial lesion, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?** **(b) In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for a radiologically proven traumatic intracranial lesion, who received a period of observation, what is the optimal frequency of reassessment and duration of observation?**
Source recommendation/s	
Imaging Q7 (a) NICE CG176 (2014) UK 1 recommendation Rec 82	**NICE CG176 Recommendation 82** After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? <u>NICE CG176 Recommendation 82</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 16	After a normal initial head CT scan in children presenting to an acute care setting following mild to moderate head injury, the clinician may conclude that the risk of clinically-important traumatic brain injury[49] requiring hospital care is low enough to warrant discharge home, provided that the child has a GCS score of 15,[50] normal neurological examination and no other factors warranting hospital admission (e.g. other injuries, clinician concerns [e.g. persistent vomiting], drug or alcohol intoxication, social factors, underlying medical conditions such as bleeding disorders or possible abusive head trauma).

[49] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

[50] Measured using an age-appropriate GCS.

PREDICT Guideline imaging Q7 (a,b)	**(a) In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for radiologically proven traumatic intracranial lesion, what are the clinical criteria and/or clinical decision rule(s) that best determine who needs/does not need a period of observation?** **(b) In infants and children with mild to moderate head injury presenting within 72 hours of injury and a negative initial cranial CT for a radiologically proven traumatic intracranial lesion, who received a period of observation, what is the optimal frequency of reassessment and duration of observation?**
PREDICT practice point L	The duration of structured observation for children with mild to moderate head injury who have a normal initial head CT scan but do not meet discharge criteria should be based on individual patient circumstances. Consider an observation frequency of every half hour for the first 2 hours, then 1-hourly until 4 hours post injury. After 4 hours, continue at least 2-hourly for as long as the child remains in hospital.

Rationale

The PREDICT GWG **adapted expert opinion recommendation** 82 from NICE CG176 based on six key studies. The PREDICT literature search identified 8 new studies, of these 5 were deemed key with an additional study identified prior to the new evidence search date (67). A PECARN secondary analysis of 13,543 patients with a normal ED CT scan and GCS ≥14 reported a 100% NPV for subsequent neurosurgical intervention (67). Subsequent, evidence from the PECARN dataset and from distinct settings provides supporting evidence for the safety of this approach and suggests that it may extend to children with post-traumatic seizure (68) or isolated non-displaced, linear skull fractures (44, 56, 57, 69).

FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☒ Yes ☐ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.8 Imaging Q8 – In infants and children with mild to moderate head injury and a negative initial cranial CT or MRI for an intracranial injury with persistent symptoms, who should undergo repeat neuroimaging?

5.8.1 PREDICT question

PREDICT Guideline imaging Q8

In infants and children with mild to moderate head injury and a negative initial cranial CT or MRI for an intracranial injury with persistent symptoms, who should undergo repeat neuroimaging?

5.8.2 Source question

There is no corresponding clinical question in the NICE CG176 (2014) Guideline.

5.8.3 Source recommendation

There are no recommendations in NICE CG176 related to IMAGING Q7 (b) in paediatric populations, but there is one expert opinion recommendation for the general population. This recommendation is also presented for IMAGING Q7 (b).

Expert opinion[51]

NICE CG176 Recommendation 105

In the case of a patient who has had a normal CT-scan but who has not achieved GCS equal to 15 after 24 hours' observation, a further CT scan or MRI scanning should be considered and discussed with the radiology department.

Developed: 2003

5.8.4 Source evidence

As there are no clinical questions in NICE CG176 related to this PREDICT question, no evidence is presented, and no evidence of relevance to the expert opinion recommendation was presented in either NICE CG176 or the subsequent surveillance in 2017.

5.8.5 New evidence

Six new studies relevant to this question were identified in the PREDICT Guideline literature search. In addition, one paper was identified out of the search date limits (67). Only Holmes was selected as a key paper for this recommendation.

Table 5.8.1 New evidence identified for imaging Q8

Ref #	Citation
4.	Badawy MK, Dayan PS, Tunik MG, Nadel FM, Lillis KA, Miskin M, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Academic Emergency Medicine. 2017;24(5):595–605.
85.	Farach SM, Danielson PD, Amankwah EK, Chandler NM. Repeat computed tomography scans after pediatric trauma: results of an institutional effort to minimize radiation exposure. Pediatric Surgery International. 2015;31(11):1027–33.
86.	Hentzen AS, Helmer SD, Nold RJ, Grundmeyer RW, 3rd, Haan JM. Necessity of repeat head computed tomography after isolated skull fracture in the pediatric population. American Journal of Surgery. 2015;210(2):322–5.
89.	Hill EP, Stiles PJ, Reyes J, Nold RJ, Helmer SD, Haan JM. Repeat head imaging in blunt pediatric trauma patients: Is it necessary? The Journal of Trauma and Acute Care Surgery. 2017;82(5):896–900.
72.	Ogrenci A, Koban O, Eksi M, Yaman O, Dalbayrak S. The Necessity of Follow-Up Brain Computed-Tomography Scans: Is It the Pathology Itself or Our Fear that We Should Overcome? Open Access Macedonian Journal of Medical Sciences. 2017;5(6):740–3.
88.	Plackett TP, Asturias S, Tadlock M, Wright F, Ton-That H, Demetriades D, et al. Re-evaluating the need for hospital admission and observation of pediatric traumatic brain injury after a normal head CT. Journal of Pediatric Surgery. 2015;50(10):1758–61.
Relevant evidence published prior to new evidence search date limit	
--	Holmes JF, Borgialli DA, Nadel FM, Quayle KS, Schambam N, Cooper A, Schunk JE, Miskin ML, Atabaki SM, Hoyle JD, Dayan PS, Kuppermann N; TBI Study Group for the Pediatric Emergency Care Applied Research Network. Do children with blunt head trauma and normal cranial computed tomography scan results require hospitalization for neurologic observation? Ann Emerg Med. 2011 Oct;58(4):315–22. doi: 10.1016/j.annemergmed.2011.03.060. Epub 2011 Jun 16

5.8.5.1 Rationale for selection of key evidence

One of the 7 identified studies was selected as key evidence for this question based on the rationale that it was the only study to address the risk of injury following repeat neuroimaging. Literature search results for this question were the same for Q7, however the Holmes study was the only evidence to directly address the question of which head-injured patients required repeat imaging. There was no evidence to guide the timing recommendation for repeat imaging.

[51] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

5.8.5.2 Key evidence data extraction

Table 5.8.2 Data from key evidence for imaging Q8

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Holmes JF**, Borgialli DA, Nadel FM et al. Do children with blunt head trauma and normal cranial computed tomography scan results require hospitalization for neurologic observation? Ann Emerg Med. 2011 Oct;58(4):315–22. **Aim:** Identify the frequency of neurologic complications in children with minor blunt head trauma and normal ED CT scan results. **Setting** 25 EDs **Type** Prospective multicentre	**Sample Size** 13,543 children <18yrs **Characteristics** **Inclusion** Children < 18 yrs with blunt head trauma **Exclusion** GCS scores less than 14, if they had traumatic findings on their initial ED cranial CT scans, or history of coagulopathy or ventricular shunt.	Descriptive analysis	In children with normal CT and GCS 14 or 15 followed for neurologic outcomes and telephone follow up.	2,485 (18%) were hospitalized (2107/12584 had GCS 15, 378/959 had GCS 14). Of children hospitalized, 137 (6%) received subsequent CT or MRI; 16 (0.6%) had abnormal CT/MRI scan results and none (0%; 95% CI 0% to 0.2%) received a neurosurgical intervention. 2% had subsequent CT or MRI, 5 (0.05%) had abnormal findings. No neurosurgical intervention 0%; 95% confidence interval [CI] 0% to 0.03%	**Limitations** Not all pts enrolled underwent CT. Some pts missed at telephone follow up. **Study conclusions** Children with blunt head trauma and initial ED GCS scores of 14 or 15 and normal cranial CT scan results are at very low risk for subsequent traumatic findings on neuroimaging and extremely low risk of needing neurosurgical intervention. Hospitalization of children with minor head trauma after normal CT scan results for neurologic observation is generally unnecessary.

5.8.6 Key considerations for assessing the evidence

None.

5.8.7 Working Group recommendation deliberations

Table 5.8.3 Clinical judgement form for imaging Q8

PREDICT Guideline imaging Q8	**In infants and children with mild to moderate head injury and a negative initial cranial CT or MRI for an intracranial injury with persistent symptoms, who should undergo repeat neuroimaging?**		
Source recommendation/s			
NICE CG176 (2014) UK 1 recommendation: Rec 105	**NICE CG176 Recommendation 105** [Expert opinion] In the case of a patient who has had a normal CT-scan but who has not achieved GCS equal to 15 after 24 hours' observation, a further CT scan or MRI scanning should be considered and discussed with the radiology department. *Note: this is the same source recommendation as used in IMAGING Q7 (b).*		
Notes on wording changes			
GENERALISABILITY of the source recommendation/s			
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A		If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:			
APPLICABILITY of the source recommendation/s			
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A			
Comment:			
Adapt, adopt or new guidance			
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? NICE CG176 Recommendation 105 ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance			
Comment:			
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable			
Comment:			
PREDICT guidance			
PREDICT evidence-informed recommendation 17	After a normal initial head CT scan in children presenting to an acute care setting following mild to moderate head injury, neurological deterioration should prompt urgent reappraisal by the treating clinician, with consideration of an immediate repeat head CT scan and consultation with a neurosurgical service. Children who are being observed after a normal initial head CT scan[52] who have not achieved a GCS score of 15[53] after up to 6 hours of observation from the time of injury, should have a senior clinician review for consideration of a further head CT scan or MRI scan and/or consultation with a neurosurgical service. The differential diagnosis of neurological deterioration or lack of improvement should take into account of other injuries, drug or alcohol intoxication and non-traumatic aetiologies.		

[52] The initial head CT scan should be interpreted by a radiologist to ensure no injuries were missed.
[53] Measured using an age-appropriate GCS.

PREDICT Guideline imaging Q8	In infants and children with mild to moderate head injury and a negative initial cranial CT or MRI for an intracranial injury with persistent symptoms, who should undergo repeat neuroimaging?	
Rationale The PREDICT GWG **adapted expert opinion recommendation** 105 from NICE CG176 Guideline. The PREDICT literature search identified 7 new studies, one study published prior to the new literature search date (67) was deemed key evidence for this question. The PECARN secondary analysis which reported a 1% prevalence of new intracranial lesions (none requiring neurosurgery) on repeat neuroimaging in 378 hospitalized patients with GCS of 14 and 0.5% prevalence of new intracranial lesions (none requiring neurosurgery) on repeat neuroimaging in 2107 hospitalised patients with GCS 15 (67). The recommendation for the six-hour interval prior to re-imaging was based on PREDICT GWG consensus opinion.		
FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.9 Imaging Q9 – In infants and children with mild to moderate head injury, presenting within 72 hours of injury with suspected abusive head trauma, i) who should undergo cranial imaging and ii) which modality should be used for initial imaging?

5.9.1 PREDICT question

Imaging Q9

In infants and children with mild to moderate head injury, presenting within 72 hours of injury with suspected abusive head trauma, i) who should undergo cranial imaging and ii) which modality should be used for initial imaging?

5.9.2 Source question

While this question does not focus on suspected abusive head trauma, one of the recommendations arising from this question provides guidance for this population.

NICE CG176 Section 7.12

What is the best initial diagnostic technique to determine which patients have sustained damage to the head and require further assessment of the head?

Note: this question in NICE CG176 (2014) is also relevant to two other question in the PREDICT Guideline – IMAGING Q10 and IMAGING Q13.

5.9.3 Source recommendations

NICE CG176 Recommendation 29

For children who have sustained a head injury and have any of the following risk factors, perform a CT head scan within 1 hour of the risk factor being identified:

- *Suspicion of non-accidental injury.*
- *Post-traumatic seizure but no history of epilepsy.*
- *On initial emergency department assessment, GCS less than 14, or for children under 1 year GCS (paediatric) less than 15.*
- *At 2 hours after the injury, GCS less than 15.*
- *Suspected open or depressed skull fracture or tense fontanelle.*
- *Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).*
- *Focal neurological deficit.*
- *For children under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head.*

A provisional written radiology report should be made available within 1 hour of the scan being performed.

Developed: 2014

Expert opinion[54]

NICE CG176 Recommendation 35

Do not use plain X-rays of the skull to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury.

Developed: 2007

Not subject to formal evidence review

NICE CG176 Recommendation 37

A clinician with training in safeguarding should be involved in the initial assessment of any patient with a head injury presenting to the emergency department. If there are any concerns identified, document these and follow local safeguarding procedures appropriate to the patient's age.

Developed: 2003

Amended: 2014

5.9.4 Source evidence

No study data was presented to support Recommendation 35 in the NICE CG176 (2014) Guideline, which was based on expert opinion when it was developed in 2007 (NICE CG176 (2014) p138).

Recommendation 37 was not subject to formal evidence review.

[54] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

5.9.5 New evidence

Twenty-five new studies relevant to this question were identified in the PREDICT Guideline literature search. Six studies and one expert panel recommendation were selected as key evidence.

Table 5.9.1 New evidence identified for imaging Q9

Ref #	Citation
90.	Alsabban Z, Stimec J, Shouldice M, Laughlin S, Branson H. Utility of skull views in skeletal surveys of children with suspected non-accidental injury who are also undergoing head CT. Pediatric Radiology Conference: 60th annual meeting of the society for pediatric radiology, SPR 2017 Canada. 2017;47:S118.
98.	Amagasa S, Matsui H, Tsuji S, Moriya T, Kinoshita K. Accuracy of the history of injury obtained from the caregiver in infantile head trauma. American Journal of Emergency Medicine. 2016;34(9):1863–7.
99.	Amagasa S, Matsui H, Tsuji S, Uematsu S, Moriya T, Kinoshita K. Characteristics distinguishing abusive head trauma from accidental head trauma in infants with traumatic intracranial hemorrhage in Japan. Acute Medicine & Surgery. 2018;5(3):265–71.
66.	Anderst JD, Carpenter SL, Presley R, Berkoff MC, Wheeler AP, Sidonio RF, Jr., et al. Relevance of Abusive Head Trauma to Intracranial Hemorrhages and Bleeding Disorders. Pediatrics. 2018;141(5):5.
100.	Atkinson N, van Rijn RR, Starling SP. Childhood Falls with Occipital Impacts. Pediatric Emergency Care. 2018;34(12):837–41.
91.	Babl FE, Pfeiffer H, Dalziel SR, Oakley E, Anderson V, Borland ML, et al. Paediatric intentional head injuries in the emergency department: A multicentre prospective cohort study. Emergency Medicine Australasia. 2018; 26:26.
101.	Berger RP, Fromkin J, Herman B, Pierce MC, Saladino RA, Flom L, et al. Validation of the Pittsburgh Infant Brain Injury Score for Abusive Head Trauma. Pediatrics. 2016;138(1):7.
92.	Boop S, Axente M, Weatherford B, Klimo P, Jr. Abusive head trauma: an epidemiological and cost analysis. Journal of Neurosurgery Pediatrics. 2016;18(5):542–9.
102.	Brown JB, Gestring ML, Leeper CM, Sperry JL, Peitzman AB, Billiar TR, et al. Characterizing injury severity in nonaccidental trauma: Does Injury Severity Score miss the mark? The Journal of Trauma and Acute Care Surgery. 2018;85(4):668–73.
103.	Chen CC, Hsieh PC, Chen CPC, Hsieh YW, Chung CY, Lin KL, et al. Clinical Characteristics and Predictors of Poor Hospital Discharge Outcome for Young Children with Abusive Head Trauma. Journal of Clinical Medicine. 2019;8(3):20.
104.	Cowley LE, Morris CB, Maguire SA, Farewell DM, Kemp AM. Validation of a prediction tool for abusive head trauma. Pediatrics. 2015;136(2):291–8.
93.	Culotta PA, Crowe JE, Tran QA, Jones JY, Mehollin-Ray AR, Tran HB, et al. Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Pediatric Radiology. 2017;47(1):74–81.
105.	Elinder G, Eriksson A, Hallberg B, Lynoe N, Sundgren PM, Rosen M, et al. Traumatic shaking: The role of the triad in medical investigations of suspected traumatic shaking. Acta Paediatrica, International Journal of Paediatrics. 2018;107(Suppl 472):44986.
106.	Escobar MA, Flynn-O'Brien KT, Auerbach M, Tiyyagura G, Borgman MA, Duffy SJ, et al. The association of nonaccidental trauma with historical factors, examination findings, and diagnostic testing during the initial trauma evaluation. Journal of Trauma and Acute Care Surgery. 2017;82(6):1147–57.
107.	Expert Panel on Pediatric Imaging, Wootton-Gorges SL, Soares BP, Alazraki AL, Anupindi SA, Blount JP, et al. ACR Appropriateness Criteria Suspected Physical Abuse-Child. Journal of the American College of Radiology. 2017;14(5S): S338-S49.
108.	Feldman KW, Sugar NF, Browd SR. Initial clinical presentation of children with acute and chronic versus acute subdural hemorrhage resulting from abusive head trauma. Journal of Neurosurgery Pediatrics. 2015;16(2):177–85.
109.	Flom L, Fromkin J, Panigrahy A, Tyler-Kabara E, Berger RP. Development of a screening MRI for infants at risk for abusive head trauma. Pediatric Radiology. 2016;46(4):519–26.
94.	Hansen JB, Frazier T, Moffatt M, Zinkus T, Anderst JD. Evaluations for abuse in young children with subdural hemorrhages: findings based on symptom severity and benign enlargement of the subarachnoid spaces. Journal of Neurosurgery Pediatrics. 2018;21(1):31–7.
110.	Hinds T, Shalaby-Rana E. The Role of Neuroimaging in the Evaluation of Abusive Head Trauma. Journal of Pediatric Neuroradiology. 2016;5(1):38–44.
111.	Hymel KP, Wang M, Chinchilli VM, Karst WA, Willson DF, Dias MS, et al. Estimating the probability of abusive head trauma after abuse evaluation. Child Abuse & Neglect. 2019;88:266–74.
95.	Khan NR, Fraser BD, Nguyen V, Moore K, Boop S, Vaughn BN, et al. Pediatric abusive head trauma and stroke. Journal of Neurosurgery Pediatrics. 2017;20(2):183–90.
112.	Kim PT, McCagg J, Dundon A, Ziesler Z, Moody S, Falcone RA, Jr. Consistent screening of admitted infants with head injuries reveals high rate of nonaccidental trauma. Journal of Pediatric Surgery. 2017;52(11):1827–30.
96.	Nguyen A, Hart R. Imaging of non-accidental injury; what is clinical best practice? Journal of Medical Radiation Sciences. 2018;65(2):123–30.
97.	Pfeiffer H, Crowe L, Kemp AM, Cowley LE, Smith AS, Babl FE, et al. Clinical prediction rules for abusive head trauma: a systematic review. Archives of Disease in Childhood. 2018;103(8):776–83.
113.	Pfeiffer H, Smith A, Kemp AM, Cowley LE, Cheek JA, Dalziel SR, et al. External Validation of the PediBIRN Clinical Prediction Rule for Abusive Head Trauma. Pediatrics. 2018;141(5):5.

Shading indicates key studies.

5.9.5.1 Rationale for selection of key evidence

Six studies of mixed quality and methodology and one expert panel recommendation addressed the population of interest. Culotta 2017 addresses the modality of interest (70).

5.9.5.2 Key evidence data extraction

Table 5.9.2 Data from key evidence for imaging Q9

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Berger RP**, Fromkin J, Herman B. Validation of the Pittsburgh Infant Brain Injury Score for Abusive Head trauma. Pediatrics 2016;138(1). **Aim:** Accuracy of Pittsburgh Infant Brain Injury Score (PIBIS), a clinical prediction rule to assist physicians deciding which high-risk infants should undergo computed tomography of the head. **Type** Prospective multicentre	**Sample Size** 214 cases 826 controls **Characteristics** 30–364 days old **Inclusion** Well appearing infants, temperature<38.3 w/o history of trauma and for evaluation for a symptom associated with increased risk of AHT **Exclusion** Previous abnormal CT scan of head	Subjects classified as case of controls based on imaging. Normal imaging or no imaging at all = control Cases had abnormal imaging	Clinical presentation, medical history, radiological and laboratory testing, neurologic and dermatologic exam were collected. Follow up at 6mths.	**Rule accuracy:** At a score of 2: Sensitivity and specificity for abnormal neuroimaging was 93.3% (95% confidence interval 89.0%–96.3%) and 53% (95% confidence interval 49.3%–57.1%), respectively.	**Limitations** Because not all subjects had neuroimaging, some cases may have been misclassified as controls. This is a convenience sample. **Study conclusions** Our data suggest that the PIBIS accurately identifies infants who would benefit from neuroimaging to evaluate for brain injury. An implementation analysis is needed before the PIBIS can be integrated into clinical practice.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Cowley L**, Morris CB, Maguire SA et al. Validation of a Prediction Tool for Abusive Head Trauma. Pediatrics 2015; 136(2):290–8 **Aim** Externally validate the PredAHT tool. **Setting** 2 datasets: case notes of 60 children <36mths in hospital with ICI and children <24mths referred to neurosurgical department, PICU or ED **Type** 1 retrospective and 1 prospective	**Sample Size** 133 non-AHT 65 AHT cases **Characteristics** 97% <24mths old **Inclusion** <36 months admitted with an intracranial injury, **Exclusion** Normal neuroimaging, age > 36 months, an underlying structural abnormality or pre-existing disease (hydrocephalus, cystic lesion or tumour, metabolic cause, malformation, or abnormal brain development), injuries caused by neglect, and birth injury.	Compares accuracy of rule to identify non-AHT vs AHT cases	Infants confirmed as abusive or non-abusive 6 influential features recorded (retinal haemorrhage, rib and long -bone fractures, apnoea, seizures, and head or neck bruising).	**Rule accuracy:** **sensitivity** 72.3% (95% CI, 60.4–81.7), **specificity** 85.7% (95% CI, 78.8–90.7), **area under the curve** 0.88 (95% CI, 0.823–0.926). When ≥3 of these 6 features are present, the estimated probability for AHT is > 81.5% (95% CI, 63.3%–91.8%).	**Limitations** Some missing data e.g. not all patients for ophthalmology if not clinically indicated. **Study conclusions** The PredAHT tool performed well. This tool has the potential to contribute to decision-making in these challenging cases.
Citation **Culotta PA**, Crowe JE, Tran QA, et al. Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Paediatric Radiology. 2017;47(1):74–81. **Aim** A cross-sectional study of infants evaluated for abusive head trauma via both skull radiographs and CT with 3-D reconstruction. **Setting** Two level I trauma centres in Houston, TX **Type:** Retrospective, 2013–14	**Sample Size** 177 **Characteristics** 47% female; mean/median age: 5 months **Inclusion** Infants (<1-year-old) in whom both skeletal surveys and CT of the head were obtained to evaluate for non-accidental trauma. **Exclusion** Paired CT and skull series radiographs were unavailable; the CT was done at the referral hospital; imaging was obtained post operatively, or the skull radiographs and the CT were performed greater than 72 h apart.	The reference standard was skull radiography. Studies were read by paediatric radiologists and neuroradiologists, with ten percent read by a second radiologist to evaluate for interobserver reliability.	**Skull series** of the skeletal survey included two views (AP/Lateral) **CT images** of the head were helically acquired from the craniocervical junction through the calvarial vertex with an Aquilion ONE™ 320 Toshiba utilizing a detector collimation of 0.5 and a pitch of 0.84. The remainder of the CT images were obtained using a GE LightSpeed VCT 64 slice machine through which an axial mode was used. Standard images included axial images (5-mm slices); coronal (1.3-mm slices) and sagittal (3-mm slices) images were reconstructed from the axial images. **Three-dimensional reconstructions** were obtained as the standard of care.	62 (35%) children had skull fractures identified on skull radiographs and 67 (38%) by CT (p = 0.18). No differences between the radiographic findings and 3- D CT scan results among all patients and the three age groups using non-parametric testing for matched data CT with 3-D reconstruction was 97% sensitive (CI, 89–100%) and 94% specific (CI: 87–97%) for skull fracture.	**Limitations** Retrospective study. Potential for selection bias. Studies read by subspecialty radiologists **Conclusion** In cases where there is a concern for head trauma and clinicians require CT scans to adequately access intracranial injury, skull radiographs should be eliminated from the medical work-up.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Escobar MA,** Flynn-O'Brien KT, Auerbach M et al. The association of nonaccidental trauma with historical factors, examination findings, and diagnostic testing during the initial trauma evaluation. J Trauma Acute Care Surg. 2017 Jun;82(6):1147–1157. **Aim** Summarize existing quality evidence on association of various elements of history, exam and diagnostic test with a diagnosis of NAT **Setting** Paediatric Trauma Society Guideline Committee **Type** Literature review	**Sample Size** N/A **Characteristics** N/A **Inclusion** N/A **Exclusion** N/A	N/A	Used GRADE methodology to rate evidence and answered clinical questions with PICO. Described the correlation between NAT and the following: bruising, burns, abusive head trauma, abdominal injuries, fractures, historical factors, and oral trauma.	**Screening tools**: The Pittsburgh Infant Brian Injury Score (PIBIS) – 862 subjects revealed a sensitivity for abnormal neuroimaging at a score of 2 of 93% (95% CI, 89–96%) and a specificity of 53% (95% CI, 49–57%). The Predicting Abusive Head Trauma Tool (PredAHT) – 133 non-AHT and 65 AHT cases in children < 36 months revealed a sensitivity of 72%, specificity of 86% and area under the curve of 0.88. When 3 or more features of AHT were present, the probability of AHT was 80% (95% CI, 63.3–91.8). The Pediatric Brain Injury Research Network (PEDIBIRN) in children <36 months. When 1 or more predictor variables were present, rule sensitivity of 96%, specificity of 43% and prevalence of 0.43 (95% CI, 0.37–0.49).	**Limitations** In original studies, not all subjects had neuroimaging, variation in physician practice, convenience sample in some cases. **Study conclusion**: A meaningful screening tool for NAT in children is not possible at this stage due to the lack of available high-quality data.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Hymel KP**, Wang M, Chinchilli WM. Estimating the probability of abusive head trauma after abuse evaluation. Child Abuse & Neglect 2019; 88: 266–274. **Aim** To derive a clinical prediction rule for paediatric abusive head trauma that incorporates the (positive or negative) predictive contributions of patients' completed skeletal surveys and retinal exams. **Setting** 18 intensive care units **Type** Retrospective secondary analysis of cross-sectional prospective data set	**Sample Size** 500 **Characteristics** **Inclusion** head injured children < 3 years Previously healthy Admitted to ICU with acute, cranial or intracranial injuries confirmed on CT or MRI **Exclusion** Motor vehicle accidents excluded	Compared accuracy of rule to identify AHT vs. non-AHT	(1) multivariable logistic regression to impute the results of abuse evaluations never ordered or completed, (2) regularized logistic regression to derive a novel clinical prediction rule that incorporates the results of completed abuse evaluations, and (3) application of the new prediction rule to calculate patient-specific estimates of abusive head trauma probability for observed combinations of its predictor variables.	For a mean probability threshold > 0.5 to classify pts as abused, rule accuracy: **Sensitivity** 0.73 (95% CI: 0.66–0.79) **Specificity** 0.87 (95% CI: 0.82–0.90). **AUC** 0.88 (95% CI: 0.85–0.92).	**Limitations** Small patient population Definition for AHT, non-AHT, skeletal survey and retinal exams are imperfect **Study conclusions** Seven variables facilitate patient-specific estimation of abusive head trauma probability after abuse evaluation in intensive care settings.
Citation **Pfeiffer H**, Smith A, Kemp AM et al. External Validation of the PediBIRN Clinical Prediction Rule for Abusive Head Trauma. Pediatrics. 2018 May;141(5). **Aim** Externally validate PediBIRN as designed (PICU only) as well as using broader inclusion criteria (admitted children with head injuries). **Setting** 5 tertiary EDs **Type** Secondary analysis of prospective multicentre study	**Sample Size** 141 pts met inclusion of original 5264 pts **Characteristics** PICU admission N = 28 Ward admission N = 113 Male (58%), 70% < 1 year **Inclusion** Children <18yrs with head injury presenting to ED **Exclusion** Trivial facial injuries, refused participation, had neuroimaging prior to arrival in ED, did not wait to be seen or were referred for care outside the ED and if social issues prevented approach to patient or family	Assessed accuracy of PediBIRN CDR to identify AHT vs. non-AHT pts	At presentation, injury & clinical variables, demographic, epidemiological recorded. Various methods to identify AHT patients with full medical record reviewal Radiologist reports and medical records used for outcomes. PediBIRN rule applied in children <3 years and admitted to PICU or ward for management of TBI.	**Accuracy of rule:** CDR identified 27 of 28 AHT positive cases **sensitivity** = 96% [82%–100% **specificity** = 43% [32%–53%] Excluding PICU group (any admission outside of PICU with abnormal imaging), rule accuracy **sensitivity** = 93% [68%–100%] **specificity** = 46% [35%–57%]	**Limitations** Small sample size Missed direct admissions to PICU and ward **Study conclusions** This validation revealed high sensitivity and low specificity for PICU patients. Specificity was improved but moderate in a broader group of admitted head injury patients.

5.9.6 Key considerations for assessing the evidence

The following was reproduced from the 2003 NICE Guideline on non-accidental injury in children:

> *These guidelines are not intended to cover the acute management of non-accidental injury, but it is important that health professionals are aware that the head injury examination is an important opportunity to identify this problem. There is evidence that a distinct pattern of brain injuries is associated with non-accidental injury in children. This results from the different mechanisms of injury in accidental versus non-accidental head injury.*
>
> *Work on the derivation of clinical decision rules to predict non-accidental injury based on imaging patterns has recently been begun. However, the decision rules in this area will require substantial validation before they can inform clinical practice. Future versions of this guideline should determine the status of research in this area. (NICE CG176 p140)*

The following statement was made for the development of the 2007 recommendation for the use of skull X-rays:

> *Generally speaking, CT is more sensitive than X-ray at detecting clinically important lesions, although evidence specific to head trauma was not retrieved. CT is likely to be cost effective but only if a) the extra lesions found by CT pose a significant health risk, b) identification leads to earlier/better treatment and c) early/modified treatment improves survival. For these variables there is no high-quality evidence. However, a decision model[253] based on case series evidence estimated that CT scanning all patients would both more effective and cost saving than with X-raying all patients in a US context.*
>
> *The GDG felt based on their expertise that CT is the most appropriate tool for diagnosing life-threatening conditions resulting from head injury. The GDG also felt that a recommendation was required to emphasize [sic] that X-ray is not a suitable substitute for CT. However, it was necessary to acknowledge that plain X-rays are useful adjuvant to CT in managing children with suspected non-accidental injury and therefore a new recommendation was developed (Recommendation 35 [2007], NICE CG176 (2014) p138).*

It was noted that in 2017 NICE produced guidelines on suspected NAI and these recommendations were not included in the above Guideline: Child Abuse and Neglect CG76: www.nice.org.uk/guidance/ng76

5.9.7 Working Group recommendation deliberations

Table 5.9.3 Clinical judgement form for imaging Q9

PREDICT Guideline imaging Q9	**In infants and children with mild to moderate head injury, presenting within 72 hours of injury with suspected non-accidental injury, i) who should undergo cranial imaging and ii) which modality should be used for initial imaging?**
Source recommendation/s	
NICE CG176 (2014) UK 3 recommendations: Recs 29, 35 and 37	**NICE CG176 Recommendation 29** For children who have sustained a head injury and have any of the following risk factors, perform a CT head scan within 1 hour of the risk factor being identified: • Suspicion of non-accidental injury. • Post-traumatic seizure but no history of epilepsy. • On initial emergency department assessment, GCS less than 14, or for children under 1 year GCS (paediatric) less than 15. • At 2 hours after the injury, GCS less than 15. • Suspected open or depressed skull fracture or tense fontanelle. • Any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid leakage from the ear or nose, Battle's sign).

PREDICT Guideline imaging Q9	In infants and children with mild to moderate head injury, presenting within 72 hours of injury with suspected non-accidental injury, i) who should undergo cranial imaging and ii) which modality should be used for initial imaging?

- Focal neurological deficit.
- For children under 1 year, presence of bruise, swelling or laceration of more than 5 cm on the head

A provisional written radiology report should be made available within 1 hour of the scan being performed.

Developed: 2014

NICE CG176 Recommendation 35

[Expert opinion]

Do not use plain X-rays of the skull to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury.

Note: this is the same source recommendation as used in IMAGING Q10.

NICE CG176 Recommendation 37

[Expert opinion]

A clinician with training in safeguarding should be involved in the initial assessment of any patient with a head injury presenting to the emergency department. If there are any concerns identified, document these and follow local safeguarding procedures appropriate to the patient's age.

Notes on wording changes

GENERALISABILITY of the source recommendation/s

Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?

☒ Yes ☐ No ☐ Unsure ☐ N/A

If not, is the recommendation generalisable/ transferable to the settings and patients of interest?

☐ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☒ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

NICE CG176 Recommendation 29	NICE CG176 Recommendation 35	NICE CG176 Recommendation 37
☐ Adopt source guidance	☐ Adopt source guidance	☐ Adopt source guidance
☒ Adapt source guidance	☒ Adapt source guidance	☒ Adapt source guidance
☐ Create new guidance	☐ Create new guidance	☐ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☒ Evidence-informed recommendation/s

☐ Consensus-based recommendation/s

☐ Practice point/s

☐ Not applicable

Comment:

PREDICT guidance

PREDICT evidence-informed recommendation 18	In children presenting to an acute care setting following mild to moderate head injury where abusive head trauma is suspected, a head CT scan should be used as the initial diagnostic tool to evaluate possible intracranial injury and other injuries (e.g. skull fractures), relevant to the evaluation of abusive head trauma. The extent of the assessment should be coordinated with the involvement of an expert in the evaluation of non-accidental injury.
PREDICT practice point M	Detection of fractures, even in the absence of other intracranial injury, is important in cases of suspected abusive head trauma.

Rationale

The PREDICT GWG **adapted expert opinion recommendations** 29,35 and 37 from the NICE CG176 Guideline. The PREDICT literature search identified 6 new studies and expert panel recommendations from the American College of Radiology (ACR), all were deemed key evidence for this question. Available evidence does not establish diagnostic superiority of other imaging modalities over CT scan and expert opinion recommends head CT scan as the first line tool for suspected abusive head trauma (AHT) in the setting of known or presumed head trauma (70, 71). The PECARN rule does not apply to abusive head trauma, and abusive head trauma screening tools predicting abnormal neuroimaging show promise but have not established adequate sensitivity (72–93%) to be recommended prior to imaging (72, 73). The PEDIBIRN-7 tool demonstrates reasonable performance in the diagnosis of AHT (Sensitivity 96%, AUC 0.78) but requires neuroimaging results (74-76). There is no evidence addressing the appropriate qualifications/training for providers assessing AHT and this recommendation was adopted by consensus.

PREDICT Guideline imaging Q9	In infants and children with mild to moderate head injury, presenting within 72 hours of injury with suspected non-accidental injury, i) who should undergo cranial imaging and ii) which modality should be used for initial imaging?	
FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.10 Imaging Q10 – In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a skull x-ray prior to, or in lieu of a cranial CT?

5.10.1 PREDICT question

PREDICT Guideline imaging Q10

In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a skull x-ray prior to, or in lieu of a cranial CT?

5.10.2 Source question

While this question does not focus on who should receive skull x-ray, one of the recommendations arising from this question provides guidance for skull x-ray.

NICE CG176 Section 7.12

What is the best initial diagnostic technique to determine which patients have sustained damage to the head and require further assessment of the head?

Note: this question in NICE CG176 (2014) is also relevant to two other question in the PREDICT Guideline – IMAGING Q9 and IMAGING Q13.

5.10.3 Source recommendation

Expert opinion[55]

NICE CG176 Recommendation 35

Do not use plain X-rays of the skull to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury.

Developed: 2007

[55] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

5.10.4 Source evidence

5.10.4.1 NICE CG176 (2014)

No study data was presented to support Recommendation 35 in the NICE CG176 (2014) Guideline, which was based on expert opinion when it was developed in 2007 (NICE CG176 (2014) p138). See 'Key considerations for assessing the evidence'.

5.10.4.2 NICE surveillance (2017)

Surveillance for this question identified six studies of CT imaging, compared with either different CT techniques or other imaging modalities. Synopses for these studies are presented for the related IMAGING Q13 in Section 5.13.4.2, and include a single study comparing X-ray with CT (70), study #1 in Table 5.13.1). The outcome for that study was detection of skull fracture rather than intracranial injury, with similar results for X-ray and CT. The intention of Recommendation 35 of the NICE CG176 (2014) Guideline would also appear to be detection of skull fracture, although this is not explicitly stated.

5.10.5 New evidence

Six new studies relevant to this question were identified in the PREDICT Guideline literature search. Two were selected as key studies (70, 77) .

Table 5.10.1 New evidence identified for imaging Q10

Ref #	Citation
90.	Alsabban Z, Stimec J, Shouldice M, Laughlin S, Branson H. Utility of skull views in skeletal surveys of children with suspected non-accidental injury who are also undergoing head CT. Pediatric radiology Conference: 60th annual meeting of the society for pediatric radiology, SPR 2017 Canada. 2017;47:S118.
115.	Arneitz C, Sinzig M, Fasching G. Diagnostic and Clinical Management of Skull Fractures in Children. Journal of Clinical Imaging Science. 2016;6:47.
93.	Culotta PA, Crowe JE, Tran QA, Jones JY, Mehollin-Ray AR, Tran HB, et al. Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Pediatric Radiology. 2017;47(1):74–81.
114.	Dremmen MHG, Wagner MW, Bosemani T, Tekes A, Agostino D, Day E, et al. Does the Addition of a "Black Bone" Sequence to a Fast Multisequence Trauma MR Protocol Allow MRI to Replace CT after Traumatic Brain Injury in Children? AJNR: American Journal of Neuroradiology. 2017;38(11):2187–92.
14.	Gravel J, Gouin S, Chalut D, Crevier L, Decarie JC, Elazhary N, et al. Derivation and validation of a clinical decision rule to identify young children with skull fracture following isolated head trauma. CMAJ Canadian Medical Association Journal. 2015;187(16):1202–8.
116.	Hansen C, Battikha M, Teramoto M. Complicated Mild Traumatic Brain Injury at a Level I Pediatric Trauma Center: Burden of Care and Imaging Findings. Pediatric Neurology. 2019;90:31–6.

Shading indicates key studies.

5.10.5.1 Rationale for selection of key evidence

The two key studies were selected as they addressed the question, Culotta, Crowe (70) directly and Gravel, Gouin (77) indirectly. The key study addressing the question (70) was low quality due to retrospective, single-centre design and due to this the Gravel study was selected as higher quality, albeit indirect, supporting evidence.

5.10.5.2 Key evidence data extraction

Table 5.10.2 Data from key evidence for imaging Q10

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Culotta PA**, Crowe JE, Tran QA, et al. Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Paediatric Radiology. 2017;47(1):74–81. **Aim** A cross-sectional study of infants evaluated for abusive head trauma via both skull radiographs and CT with 3-D reconstruction. **Setting** Two level I trauma centres in Houston, TX **Type** Retrospective, 2013–14	**Sample Size** 177 **Characteristics** 47% female; mean/median age: 5 months **Inclusion** Infants (<1-year-old) in whom both skeletal surveys and CT of the head were obtained to evaluate for non-accidental trauma. **Exclusion** Paired CT and skull series radiographs were unavailable; the CT was done at the referral hospital; imaging was obtained post operatively, or the skull radiographs and the CT were performed greater than 72 h apart.	The reference standard was skull radiography. Studies were read by paediatric radiologists and neuroradiologists, with ten percent read by a second radiologist to evaluate for interobserver reliability.	**Skull series** of the skeletal survey included two views((AP/Lateral) **CT images** of the head were helically acquired from the craniocervical junction through the calvarial vertex with an Aquilion ONE™ 320 Toshiba utilizing a detector collimation of 0.5 and a pitch of 0.84. The remainder of the CT images were obtained using a GE LightSpeed VCT 64 slice machine through which an axial mode was used. Standard images included axial images (5-mm slices); coronal (1.3-mm slices) and sagittal (3-mm slices) images were reconstructed from the axial images. **Three-dimensional reconstructions** were obtained as the standard of care.	62 (35%) children had skull fractures identified on skull radiographs and 67 (38%) by CT (p = 0.18). No differences between the radiographic findings and 3- D CT scan results among all patients and the three age groups using non-parametric testing for matched data CT with 3-D reconstruction was 97% sensitive (CI, 89–100%) and 94% specific (CI: 87–97%) for skull fracture.	**Limitations** Retrospective study. Potential for selection bias. Studies read by subspecialty radiologists **Conclusion** In cases where there is a concern for head trauma and clinicians require CT scans to adequately access intracranial injury, skull radiographs should be eliminated from the medical work-up.
Citation **Gravel J**, Gouin S, Chalut D, et al. Derivation and validation of a clinical decision rule to identify young children with skull fracture following isolated head trauma. CMAJ Canadian Medical Association Journal. 2015; 187(16):1202–1208. **Aim** Develop and validate a clinical decision rule to identify skull fracture in young children with head trauma and no immediate need for head tomography. **Setting** Quebec, 3 tertiary EDs **Type** Retrospective/Prospective observational with recursive partitioning for prediction rule.	**Sample Size** 1667 811 (derivation), 856 (validation) **Characteristics** Median age 8 months (IQR 5–12) **Inclusion** Children < 2 with head trauma w/in 24 hours **Exclusion** GCS <14 and high risk PECARN criteria	Treating physician completed a standardized report form after physical examination and before radiologic evaluation. The decision to order skull radiography was at the physician's discretion.	Descriptive data collection with inter-rater reliability and recursive partitioning. 2 predictors identified through re-cursive partitioning were parietal or occipital swelling or hematoma and age less than 2 months.	49 skull fractures in derivation phase, 44 in validation **Rule Sensitivity:** 94% (CI, 83%–99%) Validation: 89% **Rule Specificity:** 86% (CI 84%–89%) Validation: 87%	**Study Conclusion** Prediction rule identified approximately 90% of skull fractures among young children with head trauma and none at high risk for ciTBI.

5.10.6 Key considerations for assessing the evidence

5.10.6.1 Excerpt from NICE CG176

The following statement was made regarding the development of the 2007 recommendation regarding the use of skull X-rays:

> *Generally speaking, CT is more sensitive than X-ray at detecting clinically important lesions, although evidence specific to head trauma was not retrieved. CT is likely to be cost effective but only if a) the extra lesions found by CT pose a significant health risk, b) identification leads to earlier/better treatment and c) early/modified treatment improves survival. For these variables there is no high-quality evidence. However, a decision model[253] based on case series evidence estimated that CT scanning all patients would both more effective and cost saving than with X-raying all patients in a US context.*
>
> *The Guideline Development Group felt based on their expertise that CT is the most appropriate tool for diagnosing life-threatening conditions resulting from head injury. The GDG also felt that a recommendation was required to emphasize [sic] that X-ray is not a suitable substitute for CT. However, it was necessary to acknowledge that plain X-rays are useful adjuvant to CT in managing children with suspected non-accidental injury and therefore a new recommendation was developed (Recommendation 35 [2007], NICE CG176 (2014) p138).*

5.10.7 Working Group recommendation deliberations

Table 5.10.3 Clinical judgement form for imaging Q10

PREDICT Guideline imaging Q10	**In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a skull x-ray prior to, or in lieu of a cranial CT?**
Source recommendation/s	
NICE CG176 (2014) UK 1 recommendation: Rec 35	**NICE CG176 Recommendation 35** [Expert opinion] Do not use plain X-rays of the skull to diagnose significant brain injury without prior discussion with a neuroscience unit. However, they are useful as part of the skeletal survey in children presenting with suspected non-accidental injury. *Note: this is the same source recommendation as used in IMAGING Q9.*
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? NICE CG176 Recommendation 35 ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	
Comment:	

PREDICT Guideline imaging Q10	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a skull x-ray prior to, or in lieu of a cranial CT?

If new guidance needs to be developed, what type of guidance is appropriate?

☒ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance

PREDICT evidence-informed recommendation 19	In children presenting to an acute care setting following mild to moderate head injury, clinicians should not use plain X-rays of the skull prior to, or in lieu of, a head CT scan to diagnose skull fracture or to determine the risk of intracranial injury.

Rationale

The PREDICT GWG **adapted expert-opinion recommendation** 35 from the NICE CG176 Guideline. The PREDICT literature search identified 6 new studies, of these two low quality studies were deemed key evidence for this question. A retrospective study comparing skull X-rays versus CT scan with 3-D reconstruction did not demonstrate diagnostic benefit of skull x-ray (70). A Canadian 3-centre prospective prediction rule derivation and validation study identified two clinical criteria predicting skull fracture with 89–94% sensitivity (parietal or occipital swelling or hematoma and age less than 2 months) (77). This new evidence further re-enforced existing guidance to avoid routine use of skull x-ray in mild to moderate head trauma in children.

Note: In the Culotta investigation, CT scan with 3-D reconstruction was 97% sensitive (CI 89–100%) and 94% specific (CI 87–97%) for skull fracture. Standard CT scan protocol in this study included axial images (5-mm slices); coronal (1.3-mm slices) and sagittal (3-mm slices) that were reconstructed from the acquired axial thin – slice dataset.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☐ No ☒ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

5.11 Imaging Q11 – In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo ultrasound of the skull in the ED prior to, or in lieu of, a cranial CT?

5.11.1 PREDICT question

PREDICT Guideline imaging Q11

In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo ultrasound of the skull in the ED prior to, or in lieu of, a cranial CT?

5.11.2 Source question

No question is presented in the Italian Guideline (De Dalt 2018).

5.11.3 Source recommendation

> **Italian Guideline recommendation – key action statement 10b**
>
> *Clinicians may choose to use point-of-care ultrasound for the identification of skull fractures and the definition of their characteristics (e.g. depression, diastasis) in children with minor head trauma.*

5.11.4 Source evidence

This source recommendation is supported by a synopsis of eight studies, which is reproduced here in full, followed by the citations:

> *The purpose of these statements is to offer guidance on decision-making about the use of ultrasound in the diagnosis of skull fractures in children following a minor head trauma.*
>
> *As reported above, under the recommendation on the use of skull X-rays (Key Action Statement 9), skull fractures are inaccurate predictors of the presence of traumatic brain injuries and skull ultrasound should not be used as a screening tool for intracranial injuries, but rather to identify a skull fracture and define its characteristics. Point-of-care ultrasound is increasingly being used in the emergency setting to provide quick bedside information in the assessment of various fractures [140]. Ultrasound is a safe, quick and non-invasive test that does not involve exposure to ionizing radiation and can be performed in the ED, allowing observation and monitoring to continue in a safe environment.*
>
> *Although current management of pediatric minor head trauma is based on the use of accurate clinical prediction rules to guide the choice on CT or observation, the use of ultrasound may be helpful for the following reasons:*
>
> - *to favour a more rapid CT decision making in children with a scalp hematoma if a depressed and/ or diastatic skull fracture, which is likely to need neurosurgery independently of the risk of traumatic brain injury, is identified on ultrasound examination*
> - *to plan a better follow up for children found to have a skull fracture with respect to the rare, but significant late complication of a "growing skull fracture", usually occurring during infancy and early childhood [141, 142]. The tear of the dura that might be associated with a skull fracture may lead to the herniation of brain tissue or arachnoid membrane through the fracture margins with the growth of the skull, resulting in a leptomeningeal cyst or "growing skull fracture". This condition needs to undergo surgical repair that includes resection of the leptomeningeal cyst and degenerated brain tissue, repair of the dural defect, and cranioplasty [141, 142]*
> - *to tailor the advice given on discharge with respect to sport and play in children found to have a skull fracture on ultrasound, who may not require a CT scan based on clinical prediction rules*
>
> *Various studies investigated the accuracy of skull ultrasound in identifying skull fractures in children following a minor head trauma compared with CT findings (gold standard) [143–147]. These studies showed varying sensitivity (ranging from 82% to 100%), with wide confidence intervals. Specificity ranged from 94% to 100%. Overall, diagnostic accuracy based on total pooled data from four studies [143–145, 147] including a total of 185 patients with 50 skull fractures found a sensitivity of 94% (95% CI 84–98%), a specificity of 96% (95% CI 92–98%), a positive likelihood ratio of 25 (11–60) and a negative likelihood*

ratio of 0.1 (0.0–0.2) [143]. However, these studies showed variability with respect to the characteristics of the included population, the level of training of physicians performing the ultrasound, the technique used and the blinding with the results of the CT. Only one study assessed the agreement between physicians with a different level of expertise on ultrasound, finding a good agreement rate [143]. However, no study has assessed the usefulness of skull ultrasound in children younger than 2 years of age with a non-frontal scalp hematoma, which is an intermediate PECARN risk factor for clinically important traumatic brain injury [3]. In summary, point-of-care ultrasound can be used to detect skull fractures in children with minor head trauma by trained providers, however the evidence from available studies is insufficient to recommend its routine use in clinical practice, where the use of selective CT based on accurate clinical prediction rules remains the gold standard [3, 103].

Table 5.11.1 Citations for source evidence for Italian Guideline (Da Dalt 2018) key action statement 10b

Ref No	Citation
140	Burke K, Christian W. Question 1: is ultrasound scanning as sensitive as CT in detecting skull fractures in children presenting following head injury? Arch Dis Child. 2014; 99:958–60.
141	Liu XS, You C, Lu M, Liu JG. Growing skull fracture stages and treatment strategy. J Neurosurg Pediatr. 2012; 9:670–5.
142	Vignes JR, Jeelani NU, Jeelani A, Dautheribes M, Liguoro D. Growing skull fracture after minor closed-head injury. J Pediatr. 2007; 151:316–8.
143	Rabiner JE, Friedman LM, Khine H, Avner JR, Tsung JW. Accuracy of point-of-care ultrasound for diagnosis of skull fractures in children. Pediatrics. 2013; 131: e1757–64.
144	Parri N, Crosby BJ, Glass C, Mannelli F, Sforzi I, Schiavone R, et al. Ability of emergency ultrasonography to detect pediatric skull fractures: a prospective, observational study. J Emerg Med. 2013; 44:135–41.
145	Riera A, Chen L. Ultrasound evaluation of skull fractures in children: a feasibility study. Pediatr Emerg Care. 2012; 28:420–5.
146	Ramirez-Schrempp D, Vinci RJ, Liteplo AS. Bedside ultrasound in the diagnosis of skull fractures in the pediatric emergency department. Pediatr Emerg Care. 2011; 27:312–4.
147	Weinberg ER, Tunik MG, Tsung JW. Accuracy of clinician-performed point-of- care ultrasound for the diagnosis of fractures in children and young adults. Injury. 2010; 41:862–8.
Ancillary citations	
3	Kuppermann N, Holmes JF, Dayan PS, Hoyle JD Jr, Atabaki SM, Holubkov R, et al. Identification of children at very low risk of clinically important brain injuries after head trauma: a prospective cohort study. Lancet. 2009; 374:1160–70.
103	Babl FE, Borland ML, Phillips N, Kochar A, Dalton S, McCaskill M, et al. Accuracy of PECARN, CATCH, and CHALICE head injury decision rules in children: a prospective cohort study. Lancet. 2017; 389:2393–402.

5.11.5 New evidence

Two new studies relevant to this question were identified in the PREDICT Guideline literature search. These were selected as key studies (78, 79).

Table 5.11.2 New evidence identified for imaging Q11

Ref #	Citation
117.	Choi JY, Lim YS, Jang JH, Park WB, Hyun SY, Cho JS. Accuracy of Bedside Ultrasound for the Diagnosis of Skull Fractures in Children Aged 0 to 4 Years. Pediatric Emergency Care. 2018;24:24.
118.	Parri N, Crosby BJ, Mills L, Soucy Z, Musolino AM, Da Dalt L, Cirilli A, Grisotto L, Kuppermann N. Point-of-Care Ultrasound for the Diagnosis of Skull Fractures in Children Younger Than Two Years of Age. J Pediatr. 2018 May;196:230–236

Shading indicates key studies.

5.11.5.1 Rationale for selection of key evidence

Both of the new studies were selected as key evidence as they informed the question comparing ultrasound in the ED versus the gold standard (CT scan). The Choi 2018 study is a moderate-quality single centre convenience-sample design. The Parri 2018 study's relevance to the PREDICT GWG question is limited by its focus on skull fracture rather than intracranial injury.

5.11.5.2 Key evidence data extraction

Table 5.11.3 Data from key evidence for imaging Q11

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Choi JY**, Lim YS, Jang JH, Park WB, Hyun SY, Cho JS. Accuracy of Bedside Ultrasound for the Diagnosis of Skull Fractures in Children Aged 0 to 4 Years. Paediatric Emergency Care. 2018; 24:24. **Aim:** Bedside US by EP versus CT age 0–4 **Setting** South Korea, Level I Trauma Center **Type** Prospective observational	**Sample Size** 87, Age 0–4 Characteristics All pts with GCS 15 Mean patient age 21.3 ± 12.5 months (Range, 2–48 months). Inclusion Convenience sample of patients with head injury and GCS > 13 Exclusion Presented with hemodynamic instability, neurological deterioration, a GCS < 14, open deformity, or if urgent intervention was required. Patients without swelling, haematoma, or focal tenderness excluded.	Bedside US EP versus CT.	US performed before CT or practitioners blinded to results. 3 trained practitioners Ultrasonography was performed using the linear transducer (10MHz) of a Zonare US system. The transducer was placed over the area of soft tissue swelling or the point of impact. Images were scanned in 2 perpendicular planes throughout the length of the hematoma to fully view the cranium below. A positive skull US was defined as a cortical disruption, irregularity, or depression not correlating to anatomic sutures.	Skull fracture 14.9% (n= 13) on CT **Bedside US** Sensitivity: 77% (CI 46%-94%) Specificity: 100% (CI, 94%-100%) PPV: 100% (CI, 65.5%–100%) NPV: 96.1% (95% CI, 88.3%–99.0%). Three false-negative US cases were observed.	**Limitations** Single centre, convenience sample. No prediction rules used to guide CT use. 3 False Negatives limits sensitivity **Study Conclusion** Bedside ultrasound useful tool but 3 false negative cases. Meticulous examination is needed.
Citation **Parri N**, Crosby BJ, Mills L, et al. Point-of-Care Ultrasound for the Diagnosis of Skull Fractures in Children Younger Than Two Years of Age. J Pediatr. 2018 May; 196:230–236. **Aim**: determine the accuracy of skull point-of-care ultrasound (POCUS) for identifying fractures in children younger than 2 years of age with signs of head trauma, and the ability of POCUS to identify the type and depth of fracture depression. **Setting** Six emergency departments **Type** Prospective observational	**Sample Size** 115 **Characteristics** **Inclusion**[1] **Exclusion**[2]	Accuracy of POCUS for fractures in under 2 compared to CT scan. **Index test:** ultrasound **Reference standard:** CT scan	All sites encouraged to use PECARN rules for CT use to standardise. After CT requested, physician performed skull POCUS or requested ultra sonographer blinded to clinical scenario to perform POCUS.	88 skull fractures (76.5%) POCUS: **Sensitivity**: 80 of 88 (90.9%; 95% CI 82.9–96.0) **Specificity**: 23 of 27 (85.2%; 95% CI 66.3–95.8) Agreement between POCUS and CT to identify fracture as linear, depressed or complex was 84.4% (97 of 115) with a kappa of 0.75 (95% CI 0.70–0.84).	**Limitations** convenience sample of patients **Study Conclusion** POCUS may identify the type and depth of fractures in infants with local physical signs of head trauma with substantial accuracy in children < 2 years of age.

[1]Inclusion criteria: Age less than 2 years; GCS score of 14–15 after blunt head trauma resulting from nontrivial mechanisms; localizing evidence of scalp trauma (cephalohematoma, focal pain, deformity); undergoing cranial CT determined by the attending physician.

[2]Exclusions criteria: Hemodynamic instability; children with trivial mechanisms of injury (ground-level falls or walking or running into stationary objects) and no signs of TBI; open skull deformity/fracture or penetrating trauma; known brain tumours; pre-existing neurological disorders complicating assessment; ventricular shunts; bleeding disorders.

5.11.6 Key considerations for assessing the evidence

5.11.6.1 Excerpt from Italian Guideline (Da Dalt 2018)

For reference, the following table is reproduced from the Italian Guideline (Da Dalt 2018), which lists considerations made by the Italian Guideline Working Group during development of the recommendation (Table 5.11.4).

Table 5.11.4 Action statement profile for key action statement 10b from the Italian Guideline (Da Dalt 2018)

Aggregate evidence quality	**B**
Benefits	Avoiding radiation exposure and need for sedation.
Risk, harm, cost	Misdiagnosis of skull fracture
Benefit-harm assessment	Benefits outweigh harms
Values judgments	None
Intentional vagueness	None
Role of patient preference	None
Exclusion	Patients with GCS < 14
Strength	Moderate recommendation
Difference of opinion	None

5.11.7 Working Group recommendation deliberations

Table 5.11.5 Clinical judgement form for imaging Q11

PREDICT Guideline imaging Q11	**In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo ultrasound of the skull in the ED prior to, or in lieu of, a cranial CT?**
Source recommendation/s	
Da Dalt (2018) Italy 1 recommendation: KAS 10b	**Italian Guideline** **Recommendation – Key action statement 10b** Clinicians may choose to use point-of-care ultrasound for the identification of skull fractures and the definition of their characteristics (e.g. depression, diastasis) in children with minor head trauma.
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?	
<u>Italian Guideline (Da Dalt 2018) key action statement 10b</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	
Comment:	

PREDICT Guideline imaging Q11	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo ultrasound of the skull in the ED prior to, or in lieu of, a cranial CT?

If new guidance needs to be developed, what type of guidance is appropriate?

☒ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance

PREDICT evidence-informed recommendation 20	In children presenting to an acute care setting following mild to moderate head injury, clinicians should not use ultrasound of the skull prior to, or in lieu of, a head CT scan to diagnose or determine the risk of intracranial injury.

Rationale

The PREDICT GWG **adapted evidence-informed recommendation** (key action statement 10a) from the Italian Guideline (Da Dalt 2018) that included one observational study (80). The PREDICT literature search identified two new key studies (78, 79). A single centre study of 87 children aged to 4 years, comparing point of care ultrasound versus diagnostic gold standard (CT scan) to detect skull fractures found a sensitivity of 76.9% (95% CI, 46.0%-93.8%) and a specificity of 100% (95% CI, 93.9%-100%) (78). A multicentre prospective study of point of care ultrasound to patients under 2 years showed sensitivity of 80 of 88 (90.9%; 95% CI 82.9–96.0) and a specificity of 23 of 27 (85.2%; 95% CI 66.3–95.8) for identifying skull fractures as compared to CT. However, the study did not assess the relationship between ultrasound and traumatic brain injury (79). There may be limited utility for other diagnostic purposes and research is needed on diagnostic modalities which do not utilize ionizing radiation (PREDICT GWG consensus opinion).

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

5.12 Imaging Q12 – In infants with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a transfontanelle cerebral ultrasound in the ED prior to, or in lieu of a cranial CT?

5.12.1 PREDICT question

PREDICT Guideline imaging Q12

In infants with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a transfontanelle cerebral ultrasound in the ED prior to, or in lieu of a cranial CT?

5.12.2 Source question

No question is presented in the Italian Guideline (Da Dalt 2018).

5.12.3 Source recommendation

Italian Guideline (Da Dalt 2018) recommendation – key action statement 10a
Clinicians should not routinely use trans-fontanelle ultrasound for diagnosing intracranial injuries in infants presenting to the emergency department following a trauma to the head.

5.12.4 Source evidence

This recommendation is supported by a synopsis of a single study, which is reproduced here in full, followed by the citation:

> *The purpose of this statement is to offer guidance on decision-making about the use of trans-fontanelle cerebral ultrasound as a screening tool for the diagnosis of intracranial injury in infants following a minor head trauma.*
>
> *Trans-fontanelle cerebral ultrasound is a bed-side, easy-to-use, and cheap radiation free test that does not require sedation to be properly performed. Although it is an accurate test to identify neonatal and perinatal brain injuries, the very limited ability to assess peripheral sub-cranial regions makes trans-fontanelle ultrasound inaccurate to identify extra-axial hematomas in infants with head trauma.*
>
> *We could find only one prospective study where trans-fontanelle ultrasound was used as first neuroimaging test in 118 infants younger than 12 months who had a skull fracture on X-rays and an adequate size fontanelle. Of these, 2 patients were diagnosed with intracranial alterations and received a head CT scan that confirmed a small epidural hematoma in both cases, which did not need neurosurgery. No complications were found at the follow up visit at 2 months post injury in the remaining 116 patients and none required readmission [139].*
>
> *Despite the promising results of this study the GDG agreed that these data were not sufficient to support the use of trans-fontanelle ultrasound in infants with head trauma in the era of PECARN clinical prediction rules.*

Table 5.12.1 Citations for source evidence for Da Dalt (2018) key action statement 10a

Reference No	Citation
139	Trenchs V, Curcoy AI, Castillo M, Badosa J, Luaces C, Pou J, et al. Minor head trauma and linear skull fracture in infants: cranial ultrasound or computed tomography? Eur J Emerg Med. 2009;16:150–2

5.12.5 New evidence

Three new studies relevant to this question were identified in the PREDICT Guideline literature search. One was selected as key study (81).

Table 5.12.2 New evidence identified for imaging Q12

Ref #	Citation
117	Choi JY, Lim YS, Jang JH, Park WB, Hyun SY, Cho JS. Accuracy of Bedside Ultrasound for the Diagnosis of Skull Fractures in Children Aged 0 to 4 Years. Pediatric Emergency Care. 2018;24:24.
118	Elkhunovich M, Sirody J, McCormick T, Goodarzian F, Claudius I. The Utility of Cranial Ultrasound for Detection of Intracranial Hemorrhage in Infants. Pediatric Emergency Care. 2018;34(2):96–101.
--	Parri N, Crosby BJ, Mills L, Soucy Z, Musolino AM, Da Dalt L, Cirilli A, Grisotto L, Kuppermann N. Point-of-Care Ultrasound for the Diagnosis of Skull Fractures in Children Younger Than Two Years of Age. J Pediatr. 2018 May;196:230–236

Shading indicates key study

4.12.5.1 Rationale for selection of key evidence

One of the three new studies were selected as key evidence for this question based on the following rationale: Elkhunovich, Sirody (81) is a single centre retrospective cohort study and addressed the comparative detection of intracerebral haemorrhage using transfontanelle ultrasound vs CT or MRI.

4.12.5.2 Key Evidence data extraction

Table 5.12.2 Data from key evidence for imaging Q12

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Elkhunovich M**, Sirody J, McCormick T, Goodarzian F, Claudius I. The Utility of Cranial Ultrasound for Detection of Intracranial Hemorrhage in Infants. Paediatric Emergency Care. 2018;34(2):96–101. **Aim** Evaluate the sensitivity and specificity of cranial ultrasound (CUS) for detection of intracranial haemorrhage (ICH) in infants with open fontanels. **Setting** Children's LA., USA **Type** Retrospective 2008–2013	**Sample Size** 283 **Characteristics** Patient age ranged from 0 to 458 days (median 33) **Inclusion** All studies done for traumatic injury, suspected abuse, acute life-threatening event, or unexplained neurological decompensation for which acute ICH was possible. Site of study not restricted to ED. **Exclusion**[1]	CUS versus gold standard imaging (CT, MRI or clinical outcome) for ICH	Cranial ultrasound studies were performed using GE and Acuson ultrasound systems. Using a 5–7.5- to10-MHz transducer, 6 to 8 coronal planes were obtained. Next, the transducer is turned 90 degrees, and 5 more images were obtained in the sagittal and parasagittal planes. 2 chart reviewers	**CUS Sensitivity for bleed** 67% (CI 50%–81%) **CUS Specificity**: 99% (CI, 97%–100%), **CUS sensitivity for significant** bleed: 81% (CI, 62%–94%) **CUS sensitivity Insignificant Bleed**: 33% (CI, 1%–65%).	13 False Negatives **Conclusions** The sensitivity of CUS is inadequate to justify its use as a screening tool for detection of ICH in young infants.

[1]Excluded: all other studies that were done for a different purpose, including prematurity related intraventricular haemorrhage; screening for or follow-up of congenital anomalies; evaluation of ventricular shunts; screening before or after cardiothoracic surgery, extracorporeal membrane oxygenation, or organ transplantation; complications of prepartum conditions (e.g., TORCH (toxoplasmosis, other including syphilis, varicella zoster, parvovirus B19), rubella, cytomegalovirus, and herpes infections)); assessment of potential malignant metastases; meconium aspiration; or follow-up of a post meningitis or encephalitis patient for intracranial complications

5.12.6 Key considerations for assessing the evidence

5.12.6.1 Excerpt from Italian Guideline (Da Dalt 2018)

For reference, the following table is reproduced from the Italian Guideline (Da Dalt 2018), which lists considerations made by Italian Guideline Working Group during development of the recommendation (Table 5.12.3).

Table 5.12.3 Action statement profile for key action statement 10a from the Italian Guideline (Da Dalt 2018)

Aggregate evidence quality	D
Benefits	Avoiding to potentially miss an intracranial injury due to poor test accuracy.
Risk, harm, cost	Potential risk for rise in CT rate
Benefit-harm assessment	Benefits outweigh harms
Values judgments	None
Intentional vagueness	None
Role of patient preference	None
Exclusion	None
Strength	Moderate recommendation
Difference of opinion	None

5.12.7 Working Group recommendation deliberations

Table 5.12.4 Clinical judgement form for imaging Q12

PREDICT Guideline imaging Q12	**In infants with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo a transfontanelle cerebral ultrasound in the ED prior to, or in lieu of a cranial CT?**
Source recommendation/s	
Italian Da Dalt (2018) Italy 1 recommendation: Key action statement 10a	**Recommendation – Key action statement 10a** Clinicians should not routinely use trans-fontanelle ultrasound for diagnosing intracranial injuries in infants presenting to the emergency department following a trauma to the head.
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? Da Dalt (2018) Key action statement 10a ☒ Adopt source guidance ☐ Adapt source guidance ☐ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 21	In infants presenting to an acute care setting following mild to moderate head injury, clinicians should not use transfontanelle ultrasound prior to, or in lieu of, a head CT scan to diagnose intracranial injury.
Rationale The PREDICT GWG **adopted evidence-informed recommendation** (key action statement 10a) from the Italian Guideline (Da Dalt 2018) that included one observational study (80). The PREDICT literature search identified 3 new studies, of these, one low quality, single centre retrospective cohort study was deemed key evidence for this question and compared transfontanelle cerebral ultrasound versus diagnostic gold standard (CT scan or MRI). It did not demonstrate adequate diagnostic performance to justify routine use of transfontanelle ultrasound to detect intracerebral haemorrhage (81). There may be limited utility for other diagnostic purposes and research is needed on diagnostic modalities which do not utilize ionizing radiation (PREDICT consensus opinion).	
FEASIBILITY of draft recommendation/s	
Will this recommendation result in changes in usual care? ☐ Yes ☒ No ☐ Unsure	Are there any resource implications associated with implementing this recommendation? ☐ Yes ☒ No ☐ Unsure Are there barriers to the implementation of this recommendation? ☐ Yes ☒ No ☐ Unsure
Comment:	

5.13 Imaging Q13 – In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo MRI in lieu of a cranial CT?

5.13.1 PREDICT question

PREDICT Guideline imaging Q13

In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo MRI in lieu of a cranial CT?

5.13.2 Source question

While this question does not focus on who should receive MRI instead of CT, one of the recommendations arising from this question provides guidance for the use of MRI.

NICE CG176 Section 7.12

What is the best initial diagnostic technique to determine which patients have sustained damage to the head and require further assessment of the head?

Note: this question in NICE CG176 (2014) is also relevant to two other question in the PREDICT Guideline – IMAGING Q9 and IMAGING Q10.

5.13.3 Source recommendation

Expert opinion[56]

NICE CG176 Recommendation 33

For safety, logistic and resource reasons, do not perform magnetic resonance imaging (MRI) scanning as the primary investigation for clinically important brain injury in patients who have sustained a head injury, although it is recognised that additional information of importance to the patient's prognosis can sometimes be detected using MRI.

Developed: 2003

5.13.4 Source evidence

5.13.4.1 NICE CG176 (2014)

No study data was presented in NICE CG176 (2014) to support Recommendation 33, which was based on expert opinion when it was developed in 2003.

[56] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

5.13.4.2 NICE surveillance (2017)

The NICE surveillance (2017) report provided the following synopses of studies identified for the clinical question in Section 7.12. Only one study (#4) is relevant to Recommendation 33, which compared CT and rapid MRI for detecting intracranial lesions in children. The guidance was not altered.

Table 5.13.1 Subsequent evidence from NICE surveillance (2017) for choice of imaging

#	Original study citation	NICE surveillance (2017) evidence for choice of imaging
1	Culotta PA, Crowe JE, Tran QA et al. (2016) Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Pediatric Radiology 1–8.	A retrospective cross-sectional study[23] included 177 children with suspected intentional head trauma who had skull X-ray and CT with 3D reconstruction. X-ray showed skull fracture in 67% of children. CT with 3D reconstruction had sensitivity of 97% and specificity of 94%. There was no significant difference between X-ray and 3D CT results.
2	Langford S, Panigrahy A, Narayanan S et al. (2015) Multiplanar reconstructed CT images increased depiction of intracranial hemorrhages in pediatric head trauma. Neuroradiology 57:1263–1268.	A retrospective study[24] included 221 children younger than 3 years with head trauma. Unenhanced axial CT was reviewed then images with additional multiplanar reconstruction were reviewed. Multiplanar reconstruction detected haemorrhage in an additional 6.5% of children, detected additional incidental findings in 2.3% of children, and helped to confirm presence of artefacts in 2.3% of children.
3	Rabiner JE, Friedman LM, Khine H et al. (2013) Accuracy of point-of-care ultrasound for diagnosis of skull fractures in children. Pediatrics 131: e1757-e1764.	A cohort study[25] included 69 children and young people (aged under 21 years) with suspected head injury who were assessed with CT and point-of-care ultrasound. Emergency physicians had a 1-hour training session before using the ultrasound. Skull fracture was present in 8% of the sample. Ultrasound had sensitivity of 88%, specificity of 97%, positive likelihood ratio of 27 and negative likelihood ratio of 0.13.
4	Mehta H, Acharya J, Mohan AL et al. (2016) Minimizing Radiation Exposure in Evaluation of Pediatric Head Trauma: Use of Rapid MR Imaging. AJNR: American Journal of Neuroradiology 37:11–18.	A retrospective study[26] included 103 children with minor head injury who had initial CT and follow-up rapid MRI within 48 hours. Imaging was reviewed by a blinded neuroradiologist. Agreement between CT and rapid MRI was high for extra-axial haemorrhage (kappa= 0.84), substantial for haemorrhagic contusion or intraparenchymal haemorrhage (kappa= 0.61) and for skull fracture (kappa= 0.71), but poor for diffuse axonal injury (kappa = 0.154).
5	Lim D, Lee SH, Kim DH et al. (2014) The possibility of application of spiral brain computed tomography to traumatic brain injury. American Journal of Emergency Medicine 32:1051–1054.	A retrospective study[27] included 315 people with trauma who underwent CT of the brain and also had spiral facial CT. Spiral facial CT had sensitivity of 92.2%, specificity of 98.1%, positive predictive value of 95.9%, and negative predictive value of 96.3%, using standard CT as the reference standard.
6	Prichep LS, Naunheim R, Bazarian J et al. (2015) Identification of hematomas in mild traumatic brain injury using an index of quantitative brain electrical activity. Journal of Neurotrauma 32:17–22.	A cohort study[28] included 394 people with closed head injury who had CT and brain electrical activity recorded from electrodes on the forehead. Overall, 29% had positive findings on CT, and 12% had traumatic intracranial haematoma. People with negative CT findings were used as the control group. A previously developed algorithm (TBI-Index) was used to estimate CT findings from forehead electrical activity. TBI-Index had sensitivity 95.7% of and specificity of 43.9% for detecting haematoma. The TBI-Index was not significantly affected by distance of the bleed from the recording site or by the volume of blood.
Topic expert feedback		
No topic expert feedback was relevant to this evidence.		
Impact statement		
Several studies assessing the effectiveness of imaging methods compared with CT were identified. However, all studies included small sample sizes, and no method of imaging was covered by more than 1 study, or reported on additional outcomes of interest in developing the Guideline (for example, mortality, disability, neurological outcome, hospital duration, and cost). This evidence base is likely to be insufficient for formulating recommendations at this time. The study showing that 3D CT effectively identified skull fracture in children lends some support to the recommendation not to use plain X-rays for diagnosis of brain injury.		
New evidence is unlikely to change Guideline recommendations.		

Source: NICE surveillance (2017) report, Appendix A (p14).

5.13.5 New evidence

Sixteen new studies relevant to this question were identified in the PREDICT Guideline literature search. Four were selected as key studies (82-85).

Table 5.13.2 New evidence identified for imaging Q13

Ref #	Citation
119.	Bonow RH, Friedman SD, Perez FA, Ellenbogen RG, Browd SR, Mac Donald CL, et al. Prevalence of abnormal magnetic resonance imaging findings in children with persistent symptoms after pediatric sports-related concussion. Journal of Neurotrauma. 2017;34(19):2706–12.

Ref #	Citation
120.	Buttram SD, Garcia-Filion P, Miller J, Youssfi M, Brown SD, Dalton HJ, et al. Computed tomography vs magnetic resonance imaging for identifying acute lesions in pediatric traumatic brain injury. Hospital Pediatrics. 2015;5(2):79–84.
126.	Carnevale TJ, Meng D, Wang JJ, Littlewood M. Impact of an emergency medicine decision support and risk education system on computed tomography and magnetic resonance imaging use. Journal of Emergency Medicine. 2015;48(1):53–7.
121.	Chiara Ricciardi M, Bokkers RP, Butman JA, Hammoud DA, Pham DL, Warach S, et al. Trauma-specific brain abnormalities in suspected mild traumatic brain injury patients identified in the first 48 hours after injury: A blinded magnetic resonance imaging comparative study including suspected acute minor stroke patients. Journal of Neurotrauma. 2017;34(1):23–30.
127.	Cohen AR, Caruso P, Duhaime AC, Klig JE. Feasibility of "rapid" magnetic resonance imaging in pediatric acute head injury. American Journal of Emergency Medicine. 2015;33(7):887–90.
128.	Cohrs G, Huhndorf M, Niemczyk N, Volz LJ, Bernsmeier A, Singhal A, et al. MRI in mild pediatric traumatic brain injury: diagnostic overkill or useful tool? Childs Nervous System. 2018;34(7):1345–52.
129.	Dennis EL, Babikian T, Giza CC, Thompson PM, Asarnow RF. Diffusion MRI in pediatric brain injury. Childs Nervous System. 2017;33(10):1683–92.
114.	Dremmen MHG, Wagner MW, Bosemani T, Tekes A, Agostino D, Day E, et al. Does the Addition of a "Black Bone" Sequence to a Fast Multisequence Trauma MR Protocol Allow MRI to Replace CT after Traumatic Brain Injury in Children? AJNR: American Journal of Neuroradiology. 2017;38(11):2187–92.
130.	Elliott CA, Ramaswamy V, Jacob FD, Sankar T, Mehta V. Early diffusion restriction of white matter in infants with small subdural hematomas is associated with delayed atrophy. Childs Nervous System. 2017;33(2):289–95.
122.	Ellis MJ, Leiter J, Hall T, McDonald PJ, Sawyer S, Silver N, et al. Neuroimaging findings in pediatric sports-related concussion. Journal of Neurosurgery: Pediatrics. 2015;16(3):241–7.
109.	Flom L, Fromkin J, Panigrahy A, Tyler-Kabara E, Berger RP. Development of a screening MRI for infants at risk for abusive head trauma. Pediatric Radiology. 2016;46(4):519–26.
131.	Mehta H, Acharya J, Mohan AL, Tobias ME, LeCompte L, Jeevan D. Minimizing Radiation Exposure in Evaluation of Pediatric Head Trauma: Use of Rapid MR Imaging. AJNR: American Journal of Neuroradiology. 2016;37(1):43688.
132.	Mendoza D, Kadom N, Palasis S, Milla S, Allen JW. Use of Conventional and Advanced MRI Techniques in Accidental Pediatric Traumatic Brain Injury. Journal of Pediatric Neuroradiology. 2016;5(1):20–5.
123.	Roguski M, Morel B, Sweeney M, Talan J, Rideout L, Riesenburger RI, et al. Magnetic resonance imaging as an alternative to computed tomography in select patients with traumatic brain injury: a retrospective comparison. Journal of Neurosurgery Pediatrics. 2015;15(5):529–34.
124.	Torres AR, Shaikh ZI, Chavez W, Maldonado JE. Brain MRI in Children with Mild Traumatic Brain Injury and Persistent Symptoms in Both Sports- and Non-sports-related Concussion. Cureus. 2019;11(1):e3937.
125.	Wagner MW, Kontzialis M, Seeburg D, Stern SE, Oshmyansky A, Poretti A, et al. Acute Brain Imaging in Children: Can MRI Replace CT as a Screening Tool? Journal of Neuroimaging. 2016;26(1):68–74.

Shading indicates key studies.

5.13.5.1 Rationale for selection of key evidence

Four of the 16 identified studies were selected as key evidence for this question based on the following rationale: they compared CT vs MRI in same population.

5.13.5.2 Key evidence data extraction

Table 5.13.3 Data from key evidence for imaging Q13

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Buttram SDW**, Filion PG, Miller J. Computed tomography vs magnetic resonance imaging for identifying acute lesions in paediatric traumatic brain injury. Hosp Pediatr. 2015 Feb;5(2):79–84. **Aim** Compare lesion detection between CT and MRI after TBI. **Setting** Level 1 trauma centre **Type** Retrospective	**Sample Size** 150 children **Characteristics** 78% mTBI AHT were younger (5 months; IQR 3–9) than those with an accidental injury (62 months; IQR 11–137) ($p < .001$). **Inclusion** 0–21 years with TBI with head CT on day of injury and MRI within 2 weeks of injury **Exclusion** If the neuroimaging studies were unavailable or the MRI was obtained > 2 weeks after the injury.	Compare lesion detection between CT and MRI after TBI. And compare AHT vs. accidental TBI	Contiguous axial CT images of the head were obtained at 3-mm intervals. Brain MRI was performed with a 1.5-Tesla magnet under our TBI protocol for paediatric imaging with sagittal T1, axial T1/T2/fluid attenuated inversion recovery/diffusion weighted imaging/gradient echo, and coronal T2 sequences. Limited MRI included sagittal, axial, and coronal turbo spin echo T2 and axial and coronal gradient echo sequences. One paediatric radiologist and 1 paediatric neuroradiologist, blinded to clinical information, reviewed CT and MRI scans to identify abnormalities by consensus ($\kappa = 0.79$). Classification of abuse based on institution's child forensic team. Medical record reviewed.	Overall, CT and MRI demonstrated poor agreement ($\kappa = -0.083$; $p = .18$). MRI detected a greater number of intraparenchymal lesions (n= 36; 34%) compared with CT (n= 16; 15%) ($p < .001$). In patients with AHT, MRI detected intraparenchymal lesions in 16 (43%), compared with only 4 (11%) lesions with CT ($p = .03$). Of 8 subjects with a normal CT scan, 6 out of 8 had abnormal lesions on MRI.	**Limitations** Cohort restricted to pts who underwent MRI. Small study size. **Study conclusions** MRI identified more lesions in children with paediatric TBI than CT, particularly in children who had sustained AHT.
Citation **Cohen AR**, Caruso P, Duhaime AC, Klig JE. Feasibility of "rapid" magnetic resonance imaging in paediatric acute head injury. Am J Emerg Med. 2015 Jul;33(7):887–90. **Aim** Determine the feasibility of "rapid" magnetic resonance imaging (rMRI) versus non-contrast computed tomography (NCCT) for paediatric patients with possible traumatic brain injury and to compare the populations receiving imaging in an urban tertiary care emergency department (ED). **Setting** **Type** Retrospective	**Sample Size** 45 rapid MRIs 45 non-contrast computed tomography **Characteristics** Mean age was 2.7 years, 63% were male, and 65% sustained a fall. **Inclusion** Children < 19 years with possible TBI over 4 years who received a rapid MRI **Exclusion** rMRI was performed for nontrauma indications or if the rMRI was not completed during evaluation in the ED.	Compared children with possible TBI over 4 yrs who received a rapid MRI with age-matched children with possible TBI over 4 yrs who received non-contrast computed tomography	Data collection – demographic and clinical variables, ED length of stay and follow up. Radiological reports	Time parameters were longer for rMRI patients: ED arrival to completion of imaging (172 vs 93 minutes, $p < .001$) and ED LOS (266 vs 225 minutes, $p = .008$). The NCCT group had higher-acuity patients with higher paediatric intensive care unit admission rates (33% vs 7%, $p = .002$). No clinically significant intracranial injuries were missed	**Limitations** 78% patients followed up. **Study conclusions** Rapid MRI may be a viable imaging modality for moderate-risk paediatric head injury. Although rMRI took longer to obtain during this pilot study, scan time was only 3 to 4 minutes; and LOS was only 41 minutes longer.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Mehta H,** Acharya J, Mohan AL, et al. Minimizing Radiation Exposure in Evaluation of Paediatric Head Trauma: Use of Rapid MR Imaging. AJNR Am J Neuroradiol. 2016 Jan;37(1):11–8. **Aim** Assess the validity of rapid MR imaging to replace CT in the follow-up imaging of patients with head trauma. **Setting** Level 1 paediatric trauma **Type** Retrospective review	**Sample Size** 103 **Characteristics** Mean age of the 101 subjects was 6 years (range, 0–19 years **Inclusion** Initial CT and subsequent follow-up with rapid MRI within 48hrs. GCS > 13 <19years **Exclusion**	Validity of rapid MR imaging to CT	Neuroradiologist, blinded to patient information and scan parameters independently reviewed results. Used Brilliance 64–detector row CT scanner. rMRI examinations were performed by using 1.5T (Achieva 1.5T; Philips Healthcare) and 3T (Achieva 3T X; Philips Healthcare) scanners. rMRI sequences included the following: axial single-shot T2 fast-field echo EPI: 5-second scanning time; TR, 2000 ms; TE, 25 ms; axial single-shot diffusion-weighted imaging: 35-second scanning time; TR, 3000 ms; TE, 65 ms; axial single-shot FLAIR: 45-second scanning time; TR, 12,000 ms; TI, 2850 ms; TE, 135 ms; axial T2 fast-field echo: 35-second scanning time; TR, 550 ms; TE, 15 ms; coronal T2 turbo spin-echo: 35-second scanning time; TR, 3500 ms; TE, 80 ms.	Detect extra-axial haemorrhage on rapid MR imaging and CT ($\kappa = 0.84$, $p < .001$). haemorrhagic contusion /intraparenchymal haemorrhage t between MR imaging and CT ($\kappa = 0.61$, $p < .001$) **Skull fracture** ($\kappa = 0.71$, $p < .001$). **Diffuse axonal injury** ($\kappa = 0.154$, $p = .04$). Predictive agreement for the detection of an axonal injury was 91%.	**Limitations** Initial CT scans of many pts performed outside of facility. Time intervals may have increased bias. **Study conclusions** Rapid MR imaging is a valid technique for detecting traumatic cranial injuries and an adequate examination for follow-up imaging in lieu of repeat CT.
Citation **Roguski M**, Morel B, Sweeney M. Magnetic resonance imaging as an alternative to computed tomography in select patients with traumatic brain injury: a retrospective comparison. J Neurosurg Pediatr. 2015;15(5):529–34. **Aim** To evaluate the sensitivity of MRI in the setting of acute THI. **Setting** Admission to level 1 trauma centre **Type** Retrospective	**Sample Size** 30 of 574 **Characteristics** Mean age 8.5 ± 6.7 years, and 63.3% were male. Mean GCS 9 ± 5.7 **Inclusion** Included age less than 18 years and MRI of the brain obtained within 5 days of CT	Compared CT and MRI in patients with traumatic head injury	De-identified images were reviewed by a neuroradiologist for presence of any injury, intracranial haemorrhage, diffuse axonal injury (DAI), and skull fracture. Radiology reports were used to calculate interrater reliability scores. Baseline demographics and concordance analysis. MRI studies included a localizer sequence, T2-weighted sequences, T2-FLAIR images, gradient-echo T2 images, and T1-weighted sequences.	In 60 imaging studies 150 abnormal findings were noted. CT scan was negative in 3 patients whose subsequent MRI revealed findings. MRI missed findings in 13 patients; missed findings included skull fracture (n = 5), small subdural hematomas (n = 4), cerebral contusions (n = 3), subarachnoid haemorrhage (n = 3), and DAI (n = 1). MRI was negative in 1 patient whose preceding CT scan was read as positive for injury. Although MRI more frequently reported intracranial findings than CT scanning, there was no statistically significant difference between CT and MRI in the detection of any intracranial injury ($p = 0.63$), DAI ($p = 0.22$), or intracranial haemorrhage ($p = 0.25$). CT scanning tended to more frequently identify skull fractures than MRI ($p = 0.06$).	**Limitations** MRI often performed in patients whose CT results did not explain neurological impairments (explains high prevalence of DAI). **Study conclusions** MRI may be as sensitive as CT scanning in the detection of traumatic head injury, DAI, and intracranial haemorrhage, but missed skull fractures in 5 of 13 patients. MRI may be a useful alternative to CT scanning in select stable patients with mild traumatic head injury who warrant neuroimaging by clinical decision rules.

5.13.6 Key considerations for assessing the evidence

5.13.6.1 Excerpt from NICE CG176

The only comment by the GDG regarding MRI was the following statement:

> *MRI safety, availability and speed may improve in the future to the point where it becomes a realistic primary investigation option for head injury. (NICE CG176 p139)*

5.13.7 Working Group recommendation deliberations

Table 5.13.4 Clinical judgement form for imaging Q13

PREDICT Guideline imaging Q13	**In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo MRI in lieu of a cranial CT?**
Source recommendation/s	
NICE CG176 (2014) UK 1 recommendation: Rec 33	**NICE CG176 Recommendation 33** [Expert opinion] For safety, logistic and resource reasons, do not perform magnetic resonance imaging (MRI) scanning as the primary investigation for clinically important brain injury in patients who have sustained a head injury, although it is recognised that additional information of importance to the patient's prognosis can sometimes be detected using MRI.
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? NICE CG176 Recommendation 33 ☒ Adopt source guidance ☐ Adapt source guidance ☐ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☐ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☒ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 22	In children presenting to an acute care setting following mild to moderate head injury, for safety, logistical and resource reasons, MRI should not be routinely used for primary investigation of clinically-important traumatic brain injury.[57]
PREDICT practice point N	In certain settings with the capacity to perform MRI rapidly and safely in children, MRI may be equivalent to a head CT scan in terms of utility.

[57] If an MRI is planned, the concurrent imaging of the spine should be considered and may warrant discussion with other specialist teams.

PREDICT Guideline imaging Q13	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo MRI in lieu of a cranial CT?	
Rationale The PREDICT GWG **adopted expert opinion recommendation** 33 from the NICE CG176 Guideline. The PREDICT literature search identified 16 new studies, of these 4 were deemed key evidence for this question. In retrospective studies comparing CT and MRI scans in head injuries in the same population (82-85), using rapid or modified MRI protocols in some, MRI is reported as an alternative to head CT scan. The prognostic value of additional parenchymal lesions identified on MRI and additional skull fractures identified on head CT scan is unclear.		
FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

5.14 Imaging Q14 – In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo biomarker testing prior to a cranial CT?

5.14.1 PREDICT question

PREDICT Guideline imaging Q14

In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo biomarker testing prior to a cranial CT?

5.14.2 Source question

NICE CG176 Section 7.9

What is the diagnostic accuracy of biomarkers (S100B, NSE, GFAP) in the emergency department for selecting adults with head injury for CT head scan?

Although the clinical question in the NICE CG176 (2014) Guideline restricts the population to adults, the Guideline Development Group noted that it is important to look for both adult and child studies, and both populations are included in the identified evidence. This version of the Guideline did impose a restriction, however, on the biomarkers to be included based on the stage of research for other biomarkers was too early at that point. Therefore, only studies of S100B, NSE and GFAP were eligible for inclusion.

5.14.3 Source recommendations

There are no recommendations in NICE CG176 related to imaging Q14 in either adult or paediatric populations. It was therefore decided that the CDC Guideline recommendations would be used, and the relevant supporting evidence would be from the NICE CG176 Guideline, as this Guideline has the most recent literature search.

CDC (2018) Recommendation 6

Health care professionals should not use biomarkers outside of a research setting for the diagnosis of children with mTBI.

5.14.4 Source evidence

5.14.4.1 NICE CG176 (2014)

Three diagnostic accuracy of biomarker studies identifying intracranial injury in children were identified: two for S100B (Table 5.14.1) and one for NSE (Table 5.14.2). For comparison, the data for adults was also reported in these tables. For the GFAP biomarker, only one study was identified, and despite not reporting for children, the adult outcomes of intracranial injury and need for neurosurgery are reproduced here (Table 5.14.3).

Table 5.14.1 NICE CG176 (2014) clinical evidence for diagnostic accuracy of S100B for intracranial injury

Intracranial injury Population	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (e)	Specificity % (e)	PPV %	NPV %	Quality
Adults *See table note for Ref IDs*	11	Diagnostic	4264	Serious limitations (a)	Serious inconsistency (b)	No serious indirectness	Serious imprecision (c)	374	2929	8	1097	83–100	20–57	9–54	89–100	Very low quality
Children *See table note for Ref IDs*	2	Diagnostic	174	Serious limitations (d)	No serious inconsistency	No serious indirectness	No serious imprecision	59	70	0	45	100	33–42	45–46	100	Moderate quality

(a) In 3 studies, patients selected rather than included consecutively or randomly, therefore there is patient selection bias.
(b) Inconsistency in the index test across the studies (measured S100B in serum or plasma, several different reference cut-off points used, different technical equipment used in laboratories and different mean times from trauma to sampling and from sampling to measurement in the laboratory) has led to heterogeneity of the sensitivity and specificity point estimates, as demonstrated on the ROC curve.
(c) The wide range of confidence intervals around the sensitivity and specificities in the studies increases the uncertainty of the actual diagnostic accuracy.
(d) Patients selected rather than included consecutively or randomly, therefore there is patient selection bias.
(e) Relates to a sensitivity or specificity for a single study or a range of sensitivities or specificities when more than 1 study.

Source: NICE 2014 G CG176 Guideline Table 14 (p132).
Reference IDs: Eleven adult studies: 22–24, 40, 44, 77 ,173, 175, 177, 210, 290. Two studies in children: 43, 44. Study reference numbers refer to reference list in NICE CG176 (2014)

Table 5.14.2 NICE CG176 (2014) clinical evidence for diagnostic accuracy of NSE for intracranial injury

Intracranial injury Population	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (b)	Specificity % (b)	PPV %	NPV %	Quality
Adults [177]	1	Diagnostic	139	No serious limitation	No serious inconsistency	No serious indirectness	No serious imprecision	32	100	0	7	100	7	24	100	High quality
Children [91]	1	Diagnostic	49	Serious limitations (a)	No serious inconsistency	No serious indirectness	No serious imprecision	17	13	5	14	77	52	57	74	Moderate quality

(a) Method of patient selection is not reported, therefore there is a potential patient selection bias.
(b) Relates to a sensitivity or specificity for a single study or a range of sensitivities or specificities when more than 1 study.

Source: NICE CG176 (2014) Table 15 (p132).
Note: Study reference numbers refer to reference list in NICE CG176 (2014).

Table 5.14.3 NICE CG176 (2014) clinical evidence for diagnostic accuracy of GFAP for intracranial injury and need for neurosurgery

Adults Outcome	No of studies	Design	n	Limitations	Inconsistency	Indirectness	Imprecision	TP	FP	FN	TN	Sensitivity % (b)	Specificity % (b)	PPV %	NPV %	Quality
Intracranial injury [203]	1	Diagnostic	117	Very serious limitations (a)	No serious inconsistency	No serious indirectness	No serious imprecision	31	70	1	15	97	18	31	94	Low quality
Need for neurosurgery [203]	1	Diagnostic	117	Very serious limitations (a)	No serious inconsistency	No serious indirectness	No serious imprecision	14	60	0	43	100	42	19	100	Low quality

(a) Potential patient selection bias through a convenience sample rather than consecutive randomised patient selection. The study also added an additional 9 patients from the control group into the analysis who received a CT scan based on clinician judgement.
(b) Relates to a sensitivity or specificity for a single study or a range of sensitivities or specificities when more than 1 study.

Source: NICE CG176 (2014) Table 16 (p133).
Note: Study reference numbers refer to reference list in NICE CG176 (2014).

5.14.4.2 NICE surveillance (2017)

The NICE surveillance (2017) report provided the following synopses of four studies in children and 12 studies in adults (all studies are reproduced in Table 5.14.4 for the purpose of comparison). Guidance was not developed based on these additional studies.

Table 5.14.4 Subsequent evidence from NICE surveillance (2017) for biomarkers to select patients for CT

#	Original study citation	NICE surveillance (2017) evidence for biomarkers for selection of head injury patients for CT
Biomarkers in children		
1	Papa L, Zonfrillo MR, Ramirez J et al. (2015) Performance of Glial Fibrillary Acidic Protein in Detecting Traumatic Intracranial Lesions on Computed Tomography in Children and Youth with Mild Head Trauma. Academic Emergency Medicine 22:1274–1282.	A prospective cohort study included 197 children and young people with blunt head trauma and 60 controls with traumatic injury without head trauma who had blood samples obtained within 6 hours of injury. Head CT was performed in 152 children and showed traumatic intracranial lesions in 11%. Median GFAP levels were significantly higher in children with intracranial lesions than those without lesions. The AUC was 0.82 for GFAP detecting traumatic intracranial lesions on CT, and was similar for children presenting with GCS of 15 and in those aged under 5 years. At a cut-off of 0.15 ng/ml, GFAP had sensitivity of 94%, specificity of 47%, and a negative predictive value of 98%.
2	Papa L, Mittal MK, Ramirez J et al. (2016) In Children and Youth with Mild and Moderate Traumatic Brain Injury, Glial Fibrillary Acidic Protein Out-Performs S100beta in Detecting Traumatic Intracranial Lesions on Computed Tomography. Journal of Neurotrauma 33:58–64.	A prospective cohort study included 114 children with head trauma and 41 with trauma without head injury. Of 92 patients who had head CT, 9% had intracranial lesions. The AUC for distinguishing head trauma from no head trauma was 0.84 for GFAP and 0.64 for S100B. The AUC for predicting intracranial lesions on CT was 0.85 for GFAP and 0.67 for S100B. The AUC for predicting intracranial lesions in children ages 10 years or younger was 0.96 for GFAP and 0.72 for S100B. In children younger than 5 years old, the AUC was 1.00 for GFAP and 0.62 for S100B.
3	Simon-Pimmel J, Lorton F, Guiziou N et al. (2015) Serum S100beta Neuroprotein Reduces Use of Cranial Computed Tomography in Children After Minor Head Trauma. Shock 44:410–416.	An analysis assessing PECARN plus S100B included 109 children with minor head trauma, 8% of whom had clinically important intracranial injury. The modified PECARN rule, which accounted for S100B results could have avoided 32 unnecessary CTs. S100B was negative in 4 children who were at high risk of head injury according to PECARN, but would not have been missed by the combined method.
4	Manzano S, Holzinger IB, Kellenberger CJ et al. (2016) Diagnostic performance of S100B protein serum measurement in detecting intracranial injury in children with mild head trauma. Emergency Medicine Journal 33:42–46.	A prospective cohort study assessed S100B for detecting brain injury in 73 children younger than 16 years who underwent CT. Blood was obtained within 6 hours of trauma. Overall, 27.4% of the children had intracranial injury detected by CT. S100B had an AUC of 0.73. At a cut-off of 0.14 micrograms/l, S100B had sensitivity of 95% and specificity of 34% in all children and sensitivity of 100% and specificity of 37% in children aged older than 2 years.
S100B		
5	Heidari K, Vafaee A, Rastekenari AM et al. (2015) S100B protein as a screening tool for computed tomography findings after mild traumatic brain injury: Systematic review and meta-analysis. Brain Injury 29:1146–1157.	A systematic review of 22 studies evaluated S100B screening in people with mild traumatic brain injury who underwent CT. The number of participants in the included studies was not reported in the abstract. S100B concentration was significantly associated with positive findings on CT. There was a significant positive association between S100B protein concentration and positive CT scan (22 studies, SMD = 1.92, 95% CI = 1.29–2.45, I^2 = 100%; $p < 0.001$). A cut-point range of 0.16–0.20 micrograms/l had sensitivity of 98.65% and specificity of 50.69%, respectively. A threshold of S100B greater than 0.20 micrograms/l had sensitivity of 99.63% and specificity of 46.94%.
6	Bazarian JJ, Blyth BJ, He H et al. (2013) Classification accuracy of serum Apo A-I and S100B for the diagnosis of mild traumatic brain injury and prediction of abnormal initial head computed tomography scan. Journal of Neurotrauma 30:1747–1754.	A prospective study included 787 people with mild traumatic brain injury presenting within 6 hours of injury and 467 controls without head injury who had routine blood tests. Serum was analysed for S100B and apolipoprotein (apoA-I). Control blood values were used to define cut-offs. • S100B had sensitivity of 25.2% and specificity of 89.9% • AopA-I had sensitivity of 24.9% and specificity of 90.2%. The area under the curve for both tests combined was significantly higher than for either test alone. The AUC for prediction of abnormal initial head CT scan using S100B was 69.4% and was not significant for apoA-I. At a cut-off of <0.060 micrograms/l, the sensitivity for abnormal head CT was 98%, and 22.9% of CT scans could have been avoided. There was significant variation in the accuracy of S100B with age and race

7	Welch RD, Ayaz S, I, Lewis LM et al. (2016) Ability of serum glial fibrillary acidic protein, ubiquitin C-Terminal Hydrolase-L1, and S100B to differentiate normal and abnormal head computed tomography findings in patients with suspected mild or moderate traumatic brain injury. Journal of Neurotrauma 33:203–214.	A prospective study included 251 people with suspected mild to moderate brain injury, of whom 14.3% had positive CT findings. Blood samples were obtained within 6 hours of injury and were tested for S100B, GFAP and UCHL-1. For discriminating between positive and negative CT findings: • S100B had an AUC of 0.75. Sensitivity of 100% was seen at a cut-off of 30 pg/ml (0.03 micrograms/l), with specificity of 2%. • GFAP had an AUC of 0.79. Sensitivity of 100% was seen at a cut-off of 0 pg/ml (0.00 micrograms/l), with specificity of 0%. • UCHL-1 had an AUC of 0.80. Sensitivity of 100% was seen at a cut-off of 40 pg/ml (0.40 micrograms/l), with specificity of 39%.
8	Wolf H, Frantal S, Pajenda G et al. (2015) Analysis of S100 calcium binding protein B serum levels in different types of traumatic intracranial lesions. Journal of Neurotrauma 32:23–27.	A prospective cohort study included 1,696 people with head trauma who had blood samples taken before CT, and within 3 hours of injury. Patients' injuries were classified as: concussion, epidural haematoma, subdural haematoma, subarachnoid haemorrhage, brain contusions and brain oedema. Overall 8% of patients had traumatic lesions on CT. S100B levels were significantly higher. Cerebral oedema was associated with significantly higher S100B levels than the other types of injury. Significantly higher S100B levels were seen with 3 simultaneous lesions than with 1 or 2 lesions. Additionally, the presence of skull or facial fractures was also associated with significantly higher S100B levels.
9	Laribi S, Kansao J, Borderie D et al. (2014) S100B blood level measurement to exclude cerebral lesions after minor head injury: the multicenter STIC-S100 French study. Clinical Chemistry & Laboratory Medicine 52:527–536.	A validation study included 4,030 people with mild head injury who had S100B levels measured immediately and again 3 hours after injury, compared with CT findings within 6 hours of injury. Two different assays were tested. Cerebral lesions on CT scan were identified with sensitivity 96.3% and negative-predictive value of 99.4% using the Diasorin assay, with 1 incorrect result. The Roche Diagnostics assay had sensitivity of 100% and negative predictive value of 100%, with no incorrect results. S100B reduced rapidly, leading to lower sensitivity and negative predictive value at 3 hours.
10	Thelin EP, Nelson DW, and Bellander BM. (2014) Secondary peaks of S100B in serum relate to subsequent radiological pathology in traumatic brain injury. Neurocritical Care 20:217–229.	A retrospective study included 250 people with traumatic brain injury who had at least 2 radiological investigations and at least 3 blood tests for S100B, with at least one test more than 48 hours after injury. New pathological findings were seen on second imaging in 39% of the sample. And this was highly correlated with increased in S100B of more than 0.05 micrograms/l. A secondary increase of more than 0.05 micrograms/l had sensitivity of 80% and lower specificity of 89%, compared with a secondary increase of more than 0.5 micrograms/l had sensitivity of 16%, and specificity of 98%, to detect secondary radiological findings. The secondary radiological findings were also significantly correlated with outcome.
11	Thaler HW, Schmidsfeld J, Pusch M et al. (2015) Evaluation of S100B in the diagnosis of suspected intracranial hemorrhage after minor head injury in patients who are receiving platelet aggregation inhibitors and in patients 65 years of age and older. Journal of Neurosurgery 123:1202–1208.	A prospective observational study included 782 people with mild head injury who were aged older than 65 years or were taking clopidogrel or low-dose aspirin at the time of injury. Blood samples were taken within 3 hours of trauma. Overall, 6.4% of patients had intracranial bleeding. One patient with positive CT results had an S100B level below 0.105 micrograms/l. Of all patients, 33.1% had S100B values below the cut-off. S100B had sensitivity of 98.0%, specificity of 35.3%, positive predictive value of 9.4%, and negative predictive value of 99.6%.
12	Papa L, Silvestri S, Brophy GM et al. (2014) GFAP out-performs S100beta in detecting traumatic intracranial lesions on computed tomography in trauma patients with mild traumatic brain injury and those with extracranial lesions. Journal of Neurotrauma 31:1815–1822.	A prospective cohort study included 209 people with mild or moderate traumatic brain injury and 188 people with trauma without brain injury. Blood samples were obtained within 4 hours of injury and tested for S100B and GFAP. Of 262 people who had head CT, intracranial lesions were seen in 8%. Extracranial fractures were seen in 35% of the general trauma patients. Levels of S100B were significantly higher in patients with fractures, compared with those without fractures whether or not traumatic brain injury was present. However, GFAP levels were not significantly affected by the presence of fractures. The AUC for predicting intracranial lesions on CT was 0.84 for GFAP and was 0.78 for S100B. However, in the presence of extracranial fractures, the AUC increased to 0.93 for GFAP and decreased to 0.75 for S100B.
13	Linsenmaier U, Wirth S, Kanz KG et al. (2016) Imaging minor head injury (MHI) in emergency radiology: MRI highlights additional intracranial findings after measurement of trauma biomarker S-100B in patients with normal CCT. British Journal of Radiology 89:20150827.	An analysis included 41 people with minor head injury who had CT, MRI, and S100B testing. MRI detected 10 more lesions than CT. At a cut-off of 1.0 micrograms/l, S100B had sensitivity of 100% and specificity of 25%. Structural brain lesions were associated with significantly higher S100B levels.
Other biomarkers		
14	Diaz-Arrastia R, Wang KK, Papa L et al. (2014) Acute biomarkers of traumatic brain injury: relationship between plasma levels of ubiquitin C-terminal hydrolase-L1 and glial fibrillary acidic protein. Journal of Neurotrauma 31:19–25.	An observational study included 206 people with traumatic brain injury who had blood tests for ubiquitin C-terminal hydrolase L1 (UCHL-1) and glial fibrillary acidic protein (GFAP). Correlation between the 2 biomarkers was weak. UCH-L1 had an AUC of 0.87 and GFAP had an AUC of 0.91 for discriminating between people with traumatic brain injury and healthy controls. The combined use of both biomarkers had an AUC of 0.94. Both biomarkers discriminated between patients with traumatic intracranial lesions on CT and those without such lesions, but GFAP was significantly more sensitive and specific (AUC 0.88 compared with 0.71 for UCH-L1). Neither biomarker had adequate sensitivity and specificity for predicting outcome 3 months after injury.

15	Li J, Yu C, Sun Y et al. (2015) Serum ubiquitin C-terminal hydrolase L1 as a biomarker for traumatic brain injury: a systematic review and meta-analysis. American Journal of Emergency Medicine 33:1191–1196.	A systematic review and meta-analysis of 5 observational studies (673 case of traumatic brain injury and 1,004 matched controls) assessed UCHL-1 for detecting traumatic brain injury. Serum UCHL-1 was significantly increased in patients with traumatic brain injury compared with controls.
16	Okonkwo DO, Yue JK, Puccio AM et al. (2013) GFAP-BDP as an acute diagnostic marker in traumatic brain injury: results from the prospective transforming research and clinical knowledge in traumatic brain injury study. Journal of Neurotrauma 30:1490–1497.	An analysis of data from the TRACK-TBI study included 215 people with traumatic head injury who underwent CT and had testing for GFAP and breakdown products. Of this cohort, 83% had mild, 4% had moderate and 13% had severe traumatic brain injury, with 54% showing acute traumatic lesions on CT. The AUC was 0.88 for GFAP breakdown product levels identifying patients with traumatic lesions on CT and the optimum cut-off of was 0.68 ng/ml. The AUC was 0.65 for identifying unfavourable outcome at 6 months.
Topic expert feedback		
Topic expert feedback suggested that the use of biomarkers was of clinical interest.		
Impact statement		
Evidence identified in surveillance is consistent with that assessed by the Guideline in finding that biomarkers such as S100B, GFAP, and UCHL-1 generally have high sensitivity but low specificity. The evidence identified in surveillance also has similar limitations to the evidence evaluated during Guideline development including: – differences in the time from injury to blood sampling – the time from blood sampling to laboratory measurement is unclear in the abstracts – technical specifications of equipment used to measure the levels of biomarkers within blood may differ between studies – the reference cut-off for normal levels of individual biomarkers differs between studies. Additionally, evidence suggests that defining cut-offs may be problematic. For example, age, race and presence of bone fractures had important effects on serum levels of S100B. Avoiding unnecessary CT is particularly important in children, and evidence for biomarkers in children was also identified. However, this consists of small observational studies and concerns about the limitations of the evidence on adults also applies to the evidence in children. Overall, the evidence base does not seem to have developed sufficiently since the Guideline was published to warrant an update in this area.		
New evidence is unlikely to change Guideline recommendations.		

Source: NICE surveillance (2017) reports, Appendix A (pp25–27)

5.14.5 New evidence

Twelve new studies relevant to this question were identified in the PREDICT Guideline literature search. None were selected as key studies.

Table 5.14.5 New evidence identified for imaging Q14

Ref #	Citation
139.	Asadollahi S, Heidari K, Taghizadeh M, Seidabadi AM, Jamshidian M, Vafaee A, et al. Reducing head computed tomography after mild traumatic brain injury: Screening value of clinical findings and S100B protein levels. Brain Injury. 2016;30(2):172–8.
140.	Atif H, Hicks SD. A Review of MicroRNA Biomarkers in Traumatic Brain Injury. Journal of Experimental Neuroscience. 2019; 13:1.18E+5.
133.	Berger RP, Pak BJ, Kolesnikova MD, Fromkin J, Saladino R, Herman BE, et al. Derivation and Validation of a Serum Biomarker Panel to Identify Infants with Acute Intracranial Hemorrhage. JAMA Pediatrics. 2017;171(6): e170429.
134.	Bucker J, Fries GR, Kapczinski F, Post RM, Yatham LN, Vianna P, et al. Brain-derived neurotrophic factor and inflammatory markers in school-aged children with early trauma. Acta Psychiatrica Scandinavica. 2015;131(5):360–8.
135.	Cheng Y, Pereira M, Raukar N, Reagan JL, Queseneberry M, Goldberg L, et al. Potential biomarkers to detect traumatic brain injury by the profiling of salivary extracellular vesicles. Journal of Cellular Physiology. 2019;234(8):14377–88.
141.	Delefortrie Q, Lejeune F, Kerzmann B, Levy R, Adam JF, Sottiaux T, et al. Evaluation of the Roche Elecsys and the Diasorin Liaison S100 kits in the management of mild head injury in the emergency room. Clinical Biochemistry. 2018; 52:123–30.
136.	Ercole A, Thelin EP, Holst A, Bellander BM, Nelson DW. Kinetic modelling of serum S100b after traumatic brain injury. BMC Neurology. 2016; 16:93.
142.	Fiandaca MS, Mapstone M, Mahmoodi A, Gross T, Macciardi F, Cheema AK, et al. Plasma metabolomic biomarkers accurately classify acute mild traumatic brain injury from controls. PLoS ONE [Electronic Resource]. 2018;13(4):e0195318.
143.	Heidari K, Vafaee A, Rastekenari AM, Taghizadeh M, Shad EG, Eley R, et al. S100B protein as a screening tool for computed tomography findings after mild traumatic brain injury: Systematic review and meta-analysis. Brain Injury. 2015;29(10):1146–57.
144.	Hicks SD, Johnson J, Carney MC, Bramley H, Olympia RP, Loeffert AC, et al. Overlapping microRNA expression in saliva and cerebrospinal fluid accurately identifies pediatric traumatic brain injury. Journal of Neurotrauma. 2018;35(1):64–72.
145.	Joseph JR, Swallow JS, Willsey K, Lapointe AP, Khalatbari S, Korley FK, et al. Elevated markers of brain injury as a result of clinically asymptomatic high-acceleration head impacts in high-school football athletes. Journal of Neurosurgery. 2019;130(5):1642–8.
137.	Kelmendi FM, Morina AA, Mekaj AY, Blyta A, Alimehmeti R, Dragusha S, et al. Serum S100B Levels Can Predict Computed Tomography Findings in Paediatric Patients with Mild Head Injury. Biomed Research International. 2018;6954045.

Ref #	Citation
138.	Wang KK, Yang Z, Zhu T, Shi Y, Rubenstein R, Tyndall JA, et al. An update on diagnostic and prognostic biomarkers for traumatic brain injury. Expert Review of Molecular Diagnostics. 2018;18(2):165–80.

Shading indicates key studies.

5.14.5.1 Rationale for selection of key evidence

None of the 12 identified studies were selected as key evidence for this question. The quality of evidence was low due to setting and sample size and mixed adult/paediatric population limitations. Of nine potentially key studies, three evaluated the SB100 biomarker, two evaluated MicroRNAs and the remaining examined candidate biomarkers/panels.

5.14.5.2 Key evidence data extraction

N/A

5.14.6 Key considerations for assessing the evidence

5.14.6.1 Excerpt from NICE CG176

No clinical recommendations were made regarding biomarkers for selecting patients with head trauma for CT in the NICE CG176 (2014) Guideline. The Guideline Development Group included the following in their deliberations about the potential of biomarkers (NICE CG176 (2014) p135):

> *After consideration of the evidence the GDG felt that it was not appropriate to make a recommendation, as the data for many of these biomarkers is limited. One exception is S100B, which was the subject of a recent systematic review,169 and has been studied in nearly 1000 patients in over 25 studies. Many of these studies were based in the ICU and involved patients with moderate or severe head injury, thus limiting relevance and applicability to the issue of initial patient management in the full spectrum of TBI, which is the focus of these guidelines. The review concluded that S100B measurements could have a significant role in predicting prognosis in moderate and severe TBI, and potentially excluding significant intracranial injury in mild TBI. However, like the authors of the review, the GDG felt that further evidence was needed before firm recommendations could be made on the use of this biomarker, further information was needed on the confounds produced by extracranial injury, optimal sampling time point, sample processing protocols, assay techniques, and clear thresholds for outcome prediction. The GDG considered that the low numbers of false negatives was potentially promising, but concluded that there was insufficient evidence on the use of S100B in particular, and circulating biomarkers in general, to enable firm recommendations to be made concerning their use as part of a clinical decision rule or as a standalone means of triage or prognosis. Any recommendation for use of such markers may need to be specific to the severity of TBI and the aim of the analysis: for example, early (< 3 hour) S100B levels may provide indication of the presence of significant brain injury, but later S100B elevation in moderate or severe TBI may provide evidence of secondary neuronal injury, and require multiple assays and determination of peak levels as a prognostic marker. The GDG noted some significant obstacles to using biomarkers in some contexts. For example, one recommended cut off for interpreting S100B assays is three hours post-injury. If this proves to be the case, the challenge will be to ensure that the test is readily available, provides a quick result and is interpretable by staff in the emergency department. It is also important to understand that the normal levels of circulating biomarkers alter as the nervous system matures and therefore diagnostic cut off concentrations will vary between children and adults. Before significant NHS resources are targeted in this area, it is important to confirm that biomarkers are sufficiently accurate*

indicators of significant brain injury and intracranial bleeding to allow use in routine clinical practice.

And other considerations included the following (NICE CG176 (2014) p136)):

The GDG noted that UCHL-1 was an additional biomarker where evidence is published, however this is not included within the scope of this Guideline and therefore not prioritised for review.

A number of UCHL-1 studies were identified and included in the NICE surveillance (2017) report, as listed above in Table 5.14.4.

5.14.7 Working Group recommendation deliberations

Table 5.14.6 Clinical judgement form for imaging Q14

PREDICT Guideline imaging Q14	**In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo biomarker testing prior to a cranial CT?**
Source recommendation/s	
CDC (2018) US 1 recommendation: Rec 6	**CDC (2018) Recommendation 6** Health care professionals should not use biomarkers outside of a research setting for the diagnosis of children with mTBI
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? CDC (2018) ☒ Adopt source guidance ☐ Adapt source guidance ☐ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☐ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☒ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 23	In infants and children with mild to moderate head injury, presenting to an acute care setting, healthcare professionals should not use biomarkers to diagnose or determine the risk of intracranial injury outside of a research setting.

PREDICT Guideline imaging Q14	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and/or clinical decision rule(s) that best determine who should undergo biomarker testing prior to a cranial CT?

Rationale

The PREDICT GWG **adopted evidence-informed recommendation** 6 from the CDC Guideline and the relevant supporting evidence from the NICE CG176 Guideline (no recommendation was provided by NICE.) The PREDICT literature search identified 12 new studies for this question, however none were selected as key studies as they were limited by disparate diagnostic biomarker selection and small paediatric sample sizes, and none established biomarkers as superior to existing diagnostic algorithms.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

5.15 Imaging Q15 – In infants and children with mild to moderate head injury presenting within 72 hours of injury who undergo a cranial CT scan, what are the i) appropriate CT protocols/techniques and/or ii) to what extent should the cervical spine be included in the imaging?

5.15.1 PREDICT question

PREDICT Guideline imaging Q15

In infants and children with mild to moderate head injury presenting within 72 hours of injury who undergo a cranial CT scan, what are the i) appropriate CT protocols/techniques and/or ii) to what extent should the cervical spine be included in the imaging?

5.15.2 Source question

There is no corresponding clinical question in the source guidelines.

5.15.3 Source recommendations

None.

5.15.4 Source evidence

None.

5.15.5 New evidence

Twelve studies relevant to this question were identified in the PREDICT Guideline literature search (Table 5.15.1). Of these, nine are key studies.

Table 5.15.1 New evidence identified for imaging Q15

Ref #	Citation
25.	Andrade FP, Montoro RN, Oliveira R, Loures G, Flessak L, Gross R, et al. Pediatric minor head trauma: do cranial CT scans change the therapeutic approach? Clinics (Sao Paulo, Brazil). 2016;71(10):606–10.
26.	Arneitz C, Sinzig M, Achatz E, Fasching G. Can a CT be Omitted in Pediatric Minor Head Trauma? Journal of Pediatric Neurology. 2018;16(1):43647.

Ref #	Citation
93.	Culotta PA, Crowe JE, Tran QA, Jones JY, Mehollin-Ray AR, Tran HB, et al. Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Pediatric Radiology. 2017;47(1):74–81.
146.	Dundamadappa SK, Thangasamy S, Resteghini N, Vedantham S, Chen A, Takhtani D. Skull fractures in pediatric patients on computerized tomogram: comparison between routing bone window images and 3D volume-rendered images. Emergency Radiology. 2015;22(4):367–72.
151.	Kaul D, Kahn J, Huizing L, Wiener E, Boning G, Renz DM, et al. Dose reduction in paediatric cranial CT via iterative reconstruction: a clinical study in 78 patients. Clinical Radiology. 2016;71(11):1168–77.
152.	Kim HG, Choi JW, Yoon SH, Lee S. Image quality assessment of silent T<inf> 2</inf> Propeller sequence for brain imaging in infants. British Journal of Radiology. 2018;91 (1083) (20170680).
153.	Maetani K, Namiki J, Matsumoto S, Matsunami K, Narumi A, Tsuneyoshi T, et al. Routine Head Computed Tomography for Patients in the Emergency Room with Trauma Requires Both Thick- and Thin-Slice Images. Emergency Medicine International. 2016;2016 (5781790).
147.	Meltzer JA, Stone ME, Jr., Reddy SH, Silver EJ. Association of Whole-Body Computed Tomography with Mortality Risk in Children with Blunt Trauma. JAMA Pediatrics. 2018;172(6):542–9.
154.	Nabaweesi R, Ramakrishnaiah RH, Aitken ME, Rettiganti MR, Luo C, Maxson RT, et al. Injured Children Receive Twice the Radiation Dose at Nonpediatric Trauma Centers Compared with Pediatric Trauma Centers. Journal of the American College of Radiology. 2018;15 (1 Pt A):58–64.
148.	Niiniviita H, Kiljunen T, Huuskonen M, Teperi S, Kulmala J. Dose monitoring in pediatric and young adult head and cervical spine CT studies at two emergency duty departments. Emergency Radiology. 2018;25(2):153–9.
149.	Orman G, Wagner MW, Seeburg D, Zamora CA, Oshmyansky A, Tekes A, et al. Pediatric skull fracture diagnosis: should 3D CT reconstructions be added as routine imaging? Journal of Neurosurgery Pediatrics. 2015;16(4):426–31.
150.	Southard RN, Bardo DME, Temkit MH, Thorkelson MA, Augustyn RA, Martinot CA. Comparison of Iterative Model Reconstruction versus Filtered Back-Projection in Pediatric Emergency Head CT: Dose, Image Quality, and Image-Reconstruction Times. AJNR: American Journal of Neuroradiology. 2019;40(5):866–71.

Shading indicates key studies.

5.15.5.1 Rationale for selection of key evidence

Nine of the 12 new studies were selected as key evidence for this question based on the following rationale: they compared fracture detection rates using thin and thick slice and 3D CT image reconstruction techniques (70, 86-88) and evaluated variation in patient exposures during head CT at non paediatric hospitals (89, 90) as well as techniques to optimize radiation exposures (91-93). No studies relating to the detection rate of cervical spine fractures in children who had head CT for head trauma were identified in our search. Therefore, we were unable to make a recommendation supporting the routine extension of head CT to include the cervical spine.

10.15.5.2 Key evidence data extraction

Table 5.15.2 Data from key evidence for imaging Q15

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Culotta PA**, Crowe JE, Tran QA, et al. Performance of computed tomography of the head to evaluate for skull fractures in infants with suspected non-accidental trauma. Paediatric Radiology. 2017;47(1):74–81. **Aim** A cross-sectional study of infants evaluated for abusive head trauma via both skull radiographs and CT with 3-D reconstruction. **Setting** Two level I trauma centres in Houston, TX **Type** Retrospective, 2013–14	**Sample Size** 177 **Characteristics** 47% female; mean/median age: 5 months **Inclusion** Infants (<1-year-old) in whom both skeletal surveys and CT of the head were obtained to evaluate for non-accidental trauma.	The reference standard was skull radiography. Studies were read by paediatric radiologists and neuroradiologists**,** with ten percent read by a second radiologist to evaluate for interobserver reliability.	**Skull series** of the skeletal survey included two views (AP/Lateral) **CT images** of the head were helically acquired from the craniocervical junction through the calvarial vertex with an Aquilion ONE™ 320 Toshiba utilizing a detector collimation of 0.5 and a pitch of 0.84. The remainder of the CT images were obtained using a GE LightSpeed VCT 64 slice machine through which an axial mode was used. Standard images included axial images (5-mm slices); coronal (1.3-mm slices) and sagittal (3-mm slices) images were reconstructed from the axial images. **Three-dimensional reconstructions** were obtained as the standard of care.	62 (35%) children had skull fractures identified on skull radiographs and 67 (38%) by CT (p = 0.18). No differences between the radiographic findings and 3- D CT scan results among all patients and the three age groups using non-parametric testing for matched data. **CT with 3-D reconstruction** was 97% sensitive (CI, 89–100%) and 94% specific (CI: 87–97%) for skull fracture.	**Limitations** Retrospective study. Potential for selection bias. Studies read by subspecialty radiologists. **Conclusion** In cases where there is a concern for head trauma and clinicians require CT scans to adequately access intracranial injury, skull radiographs should be eliminated from the medical work-up.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Dundamadappa SK**, Thangasamy S, Resteghini N. Skull fractures in pediatric patients on computerized tomogram: comparison between routing bone window images and 3D volume-rendered images. Emerg Radiol. 2015;22(4):367-372. **Aim** Compare the sensitivity and specificity of RBW and 3DV images in detection of calvarial fractures in paediatric patients. **Setting** Radiology **Type** Retrospective	**Sample Size** 60 cases **Characteristics** 22 with fractures and 38 without **Inclusion** <17 years old Presented to ED with history of trauma Head CT in ED Repeat head CT within 5 days **Exclusion** Skull base of facial fracture without calvarial fractures	Comparing routing bone window and 3D volume rendered images for detecting and characterizing fractures.	Fractures identified as per inclusion criteria. Multi-reader, multi-case paired study. **Reference standard:** Two experienced neuroradiologists performed a consensus read after completion of study.	**Sensitivity** did not statistically differ between RBW and 3DV interpretations ($p > 0.317$), **Specificity** did not statistically differ between RBW and 3DV interpretations ($p > 0.317$), 3DV is more time efficient. In one of our cases, although the adjacent fracture was identified, the squamosal sutural diastasis was missed on RBW by all the three readers.	**Limitations** Coronal and sagittal reformats were not used when evaluating for fractures in this study. Size of study. **Study conclusions** 3DV images should be part of routine head trauma imaging, especially in the paediatric age group. It requires minimal post-processing time and no additional radiation. Furthermore, 3DV images help in reducing the interpretation time and also enhance the ability of the radiologist to characterize the calvarial fractures.
Citation **Kaul** D, Kahn J, Huizing L. Dose reduction in paediatric cranial CT via iterative reconstruction: a clinical study in 78 patients. Clinical Radiology 2016;71(11):1168-1177 **Aim** Assess how adaptive statistical iterative reconstruction (ASIR) contributes to dose reduction and affects image quality of non-contrast cranial computed tomography (cCT) **Setting** Radiology **Type** Prospective	**Sample Size** 78 patients **Characteristics** 39.7% referred after head injury 16.7% referred after seizures 15.4% referred following cranial operational procedure 7.7% referred due to loss of consciousness 5.1% after extracranial malignoma 3.8% due to cranial malformation 11.5% for other reasons. **Inclusion** 0–12 years Underwent cranial CT following acute events: trauma, loss of consciousness, seizure or focal neurological deficit.	Compare ASIR to dose reduction in terms of image quality of non-contrast cranial cCT.	The images were acquired and processed using four different protocols: Group A (control): 120 kV, filtered back projection (FBP), n = 18; Group B: 100 kV, FBP, n = 22; Group C: 100 kV, scan and reconstruction performed with 20% ASIR, n = 20; Group D1: 100 kV, scan and reconstruction performed with 30% ASIR, n = 18; Group D2: raw data from Group D1 reconstructed using a blending of 40% ASIR and 60% FBP, n = 18. The effective dose was calculated and the image quality was assessed quantitatively and qualitatively.	Compared to Group A, Groups C and D1/D2 showed a significant reduction of the dose–length product (DLP) by 34.4% and 64.4%, respectively. All experimental groups also showed significantly reduced qualitative levels of noise, contrast, and overall diagnosability. Diagnosis-related confidence grading showed Group C to be adequate for everyday clinical practice. Quantitative measures of Groups B and C were comparable to Group A with only few parameters compromised. Quantitative scores in Groups D1 and D2 were mainly lower compared to Group A, with Group D2 performing better than Group D1. Group D2 was considered adequate for follow-up imaging of severe acute events such as bleeding or hydrocephalus.	**Limitations** No explicit patient group matching was performed and there were differences in patient ages between Groups B/C and Group A **Study conclusions** ASIR and low kV reduce radiation while maintaining adequate image quality in paediatric cCT. The use of 100 kV and 20% ASIR is adequate for everyday clinical practice. The use of 100 kV and 30% ASIR (blending 40%/60%) is adequate for follow-up imaging.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Maetani K**, Namiki J, Matsumoto S, . Routine Head Computed Tomography for Patients in the Emergency Room with Trauma Requires Both Thick- and Thin-Slice Images. Emergency Medicine International.2016 **Aim** Investigated the diagnostic sensitivity of a head CT, where axial images were 10 mm thick slices, in cases of linear skull fractures **Setting** Radiology **Type** Retrospective	**Sample Size** 410 patients **Characteristics** 459 linear fractures in 410 patients 47 had two linear fracture lines One had 3 fracture lines 90 cases had depressed skull fracture **Inclusion** Patients admitted to ED All with linear skull fractures diagnosed with X-ray or head CT sliced axially with a thickness of sequential 10 mm **Exclusion**	Compare diagnostic sensitivity of head CT to skull X-rays for detecting linear fracture.	Historical database as per inclusion criteria. A skull fracture was diagnosed by board-certified neurosurgeons or consultant diagnostic radiologists, based on either the head CT or the skull X-rays.	For detecting linear fracture **Sensitivity** CT: 89% versus skull X-rays: 91% 56% for horizontal fractures vs 93% in X-ray CT technique with 10 mm slices missed 6% of patients with linear skull fractures. False-negative diagnoses were significantly more frequent for older (≥55 years) than for young (<15 years) individuals (p = 0.048).	**Limitations** Our data could not clarify why the CT sensitivity for a linear fracture was different for patients of different age groups. **Study conclusions** A routine head CT of the supratentorial region for patients in the ER with head injuries requires both thick-slice images to visualize cerebral hemispheres and thin-slice images to detect skull fractures of the cranial vault.
Citation **Meltzer JA**, Stone ME, Jr., Reddy SH. Association of Whole-Body Computed Tomography with Mortality Risk in Children with Blunt Trauma. JAMA Pediatr. 2018;172(6):542-549. **Aim** To determine whether emergent WBCT is associated with lower mortality among children with blunt trauma compared with a selective CT approach. **Setting** Radiology **Type** A retrospective, multicentre cohort study.	**Sample Size** 42912 children **Characteristics** Median age [interquartile range], 9 [5–12] years; 27 861 [64.9%] boys), 8757 (20.4%) **Inclusion** Aged 6 months-14 years Emergent CT in first 2 hours of ED arrival Sustained blunt trauma **Exclusion** Transferred to or from another facility Time of death or hospital discharge not recorded	Compared patients who received WBCT and selective CT in terms of in-hospital mortality in the 7 days after ED arrival.	Patients were classified as having WBCT if they received CT head, CT chest, and CT abdomen/pelvis scans in the first 2 hours and as having a selective CT if they did not receive all 3 scans.	405 (0.9%) children died within 7 days from ED arrival. No significant difference in mortality compared with those who received selective CT (absolute risk difference, −0.2%; 95% CI, −0.6% to 0.1%).	**Limitations** Investigated only mortality and LOS outcomes, and perhaps WBCT may have other benefits that would be helpful to the care of injured children, such as identifying non-lethal occult injuries. **Study conclusions** Among children with blunt trauma, WBCT, compared with a selective CT approach, was not associated with lower mortality. These findings do not support the routine use of WBCT for children with blunt trauma.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Nabaweesi R**, Ramakrishnaiah RH, Aitken ME. Injured Children Receive Twice the Radiation Dose at Nonpediatric Trauma Centers Compared with Pediatric Trauma Centers. J Am Coll Radiol. 2018;15(1 Pt A):58-64. **Aim** To compare the radiation exposure injured children receive when imaged at nonpediatric hospitals (NPHs) versus paediatric hospitals. **Setting** Paediatric trauma centre **Type** Cross sectional	**Sample Size** 487 **Characteristics** median age of 7.2 years (interquartile range 5–13) **Inclusion** < 18 years of age All underwent CT imaging Transferred to PTC	To compare the radiation exposure injured children receive when imaged at nonpediatric hospitals (NPHs) versus paediatric hospitals.	Injured children younger than 18 years who received a CT scan at a referring hospital during calendar years (CYs) 2010 and 2013 were included. Patient-level factors included demographics, mode of transportation, and Injury Severity Score, and hospital-level factors included region of state, radiology services, and hospital type and size. Our primary outcome of interest was the effective radiation dose.	Median effective radiation dose received at NPHs was twice that received at the paediatric trauma centre (3.8 versus 1.6 mSv, $p < .001$).	**Limitations** The study compared several NPHs to a single children's hospital. Likely wide variation among NPHs. **Study conclusions** NPHs have the potential to substantially reduce the medical radiation received by injured children. Paediatric CT protocols should be considered.
Citation **Niiniviita H**, Kiljunen T, Huuskonen M. Dose monitoring in paediatric and young adult head and cervical spine CT studies at two emergency duty departments. Emerg Radiol. 2018;25(2):153-159. **Aim** To present the imaging data, patient doses, and observations of paediatric and young adult trauma—and routine head CT and cervical spine CT collected by a dose monitoring software. **Setting** Two emergency departments **Type** Retrospective	**Sample Size** 615 head studies **Characteristics** 318 routine head, and 592 trauma cervical spine CT studies **Inclusion** CT scan following paediatric and adolescent trauma.	Compare the doses of paediatric head and cervical spine CT at two different emergency departments and introduce the data collected by a dose monitoring software.	Patient age, study date, imaging parameters, and patient dose as volume CT dose index (CTDIvol) and dose length product (DLP). The patients were divided into four age groups (0–5, 6–10, 11–15, and 16–20 years). The 75th percentile doses were evaluated to be used as local diagnostic reference levels (DRLs).	All mean CTDIvol values were statistically lower in hospital B (40.3 ± 12.3, 30.03 ± 11.1, and 6.9 ± 3.1 mGy, respectively) than in hospital A (53.0 ± 12.9, 43.2 ± 8.7, and 18.3 ± 7.3 mGy, respectively). Statistically significant differences were observed on scanning length between hospitals and between CTDIvol values when protocol was updated. The 75th percentiles of trauma cervical spine in hospital B can be used as local DRL. Non-optimized protocols were also revealed in hospital A.	**Limitations** Only a few patients in the youngest age group **Study conclusions** Dose monitoring software offers a valuable tool for evaluating the imaging practices and finding non-optimized protocols.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Orman G**, Wagner MW, Seeburg D, Paediatric skull fracture diagnosis: should 3D CT reconstructions be added as routine imaging? J Neurosurg Pediatr. 2015;16(4):426-431 **Aim** Compared the efficacy of combining 2D+3D CT reconstructions with standard 2D CT images in the diagnosis of linear skull fractures in children with head trauma **Setting** Radiology **Type** Retrospective	**Sample Size** 250 patients **Characteristics** 167 boys 83 girls Mean age 7.82 (range 4 days to 17.4 years) **Inclusion** History of minor or major head trauma Head CT studies Age younger than 18 years at scanning **Exclusion** Outside CT studies Fractures other than linear fractures	Compared the efficacy of combining 2D+3D CT reconstructions with standard 2D CT images in the diagnosis of linear skull fractures in children with head trauma. Two experienced paediatric neuroradiologist in consensus crated the reference standard.	The standard of reference for diagnosis of a fracture was established by 2 experienced paediatric neuroradiologists in consensus. These 3 readers independently evaluated the 2D CT images initially and subsequently both the 2D+3D CT images in combination to yield 2 separate readings each. There was a 4-week time lapse between the 2 readings.	2D+3D CT combined had a higher sensitivity and specificity (83.9% and 97.1%, respectively) compared with 2D alone (78.2% and 92.8%, respectively) with statistical significance for specificity ($p < 0.05$) in children less than 2 years of age. 2D+3D CT combined had a higher sensitivity and specificity (81.3% and 90.5%, respectively) compared with 2D alone (74.5% and 89.1%, respectively) with statistical significance for sensitivity ($p < 0.05$) in all children.	**Limitations** Retrospective nature of the study and inclusion of only linear skull fractures are potential limitations. **Study conclusions** D+3D CT in combination showed increased sensitivity in the diagnosis of linear skull fractures in all children and increased specificity in children less than 2 years of age. In children less than 2 years of age, added confidence in the interpretation of fractures by distinguishing them from sutures may have a significant implication in the setting of non-accidental trauma. Furthermore, 3D CT is available at no added cost, scan time, or radiation exposure, providing trainees and clinicians with limited experience an additional valuable tool for routine imaging of paediatric head trauma.

Study details	Participants	Comparison	Methods	Outcomes/results	Comments (quality)
Citation **Southard RN**, Bardo DME, Temkit MH, Comparison of Iterative Model Reconstruction versus Filtered Back-Projection in Paediatric Emergency Head CT: Dose, Image Quality, and Image-Reconstruction Times. AJNR Am J Neuroradiol. 2019;40(5):866-871. **Aim** We review our experience with children undergoing emergency head CT examinations **Setting** Radiology **Type** Retrospective	**Sample Size** 173 **Characteristics** **Inclusion** Children referred from ED for urgent head CT without contrast + 3D reconstruction. **Exclusion** Repeat studies, marked motion, and multiple implanted metallic leads or when the incorrect age-based CT protocol was used. Patient age (months) and sex were recorded for each subject.	Head CTs reconstructed using knowledge-based iterative model reconstruction (IMR; Philips Healthcare, Best, the Netherlands) versus standard filtered back-projection (FBP) reconstruction, comparing reconstruction times, radiation dose, and objective and subjective image quality.	Children scanned using standard age-based non-contrast head CT protocols reconstructed with filtered back-projection with 190 children scanned using low-dose protocols reconstructed with iterative model reconstruction. ROIs placed on the frontal white matter and thalamus yielded signal-to-noise and contrast-to-noise ratios. Volume CT dose index and study reconstruction times were recorded. Random subgroups of patients were selected for subjective image-quality review.	The volume CT dose index was significantly reduced in studies reconstructed with iterative model reconstruction compared with filtered back-projection, (mean, 24.4 ± 3.1 mGy versus 31.1 ± 6.0 mGy, $p < .001$), while the SNR and contrast-to-noise ratios improved 2-fold ($p < .001$). Radiologists graded iterative model reconstruction images as superior to filtered back-projection images for gray-white matter differentiation and anatomic detail ($p < .001$). The average reconstruction time of the filtered back-projection studies was 101 seconds, and with iterative model reconstruction, it was 147 seconds ($p < .001$), without a practical effect on workflow.	**Limitations** Retrospective. Unable to randomise patients and scanners. **Study conclusions** In children referred for emergency non-contrast head CT, optimized low-dose protocols with iterative model reconstruction allowed us to significantly reduce the relative dose, on average, 22% compared with filtered back-projection, with significantly improved objective and subjective image quality.

5.15.6 Key considerations for assessing the evidence

N/A

5.15.7 Working Group recommendation deliberations

Table 5.15.3 Clinical judgement form for imaging Q15

PREDICT Guideline imaging Q15	**In infants and children with mild to moderate head injury presenting within 72 hours of injury who undergo a cranial CT scan, what are the i) appropriate CT protocols/techniques and/or ii) to what extent should the cervical spine be included in the imaging?**
Source recommendation/s	
None available	
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? ☐ Adopt source guidance ☐ Adapt source guidance ☒ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 24	In children with head injury, radiation dose should be optimised for head CT scans, with the primary aim being to produce diagnostic quality images that can be interpreted by the radiologist and are sufficient to demonstrate a small volume of intracranial haemorrhage (e.g. thin-film subdural haematoma).
PREDICT evidence-informed recommendation 25	Age-based CT scanning protocols that are optimised and as low as reasonably achievable (ALARA) for a paediatric population should be used.
PREDICT evidence-informed recommendation 26	Soft tissue and bone algorithm standard thickness and fine-slice images and multiplanar 2D and bony 3D reconstructions should be acquired, archived and available to the radiologist for review at the time of initial interpretation.
PREDICT evidence-informed recommendation 27	Cervical spine imaging should not be routine in all children with mild to moderate head injury who require imaging.
Rationale The PREDICT GWG **developed 4 new evidence-informed recommendations** relating to this question as there were no Guideline evidence sources to inform this question. In particular, these guidelines were silent on matters relating to technical aspects of the performance of head CT in regard to patient exposures to ionising radiation; the image reconstruction techniques that optimise detection of pathology, and in particular fractures, by the radiologist interpreting head CT in this clinical context; the minimum image dataset requirements at the time of interpretation; recommendations for image data archiving for future review / retrieval; and whether inclusion of part or all of the cervical spine in the imaged volume should be routine practice when head CT is performed. The PREDICT Guideline literature search identified 12 new studies relating to this question and 9 of these were selected as key evidence. These compared fracture detection rates using thin and thick slice and 3D CT image reconstruction techniques (70, 86-88) and evaluated variation in patient exposures during head CT at non paediatric hospitals (89, 90) as well as techniques to optimize radiation exposures (91-93). No studies relating to the detection rate of cervical spine fractures in children who had head CT for head trauma were identified in our search. Therefore, we were unable to make a recommendation supporting the routine extension of head CT to include the cervical spine.	

PREDICT Guideline imaging Q15	In infants and children with mild to moderate head injury presenting within 72 hours of injury who undergo a cranial CT scan, what are the i) appropriate CT protocols/techniques and/or ii) to what extent should the cervical spine be included in the imaging?	
FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure
Comment:		

6 Discharge (Working Group 3)

6.1 Discharge Q1 – In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and pragmatic considerations (distance/time to travel, capacity to contact hospital) required for safe discharge from the ED or hospital?

6.1.1 PREDICT question

PREDICT Guideline discharge Q1

In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and pragmatic considerations (distance/time to travel, capacity to contact hospital) required for safe discharge from the ED or hospital?

6.1.2 Source question

No review question in NICE CG176 addressed criteria or considerations for safe discharge.

6.1.3 Source recommendation

Expert opinion[58]

NICE CG176 Recommendation 81

If CT is not indicated on the basis of history and examination the clinician may conclude that the risk of clinically important brain injury to the patient is low enough to warrant transfer to the community, as long as no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).

Developed: 2003

Expert opinion[59]

NICE CG176 Recommendation 82

After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home).

Developed: 2003

[58] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".
[59] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

Expert opinion[60]

NICE CG176 Recommendation 84

Patients admitted after a head injury may be discharged after resolution of all significant symptoms and signs providing they have suitable supervision arrangements at home.

Developed: 2003

Expert opinion[61]

NICE CG176 Recommendation 85

Do not discharge patients presenting with head injury until they have achieved GCS equal to 15, or normal consciousness in infants and young children as assessed by the paediatric version of the GCS.

Developed: 2003

Expert opinion[62]

NICE CG176 Recommendation 91

All patients with any degree of head injury should only be transferred to their home if it is certain that there is somebody suitable at home to supervise the patient. Discharge patients with no carer at home only if suitable supervision arrangements have been organised, or when the risk of late complications is deemed negligible.

Developed: 2003

6.1.4 Source evidence

No evidence presented – recommendations based on expert opinion.

6.1.5 New evidence

No new evidence was identified in the literature search for the PREDICT Guideline.

6.1.6 Key considerations for assessing the evidence

None.

---

[60] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".
[61] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".
[62] Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles".

6.1.7 Working Group recommendation deliberations

Table 6.1.1 Clinical judgement form for discharge Q3

PREDICT Guideline discharge Q1	**In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and pragmatic considerations (distance/time to travel, capacity to contact hospital) required for safe discharge from the ED or hospital?**
Source recommendation/s	
NICE CG176 (2014) UK 5 recommendations: Recs 81, 82, 84, 85 and 91	**NICE CG176 Recommendation 81** [Expert opinion] If CT is not indicated on the basis of history and examination the clinician may conclude that the risk of clinically important brain injury to the patient is low enough to warrant transfer to the community, as long as no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home). **NICE CG176 Recommendation 82** [Expert opinion] After normal imaging of the head, the clinician may conclude that the risk of clinically important brain injury requiring hospital care is low enough to warrant transfer to the community, as long as the patient has returned to GCS equal to 15, and no other factors that would warrant a hospital admission are present (for example, drug or alcohol intoxication, other injuries, shock, suspected non-accidental injury, meningism, cerebrospinal fluid leak) and there are appropriate support structures for safe transfer to the community and for subsequent care (for example, competent supervision at home). **NICE CG176 Recommendation 84** [Expert opinion] Patients admitted after a head injury may be discharged after resolution of all significant symptoms and signs providing they have suitable supervision arrangements at home. **NICE CG176 Recommendation 85** [Expert opinion] Do not discharge patients presenting with head injury until they have achieved GCS equal to 15, or normal consciousness in infants and young children as assessed by the paediatric version of the GCS. **NICE CG176 Recommendation 91** [Expert opinion] All patients with any degree of head injury should only be transferred to their home if it is certain that there is somebody suitable at home to supervise the patient. Discharge patients with no carer at home only if suitable supervision arrangements have been organised, or when the risk of late complications is deemed negligible.

GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?	If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☒ Yes ☐ No ☐ Unsure ☐ N/A	☐ Yes ☐ No ☐ Unsure ☒ N/A
Comment:	

APPLICABILITY of the source recommendation/s
Is the recommendation relevant to the Australian health care setting?
☒ Yes ☐ No ☐ Unsure ☐ N/A

Adapt, adopt or new guidance		
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?		
<u>NICE CG176 Recommendation 81</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	<u>NICE CG176 Recommendation 82</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	<u>NICE CG176 Recommendation 84</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance
<u>NICE CG176 Recommendation 85</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	<u>NICE CG176 Recommendation 91</u> ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	
Comment:		

PREDICT Guideline discharge Q1	In infants and children with mild to moderate head injury presenting within 72 hours of injury, what are the clinical criteria and pragmatic considerations (distance/time to travel, capacity to contact hospital) required for safe discharge from the ED or hospital?

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☒ Not applicable

Comment:

PREDICT guidance

PREDICT Consensus-based Recommendation 28	Children presenting within 72 hours of a mild to moderate head injury can be safely discharged into the community if they meet all of the following criteria: - deemed at low risk of a clinically-important traumatic brain injury[63] as determined either by a negative head CT scan or, structured observation, or the absence of risk factors for a clinically-important traumatic brain injury (see PREDICT Recommendation 5 or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*) - neurologically normal - a GCS score of 15[64] - no other factors that warrant admission or a longer period of structured observation (e.g. other injuries or suspected abusive head trauma, clinician concerns [e.g. persistent vomiting], drug or alcohol intoxication).
PREDICT Consensus-based Recommendation 29	Children presenting within 72 hours of a mild to moderate head injury, and deemed appropriate for discharge with respect to low risk of a clinically-important traumatic brain injury,[63] should be discharged home according to local clinical practice regarding their ability to return to hospital (in terms of distance, time, social factors and transport).
PREDICT Consensus-based Recommendation 30	Children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should have a suitable person at home to supervise them for the first 24 hours post injury.

Rationale

The PREDICT GWG **adapted expert opinion recommendations** 81, 82, 84, 85 and 91 from the NICE CG176 Guideline. The PREDICT literature search did not identify any new studies.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

[63] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.
[64] Measured using an age-appropriate GCS.

6.2 Discharge Q2 (a,b) and Q3 – In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning an acute intracranial injury?; In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning possible post concussive symptoms? and In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital without evidence of radiologically proven traumatic intracranial lesion, which require follow-up for an acute intracranial injury?

6.2.1 PREDICT questions

The questions included in DISCHARGE Q2 (a) and (b) are shown here as they draw on the same source guideline question and recommendations as DISCHARGE Q3.

PREDICT Guideline discharge Q2 (a)

In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning an acute intracranial injury?

Discharge Q2 (b)

In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning possible post concussive symptoms?

PREDICT Guideline discharge Q3

In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital without evidence of radiologically proven traumatic intracranial lesion, which require follow-up for an acute intracranial injury?

6.2.2 Source question

NICE CG176 Section 10.8

What information and support do patients with head injury say they want? What discharge information should be given to patients with head injury?

6.2.3 Source recommendations

NICE CG176 Recommendation 86

Give verbal and printed discharge advice to patients with any degree of head injury who are discharged from an emergency department or observation ward, and their families and carers. Follow recommendations in Patient experience in adult NHS services [NICE clinical Guideline 138] about providing information in an accessible format).

Developed: 2014

NICE CG176 Recommendation 87

Printed advice for patients, families and carers should be age-appropriate and include:

- *Details of the nature and severity of the injury.*
- *Risk factors that mean patients need to return to the emergency department (see recommendation 4 and 5).*
- *A specification that a responsible adult should stay with the patient for the first 24 hours after their injury.*
- *Details about the recovery process, including the fact that some patients may appear to make a quick recovery but later experience difficulties or complications.*
- *Contact details of community and hospital services in case of delayed complications.*
- *Information about return to everyday activities, including school, work, sports and driving.*
- *Details of support organisations.*

Developed: 2014

NICE CG176 Recommendation 89

Inform patients and their families and carers about the possibility of persistent or delayed symptoms.

Developed: 2014

6.2.4 Source evidence

6.2.4.1 NICE CG176 (2014)

Recommendation 88 is a 2003 consensus recommendation based on expert opinion, which is also discussed in IMAGING Q5. Recommendation 92 is also a 2003 consensus recommendation based on expert opinion and is not related to a clinical question in NICE CG176 Guideline.

Recommendations 86, 87 and 89 were derived from three qualitative studies and six surveys (Table 6.2.1). Various themes were identified across patient information and patient support. Information relevant to children was limited to the following synopsis of one qualitative study and one survey:

> *One qualitative study[93] and one survey[87] identify that children and young people want information specific to their age. Adolescents[93] expressed the need to exert some control over the situation (either during their hospital stay or when receiving care from their parents). Adolescents and parents felt that information should be readily available and that professionals should address the patient directly, not speaking only to their parents, and appear genuinely interested in them. There is also an overlap with return to school as the study describes the need for professionals to develop appropriate and timely communication with their teachers and high school to facilitate a progressive and smooth return to academic activities. Falk et al., 2009[87] states that 58% (26/45) of children aged 5*

and over received age appropriate information compared to 16% (8/51) in the younger age group. (NICE CG176 p189)

Table 6.2.1 Citations of studies identified for discharge information

Ref No	Citation
Qualitative studies	
86	Falk AC, von Wendt L, Klang B. Informational needs in families after their child's mild head injury. Patient Education and Counselling. 2008; 70(2):251–255
93	Gagnon I, Swaine B, Champagne F, Lefebvre H. Perspectives of adolescents and their parents regarding service needs following a mild traumatic brain injury. Brain Injury. 2008; 22(2):161–173
142	Keenan A, Joseph L. The needs of family members of severe traumatic brain injured patients during critical and acute care: a qualitative study. Canadian Journal of Neuroscience Nursing. 2010; 32(3):25–35
Surveys	
80	Engel KG, Buckley BA, Forth VE, McCarthy DM, Ellison EP, Schmidt MJ et al. Patient understanding of emergency department discharge instructions: where are knowledge deficits greatest? Academic Emergency Medicine. 2012; 19(9):E1035-E1044
87	Falk AC, von Wendt L, Soderkvist BK. Families' perceptions of given information in relation to their child's head injury. Scandinavian Journal of Caring Sciences. 2009; 23(1):125–129
119	Heng KWJ, Tham KY, How KY, Foo JS, Lau YH, Li AYK. Recall of discharge advice given to patients with minor head injury presenting to a Singapore emergency department. Singapore Medical Journal. 2007; 48(12):1107–1110
165	McMillan TM, McKenzie P, Swann IJ, Weir CJ, McAviney A. Head injury attenders in the emergency department: the impact of advice and factors associated with early symptom outcome. Brain Injury. 2009; 23(6):509–515
254	Stevens PK, Penprase B, Kepros JP, Dunneback J. Parental recognition of post-concussive symptoms in children. Journal of Trauma Nursing. 2010; 17(4):178–4
288	Yates KM, Pena A. Comprehension of discharge information for minor head injury: A randomised controlled trial in New Zealand. New Zealand Medical Journal. 2006; 119(1239):U2101

6.2.4.2 NICE surveillance (2017)

Table 6.2.2 Subsequent evidence from NICE surveillance (2017) for discharge information

#	Original study citation	NICE surveillance (2017) evidence for information at discharge
1	Suffoletto B, Wagner AK, Arenth PM et al. (2013) Mobile phone text messaging to assess symptoms after mild traumatic brain injury and provide self-care support: a pilot study. Journal of Head Trauma Rehabilitation 28:302–312.	A pilot RCT[98] included 43 people with mild traumatic brain injury who received 14 days' of text message-based education and support for post-concussion symptoms. The abstract did not report the number of participants in the control group, only that test-messaging support was not provided to this group. People who received text message education and had lower odds of reporting headache, difficulty concentrating, and irritability or anxiety. Mean scores for headaches, difficulty concentrating, and irritability or anxiety were not significantly improved with text message support.
Topic expert feedback		
No topic expert feedback was relevant to this evidence.		
Impact statement		
Evidence suggests that text messaging may be a useful tool for providing education and support to people with recent mild traumatic brain injury. However, the small sample size in this study, and that it was referred to by its authors as a pilot study, means that it is unlikely to be sufficient to inform recommendations in this area.		
New evidence is unlikely to change Guideline recommendations.		

6.2.5 New evidence

Nine studies relevant to this question were identified in the PREDICT Guideline literature search (Table 6.2.3). One key study (57) was selected.

Table 6.2.3 New evidence identified for discharge Q1 and discharge Q4 (a,b)

Ref #	Citation	Relevant PREDICT question
54.	Andersson K, Bellon M, Walker R. Parents' experiences of their child's return to school following acquired brain injury (ABI): A systematic review of qualitative studies. Brain Injury. 2016;30(7):829–38.	DISCHARGE Q2

Ref #	Citation	Relevant PREDICT question
55.	Bodde TR, Scheinberg A, McKinlay A. A Critical Examination of Mild Traumatic Brain Injury Management Information Distributed to Parents. Developmental Neuropsychology. 2015;40(4):254–71.	DISCHARGE Q2
56.	Brooks TM, Smith MM, Silvis RM, Lerer T, Mulvey CH, Maitland R, et al. Symptom-Guided Emergency Department Discharge Instructions for Children with Concussion. Pediatric Emergency Care. 2017;33(8):553–63.	DISCHARGE Q2
57.	Curran JA, Murphy A, Burns E, Plint A, Taljaard M, MacPhee S, et al. Essential Content for Discharge Instructions in Pediatric Emergency Care: A Delphi Study. Pediatric Emergency Care. 2018;34(5):339–43.	DISCHARGE Q2
58.	Ismail S, McIntosh M, Kalynych C, Joseph M, Wylie T, Butterfield R, et al. Impact of Video Discharge Instructions for Pediatric Fever and Closed Head Injury from the Emergency Department. Journal of Emergency Medicine. 2016;50(3):e177–83.	DISCHARGE Q2
59.	Olsson K, Kenardy JA, Brown EA, Charlton E, Brown FL, Lloyd O, et al. Evaluation of parent and child psychoeducation resources for the prevention of paediatric post-concussion symptoms. Brain Impairment. 2015;15(3):177–89.	DISCHARGE Q2
60.	Petrelli T, Farrokhyar F, McGrath P, Sulowski C, Sobhi G, DeMatteo C, et al. The use of ibuprofen and acetaminophen for acute headache in the postconcussive youth: a pilot study. Paediatrics and Child Health (Canada). 2017;22(1):2–6.	DISCHARGE Q2
-	Plackett TP, Asturias S, Tadlock M, Wright F, Ton-That H, Demetriades D, et al. Re-evaluating the need for hospital admission and observation of pediatric traumatic brain injury after a normal head CT. Journal of Pediatric Surgery. 2015;50(10):1758–61.	DISCHARGE Q3
61.	Zamarripa A, Clark SJ, Rogers AJ, Wang-Flores H, Stanley RM. Pediatric Concussion Management in the Emergency Department: A National Survey of Parents. Journal of Pediatrics. 2017;181:229–34.	DISCHARGE Q2

Shading indicates key studies

6.2.5.1 Rationale for selection of key evidence

One of the nine new studies was selected as key evidence for question 3: which children require follow-up for an acute intracranial injury (57). It directly addressed the question of outcome following a negative head CT scan for intracranial trauma and which children require follow-up. Of the 631 participants included in Plackett, Asturias (57), 63% had a negative head CT scan and did not require neurosurgical intervention and could be considered for safe discharge home from the ED at the time of their negative CT scan. The remaining studies identified did not contribute significantly to recommendations concerning the PREDICT questions around which require follow-up and discharge advice.

6.2.5.2 Key evidence data extraction

Table 6.2.4 Data from key evidence for discharge Q3

Study details	Participants	Methods	Outcomes/results
Citation **Plackett TP**, Asturias S, Tadlock M, Wright F, Ton-That H, Demetriades D, et al. Re-evaluating the need for hospital admission and observation of pediatric traumatic brain injury after a normal head CT. Journal of Pediatric Surgery. 2015;50(10):1758–61. **Country** USA **Study type** Retrospective cohort **Aim** To characterizes the clinical outcomes of patients with a normal initial CT scan of the head.	**Characteristics** 631 blunt paediatric trauma patients underwent a head CT. 63% had a negative CT, 7% had a non-displaced skull fracture, and 31% had an intracranial haemorrhage and/or displaced skull fracture. For patients without intracranial injury, the mean age was 8 years, mean ISS was 5, and 92% had a GCS of 13–15 on arrival.	A retrospective chart review of paediatric blunt trauma patients who underwent head CT for closed head injury at two trauma centres.	All patients with an initial GCS of 13–15 and no intracranial injury were eventually discharged to home with a normal neurologic exam and no patient required craniotomy. Not admitting those children with an initial GCS of 13–15, normal CT scan, and no other injuries would have saved 1.8 ± 1.5 hospital days per patient. Pediatric patients who have sustained head trauma, have a negative CT scan, and present with a GCS 13–15 can safely be discharged home without admission.

6.2.6 Key considerations for assessing the evidence

6.2.6.1 Notes from NICE CG176

The NICE GDG noted that the evidence highlighted that patients and families want age appropriate information such as younger children require different information and different ways of explaining information compared to adolescents. No further discussions of discharge information for children and infants were reported.

6.2.7 Working Group recommendation deliberations

Table 6.2.5 Clinical judgement form for discharge Q1, discharge Q4 (a) and discharge Q4 (b)

PREDICT Guideline discharge Q2 (a)	**In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning an acute intracranial injury?**
Discharge Q2 (b)	**In infants and children with mild to moderate head injury discharged from the ED or hospital presenting within 72 hours of injury, what discharge advice should be provided concerning possible post concussive symptoms?**
Discharge Q3	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital without evidence of radiologically proven traumatic intracranial lesion, which require follow-up for an acute intracranial injury?**
Source recommendation/s	
NICE CG176 (2014) UK 3 recommendations: Recs 86, 87 and 89	**NICE CG176 Recommendation 86** Give verbal and printed discharge advice to patients with any degree of head injury who are discharged from an emergency department or observation ward, and their families and carers. Follow recommendations in Patient experience in adult NHS services [NICE clinical Guideline 138] about providing information in an accessible format). **NICE CG176 Recommendation 87** Printed advice for patients, families and carers should be age-appropriate and include: • Details of the nature and severity of the injury. • Risk factors that mean patients need to return to the emergency department (see recommendation 4 and 5). • A specification that a responsible adult should stay with the patient for the first 24 hours after their injury. • Details about the recovery process, including the fact that some patients may appear to make a quick recovery but later experience difficulties or complications. • Contact details of community and hospital services in case of delayed complications. • Information about return to everyday activities, including school, work, sports and driving. • Details of support organisations. **NICE CG176 Recommendation 89** Inform patients and their families and carers about the possibility of persistent or delayed symptoms.

GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☒ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	

Adapt, adopt or new guidance		
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?		
NICE CG176 Recommendation 86	NICE CG176 Recommendation 87	NICE CG176 Recommendation 89
☒ Adopt source guidance ☐ Adapt source guidance ☐ Create new guidance	☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	☒ Adopt source guidance ☐ Adapt source guidance ☐ Create new guidance
Comment:		
If new guidance needs to be developed, what type of guidance is appropriate?		

☒ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance	
Discharge Q2 (a)	
PREDICT evidence-informed recommendation 31	All parents and caregivers of children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should be given clear, age-appropriate, written and verbal advice on when to return to the emergency department; this includes worsening symptoms (e.g. headache, confusion, irritability, or persistent or prolonged vomiting), a decreased level of consciousness or seizures.
PREDICT evidence-informed recommendation 32	All parents and caregivers of children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should be given contact information for the emergency department, telephone advice line or other local providers of advice.
Discharge Q2 (b)	
PREDICT evidence-informed recommendation 33	All parents and caregivers of children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should be given clear, age-appropriate written and verbal advice on the possibility of persistent or delayed post-concussive symptoms, and the natural history (including the recovery process) of post-concussive symptoms in children.
PREDICT evidence-informed recommendation 34	All parents and caregivers of children discharged from hospital after presenting within 72 hours of a mild to moderate head injury should be given clear, age-appropriate written and verbal advice on exercise, return to sport, return to school, alcohol and drug use, and driving.
Discharge Q3	
PREDICT evidence-informed recommendation 35	Children presenting within 72 hours of a mild to moderate head injury deemed at low risk of a clinically-important traumatic brain injury,[65] as determined by any of the following – a negative head CT scan, structured observation or the absence of risk factors for clinically-important traumatic brain injury [45] (see PREDICT recommendation 5 or Box A for risk factors and *Algorithm: Imaging & Observation Decision-making for Children with Head Injuries*) – do not require specific follow-up for an acute intracranial lesion (e.g. bleeding).

Rationale

The PREDICT GWG **adopted evidence-based recommendations** 86 and 89, and **adapted evidence-based recommendation** 87 from the NICE CG176 Guideline for questions PREDICT 2a and 2b: what discharge advice should be provided concerning i) an acute intracranial injury and ii) possible post-concussive symptoms.
The NICE Guideline recommendations were derived from three qualitative studies and six surveys of patients. A pilot RCT of 43 people with mild head injuries to assess the effectiveness of mobile phone text messaging to provide education and self-care support was identified in a NICE surveillance report 2017 (94). However, due to it being a pilot study with a small sample size, NICE Guideline recommendations were not changed. None of the new studies identified in the PREDICT literature search were selected as key evidence for this question and did not contribute significantly to these recommendations.

The PREDICT GWG developed **new evidence-informed recommendations** for question 3: which children require follow up for an acute intracranial injury. There was no Guideline evidence source to inform this recommendation however the PREDICT literature search identified 1 new study that was selected as key evidence for this question. Plackett 2015 (57) is a moderately sized retrospective study of 631 children who presented to 2 trauma centres with blunt TBI and received a head CT scan. Of these 63% had a negative head CT scan and did not require neurosurgical intervention and could be considered for safe discharge home from the ED at the time of their negative CT scan.

FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure

Comment: These resources need to be made widely available to emergency departments.

[65] Clinically-important traumatic brain injury is defined as death from traumatic brain injury, neurosurgical intervention for traumatic brain injury, intubation for more than 24 hours for traumatic brain injury, or hospital admission of 2 nights or more associated with traumatic brain injury on CT.

6.3 Discharge Q4 (a,b,c) – In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, which require follow-up for post-concussive symptoms?; In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, what type of follow-up should it be? and In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, when should they be followed-up?

6.3.1 PREDICT questions

PREDICT Guideline discharge Q4 (a)

In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, which require follow-up for post-concussive symptoms?

PREDICT Guideline discharge Q4 (b)

In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, what type of follow-up should it be?

PREDICT Guideline discharge Q4 (c)

In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, when should they be followed-up?

6.3.2 Source questions – CDC Guideline (2018)

The CDC (2018) Guideline was selected as the source guideline for these questions. A recommendation from the Berlin (2017) Guideline is presented for discharge Q4 (a), the Berlin (2017) Guideline question, recommendation and evidence base is presented, after all the CDC (2018) Guideline information in Section 6.3.5.

The Lumba-Brown (2018) systematic review for the CDC (2018) Guideline included two clinical questions to investigate factors that predict delayed recovery or ongoing sequelae – one question for outcomes less than one year from injury, and another question for longer follow up.

Lumba-Brown (2018) systematic review Question 4

For children (18 years of age and younger) with mild traumatic brain injury (mTBI), what factors identify patients at increased risk for ongoing impairment, more severe symptoms, or delayed recovery (less than 1 year postinjury)?

Lumba-Brown (2018) systematic review Question 5

For children (18 years of age and younger) with mTBI, which factors identify patients at increased risk of long-term (≥1 year) sequelae?

6.3.3 Source recommendations – CDC (2018)

The eight relevant recommendations from the CDC (2018) Guideline are grouped according to the source guideline.

6.3.3.1 Prognostic factors

Recommendation 9A

Health care professionals should screen for known risk factors for persistent symptoms in children with mTBI.

(moderate; level B)

Recommendation 9B

Health care professionals may use validated prediction rules, which combine information about multiple risk factors for persistent symptoms, to provide prognostic counselling to children with mTBI evaluated in ED settings.

(high; level C)

6.3.3.2 Follow up for patients with poor prognosis

Recommendation 11A

Health care professionals should closely monitor children with mTBI who are determined to be at high risk for persistent symptoms based on their premorbid history, demographics, and/or injury characteristics.

(high; level B)

Recommendation 11B

For children with mTBI whose symptoms do not resolve as expected with standard care (i.e., within 4–6 weeks), health care professionals should provide or refer for appropriate assessments and/or interventions.

(moderate; level B)

6.3.4 Source evidence – CDC (2018)

The evidence supporting the source recommendations is presented in two sections that reflect the organisation of the CDC (2018) Guideline recommendations:

- **Prognostic factors for poor outcomes**
  - Assessment of Cumulative Risk Factors and Prognosis – Recommendations 9A & 9B
- **Follow up for patients with poor prognosis**
  - Interventions for mTBI With Poor Prognosis – Recommendations 11A & 11B

The CDC Guideline draws on evidence from a systematic review (Lumba-Brown, 2018) that was conducted for the purpose of the Guideline. However, not all recommendations in the CDC (2018) Guideline are covered by a review question in the systematic review. While the first section (prognostic factors for poor outcomes) is covered off by two review questions in the Lumba-Brown (2018) systematic review, the other two sections are not, and the Guideline cites references not necessarily discussed or identified in the systematic review.

The source of the evidence presented here is specified as coming from either the systematic review (Lumba-Brown (2018)) or the CDC Guideline. As the systematic review provides a lot more detail than the brief synopses of the published Guideline, it is presented in the first instance, followed by the higher-level Guideline synopsis. Where little information was available from either of these sources, the Report from the Pediatric Mild Traumatic Brain Injury Guideline Workgroup was checked for further content.

6.3.4.1 Prognostic factors – source evidence

(Assessment of Cumulative Risk Factors and Prognosis – Recommendations 9A & 9B)

Prognostic factors – systematic review

Two clinical questions in the Lumba-Brown (2018) systematic review addressed prognostic factors for poor outcomes. One of the two questions include follow up for less than 12 months post injury while the other includes follow up of 12 months or longer. A total of 27 studies were identified exploring associations between candidate factors and various post-concussive outcomes across both timeframes: 19 for <12 months and 15 for ≥12 months follow up, with some studies including outcomes for both timeframes (derived from Lumba-Brown (2018) systematic review). Citations for all 27 studies are provided in Table 6.3.1.

The systematic review (Lumba-Brown, 2018) attributed a rating to each of the 27 studies that reflects a combination of study design and some aspects of study quality (Class I-IV; see Table 6.3.2 for Classification of Evidence Scheme), and these are shown with the citations in Table 6.3.1.

Table 6.3.1 Citations for prognostic factor studies identified in the Lumba-Brown (2018) systematic review

Ref No. **Class of study**	**Citation**	**Follow up (time from injury)** <12 mo	≥12 mo
59 **Class I**	Blume HK, Vavilala MS, Jaffe KM, et al. Headache after pediatric traumatic brain injury: a cohort study. Pediatrics. 2012;129(1):e31-e39. doi:10.1542/peds.2011–1742	✓	
60 **Class I**	Barlow KM, Crawford S, Stevenson A, Sandhu SS, Belanger F, Dewey D. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. Pediatrics. 2010;126(2): e374-e381. doi:10.1542/peds.2009–0925	✓	✓
61 **Class I**	Zonfrillo MR, Durbin DR, Koepsell TD, et al. Prevalence of and risk factors for poor functioning after isolated mild traumatic brain injury in children. J Neurotrauma. 2014;31(8):722–727. doi:10.1089/neu .2013.3088	✓	✓
62 **Class II**	Chrisman SP, Rivara FP, Schiff MA, Zhou C, Comstock RD. Risk factors for concussive symptoms 1 week or longer in high school athletes. Brain Inj. 2013;27(1):1–9. doi:10.3109/02699052 .2012.722251	✓	

Ref No. Class of study	Citation	Follow up (time from injury) <12 mo	≥12 mo
63 **Class II**	Smyth K, Sandhu SS, Crawford S, Dewey D, Parboosingh J, Barlow KM. The role of serotonin receptor alleles and environmental stressors in the development of post-concussive symptoms after pediatric mild traumatic brain injury. Dev Med Child Neurol. 2014;56(1):73–77. doi:10.1111/dmcn.12263	✓	✓
64 **Class I**	Castile L, Collins CL, McIlvain NM, Comstock RD. The epidemiology of new versus recurrent sports concussions among high school athletes, 2005–2010. Br J Sports Med. 2012;46(8):603–610. doi:10.1136/bjsports-2011–090115	✓	
65 **Class II**	Zuckerman SL, Solomon GS, Forbes JA, Haase RF, Sills AK, Lovell MR. Response to acute concussive injury in soccer players: is gender a modifying factor? J Neurosurg Pediatr. 2012;10(6): 504–510. doi:10.3171/2012.8.PEDS12139	✓	
66 **Class II**	Ponsford J, Willmott C, Rothwell A, et al. Cognitive and behavioral outcome following mild traumatic head injury in children. J Head Trauma Rehabil. 1999;14(4):360–372. doi:10.1097/00001199 -199908000–00005	✓	
67 **Class II**	van der Veek EM, Oosterhoff M, Vos PE, Hageman G. The juvenile head trauma syndrome: a trauma triggered migraine? Neuropediatrics. 2015; 46(2):116–122. doi:10.1055/s-0035–1547344	✓	
68 **Class I**	Rivara FP, Koepsell TD, Wang J, et al. Disability 3, 12, and 24 months after traumatic brain injury among children and adolescents. Pediatrics. 2011; 128(5):e1129-e1138. doi:10.1542/peds.2011–0840	✓	✓
69 **Class I**	Babikian T, Satz P, Zaucha K, Light R, Lewis RS, Asarnow RF. The UCLA longitudinal study of neurocognitive outcomes following mild pediatric traumatic brain injury. J Int Neuropsychol Soc. 2011; 17(5):886–895. doi:10.1017/S1355617711000907	✓	
70 **Class I**	Levin HS, Hanten G, Roberson G, et al. Prediction of cognitive sequelae based on abnormal computed tomography findings in children following mild traumatic brain injury. J Neurosurg Pediatr. 2008;1(6):461–470. doi:10.3171/PED/2008 /1/6/461	✓	✓
71 **Class II**	O'Connor SS, Zatzick DF, Wang J, et al. Association between posttraumatic stress, depression, and functional impairments in adolescents 24 months after traumatic brain injury. J Trauma Stress. 2012;25(3):264–271. doi:10.1002 /jts.21704	✓	✓
72 **Class I**	Agrawal D, Gowda NK, Bal CS, Pant M, Mahapatra AK. Is medial temporal injury responsible for pediatric postconcussion syndrome? a prospective controlled study with single-photon emission computerized tomography. J Neurosurg. 2005;102(2)(suppl):167–171. doi:10.3171 /jns.2005.102.2.0167	✓	
73 **Class I**	Bouvier D, Fournier M, Dauphin JB, et al. Serum S100B determination in the management of pediatric mild traumatic brain injury. Clin Chem. 2012;58(7):1116–1122. doi:10.1373/clinchem.2011 .180828	✓	
74 **Class II**	Yeates KO, Luria J, Bartkowski H, Rusin J, Martin L, Bigler ED. Postconcussive symptoms in children with mild closed head injuries. J Head Trauma Rehabil. 1999;14(4):337–350. doi:10.1097 /00001199–199908000–00003	✓	
75 **Class I**	Olsson KA, Lloyd OT, Lebrocque RM, McKinlay L, Anderson VA, Kenardy JA. Predictors of child post-concussion symptoms at 6 and 18 months following mild traumatic brain injury. Brain Inj. 2013; 27(2):145–157. doi:10.3109/02699052.2012.729286	✓	✓
76 **Class I**	Moran LM, Taylor HG, Ganesalingam K, et al. Apolipoprotein E4 as a predictor of outcomes in pediatric mild traumatic brain injury. J Neurotrauma. 2009;26(9):1489–1495. doi:10.1089/neu.2008.0767	✓	
77 **Class I**	Max JE, Schachar RJ, Landis J, et al. Psychiatric disorders in children and adolescents in the first six months after mild traumatic brain injury. J Neuropsychiatry Clin Neurosci. 2013;25(3):187–197.	✓	
78 **Class I**	Babikian T, McArthur D, Asarnow RF. Predictors of 1-month and 1-year neurocognitive functioning from the UCLA longitudinal mild, uncomplicated, pediatric traumatic brain injury study. J Int Neuropsychol Soc. 2013;19(2):145–154. doi:10.1017 /S135561771200104X		✓
79 **Class II**	Teasdale TW, Engberg AW. Cognitive dysfunction in young men following head injury in childhood and adolescence: a population study. J Neurol Neurosurg Psychiatry. 2003;74(7):933–936. doi:10.1136/jnnp.74.7.933		✓
80 **Class I**	Max JE, Pardo D, Hanten G, et al. Psychiatric disorders in children and adolescents six-to-twelve months after mild traumatic brain injury. J Neuropsychiatry Clin Neurosci. 2013;25(4):272–282. doi:10.1176/appi.neuropsych.12040078		✓
81 **Class I**	Fay TB, Yeates KO, Taylor HG, et al. Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. J Int Neuropsychol Soc. 2010;16(1):94–105. doi:10.1017 /S1355617709991007		✓
82 **Class I**	Taylor HG, Orchinik LJ, Minich N, et al. Symptoms of persistent behavior problems in children with mild traumatic brain injury. J Head Trauma Rehabil. 2015;30(5):302–310. doi:10.1097 /HTR.0000000000000106		✓
83 **Class I**	Hessen E, Anderson V, Nestvold K. MMPI-2 profiles 23 years after paediatric mild traumatic brain injury. Brain Inj. 2008;22(1):39–50. doi:10 .1080/02699050701846179		✓
84 **Class II**	Papoutsis J, Stargatt R, Catroppa C. Long-term executive functioning outcomes for complicated and uncomplicated mild traumatic brain injury sustained in early childhood. Dev Neuropsychol. 2014;39(8):638–645. doi:10.1080/87565641.2014 .979926		✓

Ref No. Class of study	Citation	Follow up (time from injury) <12 mo	≥12 mo
85 **Class I**	Massagli TL, Fann JR, Burington BE, Jaffe KM, Katon WJ, Thompson RS. Psychiatric illness after mild traumatic brain injury in children. Arch Phys Med Rehabil. 2004;85(9):1428–1434. doi:10.1016/j .apmr.2003.12.036		✓

Source: Lumba-Brown (2018) systematic review for CDC (2018) Guideline.
Note: shading indicates studies included in overall synopsis in CDC (2018) Guideline.

Table 6.3.2 Criteria used for rating prognostic accuracy studies

Classification criteria for prognostic studies – American Academy of Neurology Classification of Evidence Schemes

Class I Criteria

- Cohort survey with prospective data collection
- Inclusion of a broad spectrum of persons at risk for developing the outcome
- Outcome measurement is objective or determined without knowledge of risk factor status
- Additional Class I criteria:
  a. Exclusion/inclusion criteria clearly defined
  b. Both the risk factor and the outcome measured in at least 80 percent of participants

Class II Criteria

- Cohort study with retrospective data collection or case-control study. Study meets Class I criteria a and b (see above)
- Inclusion of a broad spectrum of persons with and persons without both the risk factor and the outcome
- Presence of the risk factor and outcome are determined objectively or without the investigator's knowledge of both in each study participant

Class III Criteria

- Cohort or case-control study
- Narrow spectrum of persons with or without the disease
- Presence of the risk factor and outcome are determined objectively, without the investigator's knowledge of both in each study participant, or by different investigators

Class IV Criteria

If any study meets any one of the following criteria, the study must be classified as Class IV

- Persons at risk for the outcome are not included
- Patients with and patients without the risk factor are not included
- Measures of risk factor or outcomes are undefined or unaccepted
- Measures of association or statistical precision are either not presented or not calculable

Source: Supplementary online content for CDC (2018) Guideline: eAppendix 2 Classification of Evidence Scheme, pp58–59
Based on classification system in Gronseth GS, Woodroffe LM, Getchius TSD. Clinical Practice Guideline Process Manual. St. Paul, MN: American Academy of Neurology; 2011

Prognostic factors from systematic review – up to 12 months

Table 6.3.3 shows a summary of findings from the prognostic factor studies that report outcomes up to 12 months post injury (reproduced from the Lumba-Brown (2018) systematic review). All but two of the 19 studies with outcomes in this timeframe are included in this table.[66] Class II studies (n= 8) are indicated by yellow shading – the other 9 are Class I.

Table 6.3.3 Study findings for factors associated with increased risk of ongoing impairment, more severe symptoms or delayed recovery within 12 months

Risk Factor	Likelihood of Association	Outcome	Population	Period	Confidence
Hispanic (vs white non-Hispanic) ethnicity[61]	Highly likely	Decline in quality of life (social, academic, and/or physical functioning)	Patients in the ED	3 mo	High
Premorbid factors such as neurological/ psychiatric problems, learning difficulties, behavioural problems, and post-concussion-like symptoms[66]	Highly likely	Persistent symptoms and behavioural problems	Patients in the ED	3 mo	High

[66] Studies not included in table are No 63 (Smyth et al, 2014) and No 73 (Bouvier et al, 2012).

Risk Factor	Likelihood of Association	Outcome	Population	Period	Confidence
Socioeconomic status[61]	Highly likely	Worse social, academic, and physical outcomes	Patients in the ED, Inpatient	3 mo	High
Apolipoprotein E ε4 allele[76]	Highly likely	Glasgow Coma Scale scores less than 15	Patients in the ED	12 mo	High
Older age[60]	Likely	Post-concussive symptoms	Patients in the ED	3 mo	Moderate
Age[59]	Likely not	Post-concussive symptoms	Teenage patients	3–12 mo	Moderate
Female sex[59]	Likely	Headaches	Children age 5 to 17 y	3–12 mo	Moderate
Sex[62,65]	Likely not	Persistent self-reported headaches	Teenage patients	NA	Moderate
Hispanic (vs white non-Hispanic) ethnicity[61]	Likely	Decline in quality of life (social, academic, and/or physical functioning)	General patients	3 mo	Moderate
Higher ACRM severity score[60]	Likely	Persistent post-concussive symptoms	Patients in the ED	3 mo	Moderate
Intracranial haemorrhage on computed tomographic scan[70]	Possibly	Neurocognitive impairment	Children age 5 to 15 y	12 mo	Moderate
Early symptoms, including light and noise sensitivity, drowsiness, decreased concentration and confusion, and nausea[62]	Likely	Post-concussive symptoms	High school athletes	> 1 wk	Moderate
≥4 Symptoms[62]	Likely	Post-concussive symptoms	High school athletes	> 1 wk	Moderate
Premorbid factors such as neurological or psychiatric problems, learning difficulties, behavioural problems, and post-concussion-like symptoms[66]	Likely	Persistent symptoms and behavioural problems	General patients	3 mo	Moderate
Socioeconomic status[61]	Likely	Worse social, academic, and physical outcomes	General patients	3 mo	Moderate
Apolipoprotein E ε4 allele[76]	Likely	Glasgow Coma Scale scores <15	General patients	12 mo	Moderate
Prior concussion[62,64]	Likely	Longer period until symptom resolution and higher rate of medical retirement	High school athletes	NA	Moderate
Older age[59]	Possibly	Post-concussive symptoms	General patients	3–12 mo	Low
Male[64]	Possibly	Post-traumatic amnesia	High school athletes	NA	Low
Female[59]	Possibly	Persistent self-reported headaches	Children age 5 to 17 y	3–12 mo	Low
Sex[61,65,66]	Possibly not	Change in neurocognitive function and academic, social, and physical problems	Children age 0–17 y and high school athletes	3 mo; NA	Low
Sex[67]	Possibly not	Neurological decline after lucid interval	ED patients age 0–18 y	NA	Low
Heavier weight[62]	Possibly	Post-concussive symptoms	Football players	> 1 wk	Low
Higher ACRM severity score[60]	Possibly	Persistent post-concussive symptoms	General patients	3 mo	Low
Higher ACRM severity score[68]	Possibly	Impairment in adaptive functioning	Children age 0–18 y	3–24 mo	Low
Higher ACRM severity score[69]	Possibly not	Neurocognitive functioning	Children age 8–17 y	1–12 mo	Low
Higher ACRM severity score[61]	Possibly not	Decline in quality of life	Patients in the ED, Inpatients	3 mo	Low
Intracranial haemorrhage on computed tomographic scan[71]	Likely	Post-traumatic stress disorder	Teenagers age 14–17 y	24 mo	Low
Medial temporal hypometabolism[72]	Possibly	Post-concussion syndrome	Patients in Eds with single-photon emission computed tomography (within 72 h of mTBI)	3 mo	Low

Risk Factor	Likelihood of Association	Outcome	Population	Period	Confidence
Early post-concussive symptoms[69,74]	Possibly not	Neurocognitive outcomes or behavioural functioning	Patients in the ED	1, 6, 12 mo[69]; 7 d and 3mo[74]	Low
Early symptoms, including light and noise sensitivity, drowsiness, decreased concentration and confusion, and nausea[62]	Possibly	Post-concussive symptoms	General patients	> 1 wk	Low
≥4 Symptoms[62]	Possibly	Post-concussive symptoms	General patients	> 1 wk	Low
No. of preinjury comorbidities[61]	Possibly not	Decline in school, social, or physical functioning	Patients in the ED	3 mo	Low
Family history of migraine in a first-degree relative[67]	Possibly	Neurological deterioration after a lucid interval	Patients in the ED	NA	Low
Parental history of psychiatric symptoms such as hyperarousal, depression, and anxiety[75]	Possibly	Persistent post-concussive symptoms	Patients in the ED	6–18 mo	Low
Preinjury family functioning[61]	Possibly not	Social, academic, and physical functioning	Patients in the ED	3 mo	Low
Apolipoprotein E ε4 allele[76]	Possibly not	Neurocognitive outcomes or post-concussive symptoms	Patients in the ED	2 wk, 3 mo, 12 mo	Low
Prior concussion[64]	Possibly	Loss of consciousness and light or noise sensitivity	High school athletes	NA	Low
Age at injury, socioeconomic status, preinjury adaptive functioning, family psychiatric history, general family functioning, preinjury psychosocial stressors, and injuries to body parts other than the head[77]	Possibly not	Development of new psychiatric disorders	Patients in the ED	6 mo	Low

Source: Lumba-Brown (2018) systematic review, Table 1.
Notes from original source: The scale ranges from highly likely to likely, possibly, possibly not, likely not, and highly likely not. The difference between 'possibly' and 'possibly not' is that for 'possibly' there is some very limited evidence supporting an association, whereas for 'possibly not' there is some very limited evidence suggesting there is not an association. Because of the large number of conclusions, those deemed to have insufficient evidence were excluded from this Table.
Notes for this version: highlighted citations are Class II studies. All remaining studies are Class I.
Abbreviations: ACRM, American Congress of Rehabilitation Medicine; ED, emergency department; mo, months; wk, weeks.

Prognostic factors from systematic review – from 12 months

Table 6.3.4 shows a summary of findings from the prognostic factor studies that report outcomes from 12 months post injury (reproduced from the Lumba-Brown (2018) systematic review). All but two of the 15 studies with outcomes in this timeframe are included in this table.[67] Class II studies (n= 2) are indicated by yellow shading – the other 11 are Class I.

Table 6.3.4 Study findings for factors associated with increased risk of long-term sequelae (≥12 months)

Risk Factor	Likelihood of Association	Outcome	Population	Period	Confidence
Age at injury[80]	Likely not	Develop a novel psychiatric disorder	Patients in the ED	6–12 mo after injury	Moderate
Age at injury[61]	Likely not	Declines in HRQoL	Patients in the ED	First 12 mo after injury	Moderate
Neurocognitive impairment at 1 mo post-mTBI[78]	Likely	Neurocognitive Impairment	Patients in the ED	First mo after injury	Moderate
Severity of extracranial injury[80]	Likely not	Novel psychiatric disorder	Patients in the ED	≥12 mo	Moderate
Greater severity (Abbreviated Injury Scale score and acute concussive symptoms)[78]	Likely not	Neurocognitive impairment	Patients in the ED	First 12 mo after injury	Moderate

[67] Studies not included in table are No 79 (Teasdale et al, 2003) and No 83 (Hessen et al, 2008).

Risk Factor	Likelihood of Association	Outcome	Population	Period	Confidence
Greater severity based on clinical characteristics[61]	Likely not	Declines in HRQoL	Patients in the ED	First 12 mo after injury	Moderate
Greater severity based on clinical characteristics[84]	Likely not	Long-term problems with everyday executive functioning	Patients in the ED	First 12 mo after injury	Moderate
Greater severity based on clinical characteristics[82]	Likely	Behavioural problems	Patients in the ED	8 years after injury	Moderate
Intracranial lesion on acute head computed tomography[70]	Likely	Poor performance on tests of specific cognitive abilities	Patients in the ED	12 mo	Moderate
Intracranial lesion on acute head computed tomography[70]	Likely not	Poor performance on tests of general cognitive ability/ achievement	Patients in the ED	12 mo	Moderate
Intracranial lesion on magnetic resonance imaging[81]	Possibly	Cognitive symptoms	Children of lower cognitive ability	12 mo	Moderate
Preinjury academic functioning[78]	Likely	Global neurocognitive impairment	Patients in the ED	12 mo	Moderate
Preinjury behavioural problems[78]	Likely not	Global neurocognitive impairment	Patients in the ED	12 mo	Moderate
Preinjury adaptive functioning[80]	Likely not	Novel psychiatric disorder	Patients in the ED	6–12 mo	Moderate
Poor preinjury family functioning[80]	Likely	Novel psychiatric disorder	Patients in the ED	6–12 mo after injury	Moderate
Preinjury family functioning[61]	Likely not	Declines in HRQoL	Patients in the ED	First 12 mo after injury	Moderate
Concurrent behavioural problems[78]	Likely	Global neurocognitive impairment	Patients in the ED	12 mo	Moderate
Concurrent family stress[78]	Likely not	Global neurocognitive impairment	Patients in the ED	12 mo	Moderate
Socioeconomic status[80]	Likely	Novel psychiatric disorder	Patients in the ED	6–12 mo	Moderate
Socioeconomic status[61]	Likely	Declines in HRQoL	Patients in the ED	First 12 mo after injury	Moderate
Sex and race/ethnicity of patient[80]	Likely not	Novel psychiatric disorder	Patients in the ED	6–12 mo Post-TBI	Moderate
Sex and race/ethnicity of patient[61]	Likely not	Declines in HRQoL	Patients in the ED	First 12 mo after injury	Moderate
Age > 6 years[60]	Possibly	Remaining symptomatic (5% to 10% increased risk)	Patients in the ED	≥12 mo	Low
Lower cognitive ability[81]	Possibly	Cognitive symptoms	Intracranial Lesion	12 mo	Low
Presence of extracranial injury[82]	Likely not	Significant behavioural problems	Patients in the ED	12 mo	Low
Greater severity[80]	Likely not	Novel psychiatric disorder	Patients in the ED	12 mo	Low
Greater severity based on clinical characteristics[60]	Possibly	Remain symptomatic	Patients in the ED	≥12 mo	Low
Greater severity[84]	Possibly not	Long-term cognitive deficits	Age <4 y	8 y After injury	Low
Intracranial lesion on neuroimaging[68]	Possibly	Deficits in psychosocial adjustment	Patients in the ED or hospital	12–24 mo	Low
Intracranial haemorrhage on head computed tomography[71]	Likely	Psychiatric disorder	Patients in the ED or hospital	12–24 mo	Low
Premorbid psychiatric disorder[80,85]	Possibly	Novel psychiatric illness	Patients in the ED, hospital, or outpatient clinics	6 to 12 mo; First 3 y	Low
Preinjury child functioning[75]	Possibly not	Post-concussive symptoms	Patients in the ED	18 mo	Low
Preinjury child functioning[61]	Likely not	Declines in HRQoL	Patients in the ED	First 12 mo after injury	Low
Level of post-concussive symptoms reported 7 to 10 d or 6 mo postinjury[63,75]	Possibly	Post-concussive symptoms	General population; patients in the hospital	1–2 y	Low

Risk Factor	Likelihood of Association	Outcome	Population	Period	Confidence
Postinjury HRQoL and dissociative symptoms[75]	Possibly not	Post-concussive symptoms	Patients in the hospital	18 mo	Low
Post-concussive symptoms reported 7 to 10 d postinjury[63]	Possibly	Depressive symptoms	General population	1–2 y	Low
Parents' postinjury somatic symptoms[75]	Possibly	Children's post-concussive symptoms	Patients in the hospital	18 mo	Low
Lower parental education[78]	Possibly	Global neurocognitive impairment	Patients in the ED	12 mo	Low
Sex of patient[75]	Possibly not	Post-concussive symptoms	Patients in the hospital	18 mo	Low

Source: Lumba-Brown (2018) systematic review, Table 2.
Notes from original source: The scale ranges from highly likely to likely, possibly, possibly not, likely not, and highly likely not. The difference between 'possibly' and 'possibly not' is that for 'possibly' there is some very limited evidence supporting an association, whereas for 'possibly not' there is some very limited evidence suggesting there is not an association. Because of the large number of conclusions, those deemed to have insufficient evidence were excluded from this Table.
Notes for this version: highlighted citations are Class II studies. All remaining studies are Class I.
Abbreviations: ACRM, American Congress of Rehabilitation Medicine; ED, emergency department; HRQoL, health-related quality of life; mo, months; mTBI, mild traumatic brain injury; TBI, traumatic brain injury; wk, weeks.

Conclusions from the systematic review

The following narrative summary was provided for outcomes up to 12 months in the Lumba-Brown (2018) systematic review:

> *There were 4 conclusions drawn with high confidence:*
>
> *(1) Hispanic ethnicity compared with white, non-Hispanic ethnicity is highly likely to be associated with a decline in quality of life (social, academic, and/or physical functioning) 3 months after mTBI in children who present to an emergency department;*
>
> *(2) premorbid factors such as neurological or psychiatric problems, learning difficulties, behavioural problems, and post-concussion-like symptoms are highly likely to be associated with an increased risk of persistent symptoms and behavioural problems 3 to 6 months postinjury in children with mTBI who present to an emergency department;*
>
> *(3) socioeconomic status as measured by lower parental income and lower parental education is highly likely to be associated with worse social, academic, and physical outcomes 3 months post-mTBI in children seen for mTBI in an emergency or inpatient setting ; and*
>
> *(4) among children presenting to the emergency department with mTBI, the apolipoprotein E ε4allele is highly likely to be associated with GCS scores lower than 15 after injury.*

For long-term sequelae of mTBI, no conclusions were drawn with a high level of confidence (Lumba-Brown (2018) systematic review, p12).

Prognostic factors – CDC Guideline synopsis

The CDC (2018) Guideline provides a brief overall synopsis of the evidence for prognostic factors, citing a selection of studies, all but two of which are listed in Table 6.3.1 (Section 'Prognostic factors – systematic review'):

> *Evidence of varying strength indicates that a variety of non-injury (e.g., demographic) and injury-related factors predict outcomes in pediatric mTBI. Specifically, symptoms may last longer among older children/adolescents,[60,59,61] children of Hispanic race/ ethnicity (compared with white race/ethnicity),[61] children of lower socioeconomic status,[77,61] children with more severe presentations of mTB,[68,82,†] (including those associated with ICI),[68,70] and*

children reporting more acute post-concussion symptoms.[78,62,63] In addition, headaches persist longer in girls.[59] However, no single factor is strongly predictive of outcome. Only 1 prediction rule has been validated to date. It is based on a 2016 study[‡] of 3,063 children with mTBI seen in the ED and demonstrated that an empirically derived set of risk factors predicted the risk of persistent post-concussion symptoms at 28 days. (CDC (2018) Guideline, pp5–6)

Citation numbering changed to match that in Table 6.3.1
†Yeates 2009
‡ Zemeck 2016

A prediction rule development and validation study (Zemek et al 2016) was published after the Lumba-Brown (2018) systematic review literature search date in 2015 and, being the only example of such a study, was incorporated into the synopsis.

6.3.4.2 Follow up for patients with poor prognosis – source evidence

(Interventions for mTBI With Poor Prognosis – Recommendations 11A & 11B)

The CDC (2018) Guideline provides a brief overall synopsis of the evidence for follow up for patients with a poor prognosis:

The symptoms experienced by most children with mTBI resolve within 1 to 3 months after injury,[73] but some children are at risk for persistent symptoms and delayed recovery (i.e., those who demonstrate certain premorbid characteristics and other risk factors [see recommendations 8 and 9]). Children with mTBI who are at high risk for persistent symptoms or delayed recovery are more likely to require intervention than children at low risk. Health care professionals can more effectively counsel patients with mTBI when they have assessed prognostic risk factors. (CDC (2018) Guideline p6)

The single study cited in this Guideline synopsis (Table 6.3.5) was also identified by the Lumba-Brown (2018) systematic review as a study reporting on prognostic factors for poor outcomes. No further substantial information is provided in the Report from the Pediatric Mild Traumatic Brain Injury Guideline Workgroup.

Table 6.3.5 Citation used in the overall synopsis for follow-up for patients with poor prognosis in the CDC (2018) Guideline

Ref No	Citation
73	Barlow KM, Crawford S, Stevenson A, Sandhu SS, Belanger F, Dewey D. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. Pediatrics. 2010;126(2): e374-e381. doi:10.1542/peds.2009–0925

6.3.5 Alternative source question for Q4a – Berlin Guideline (2017)

The following question was included in the Berlin Guideline (2017).

Berlin (2017) Question 5

What are the predictors of prolonged recovery of concussion in children?

6.3.6 Alternative source recommendation for Q4a – Berlin Guideline (2017)

Berlin (2017) Prolonged recovery – Recommendation 1

The determination of prognosis for prolonged symptoms should take multiple risk factors into account, including variables of headache, migraine history, female sex, dizziness and a history of receiving multiple head injuries.

6.3.7 Alternative source evidence for Q4a – Berlin Guideline (2017)

Eighteen studies relevant to review Question 8 were identified in the Berlin Guideline (Table 6.3.6), with a synopsis provided for the key study (95), which reports a clinical prediction rule development and validation study in children. The study characteristics and summary of findings are presented in Table 6.3.7. The single study synopsis and the overall summary of the topic are reproduced here:

Berlin Guideline (2017) synopsis of prediction rule development and validation study

The largest cohort study (Zemek et al, 2016) examined 3063 patients who were recruited within 48 hours of head injury in an ED setting and were not restricted to sport-related concussion. Persistent post-concussive symptoms (PPCS) (which required persistence beyond 4 weeks of at least three symptoms compared with state of being prior to the injury), defined based on self-ratings, was present in 31% of the study participants. The authors developed a 12-point risk score model, which had modest discrimination to stratify PPCS risk at 28 days (area under the curve 0.71) and was significantly better than physician judgement in predicting PPCS. The nine variables found to predict the risk of developing PPCS in this selected population were: female sex, age 13 years or older, prior physician diagnosis of migraine, prior concussion with symptoms lasting longer than 1 week, headache, sensitivity to noise, fatigue, answering questions slowly and four or more errors on the Balance Error Scoring System tandem stance.

Overall summary from Berlin Guideline (2017)

Identifying children likely to have prolonged recovery after sport-related concussion is an important component of concussion assessment because it may influence the management of the patient's symptoms, help allay parental anxiety, and assist with return to school and return to play recommendations. Given the variable time point for assessment of prolonged recovery in the retrieved studies (2 weeks, 1 month and 3 months), it is not surprising that the incidence of prolonged recovery varied from 11% to 55%. Because children with prolonged symptoms are more likely to present to hospitals and concussion clinics, studies selecting participants from these locations are likely to demonstrate a higher incidence of prolonged recovery. The most consistent predictors of prolonged recovery were headache, history of migraine, female sex, dizziness and a history of receiving multiple concussions. However, data are insufficient regarding predictors of prolonged recovery in children at the community level with sport-related concussion who do not present to EDs or specialty clinics, and who may be considered to have had 'milder' concussions.

A distinction between persistent/prolonged symptoms and secondary reaction to concussion in children has not been clearly defined; however, clinical experience suggests that a subgroup of children and adolescents with sport-related concussion develop a significant secondary reaction to sport-related concussion, including headache, depression and anxiety. A secondary reaction may be due to a combination of factors, including the desire to play sport while recovering, a sense of 'letting the team down', concerns about missing team selections or finals, worries about falling behind with school work, concerns *about peer group perceptions of the injured child, and parental anxiety and concerns. Whether a biological basis, such as delayed neurometabolic cascade, may also contribute is unknown. Differentiating between the primary symptoms of sport-related concussion and secondary reaction to sport-related concussion in children and adolescents requires further evaluation.*

Table 6.3.6 Studies identified for prediction of prolonged recovery – Question 5 in Berlin Guideline (2017)

Ref No.	Citation
13	Babcock L, Byczkowski T, Wade SL, et al. Predicting postconcussion syndrome after mild traumatic brain injury in children and adolescents who present to the emergency department. JAMA Pediatr 2013; 167:156–61.
16	Barlow KM, Crawford S, Stevenson A, et al. Epidemiology of postconcussion syndrome in pediatric mild traumatic brain injury. Pediatrics 2010;126:e374–e381.
31	Meehan WP, Mannix RC, Stracciolini A, et al. Symptom severity predicts prolonged recovery after Sport-Related concussion, but age and amnesia do not. J Pediatr 2013;163:721–5.
44	Zemek R, Barrowman N, Freedman SB, et al; for the Pediatric Emergency Research Canada (PERC) Concussion Team. Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED. JAMA 2016;315:1014–25.
45	Lee YM, Odom MJ, Zuckerman SL, et al. Does age affect symptom recovery after sports-related concussion? A study of high school and college Athletes. J Neurosurg 2013;12:537–44.
49	Lee MA, Fine B. Adolescent concussions. Conn Med 2010;74:149–56
58	Lau BC, Collins MW, Lovell MR. Sensitivity and specificity of subacute computerized neurocognitive testing and symptom evaluation in predicting outcomes after sports related concussion. Am J Sports Med 2011;39:1209–16.
90	Barr WB, Prichep LS, Chabot R, et al. Measuring brain electrical activity to track recovery from sport-related concussion. Brain Inj 2012;26:58–66.
91	Grubenhoff JA, Deakyne SJ, Brou L, et al. Acute concussion symptom severity and delayed symptom resolution. Pediatrics 2014;134:54–62.
92	Korinthenberg R, Schreck J, Weser J, et al. Post-traumatic syndrome after minor head injury cannot be predicted by neurological investigations. Brain and Development 2004;26:113–7.
93	Thomas DG, Collins MW, Saladino RA, et al. Identifying neurocognitive deficits in adolescents following concussion. Academic Emergency Medicine 2011;18:246–54.
94	Yeates KO, Taylor HG, Rusin J, et al. Longitudinal trajectories of postconcussive symptoms in children with mild traumatic brain injuries and their relationship to acute clinical status. Pediatrics 2009;123:735–43
95	Zemek R, Clarkin C, Farion KJ, et al. Parental anxiety at initial acute presentation is not associated with prolonged symptoms following pediatric concussion. Academic Emergency Medicine 2013;20:1041–9.
96	Barlow M, Schlabach D, Peiffer J, et al. Differences in change scores and the predictive validity of three commonly used measures following concussion in the middle school and high school aged population. Int J Sports Phys Ther 2011;6:150–7.
97	Merritt VC, Arnett PA. Premorbid predictors of postconcussion symptoms in collegiate Athletes. J Clin Exp Neuropsychol 2014;36:1098–111.
98	Morgan CD, Zuckerman SL, Lee YM, et al. Predictors of postconcussion syndrome after sports-related concussion in young Athletes: a matched case-control study. J Neurosurg 2015;15:589–98.
99	Ponsford J, Willmott C, Rothwell A, et al. Cognitive and behavioral outcome following mild traumatic head injury in children. Journal of Head Trauma Rehabilitation 1999;14:360–72.
100	Yeates KO, Luria J, Bartkowski H, et al. Postconcussive symptoms in children with mild closed head injuries. Journal of Head Trauma Rehabilitation 1999;14:337–50.

Table 6.3.7 Study characteristics and findings for prediction of prolonged recovery – Question 5 in Berlin Guideline (2017)

Paper	Study design	N	Age: mean (SD) [range]	Male %	Time points	Measures	Concussion definition/ inclusion	Main finding	LoE
Babcock 2013 (96)	Secondary analysis of a prospective observational study (Retrospective)	(n= 406)	13.2 (3.5) [5–18]	Total 61.2%;	ED and 3 months	RPQ for both time points; PCS defined as > 3 symptoms that were worse than pre-mTBI.	Case definition of mTBI developed by the Mild Traumatic Brain Injury Committee of the American Congress of Rehabilitation Medicine: A blow to the head or acceleration/ deceleration movement of the head resulting in 1 or more of the following: • LOC of < 30 min • amnesia of < 24 h or • any alteration in mental state, and a GCS score of 13 or more measured 30 min or more after injury.	29.3% developed Postconcussion syndrome (PCS). Predictors of PCS: adolescent age, headaches on presentation to the ED, admission to the hospital.	3
Barlow 2010 (97)	Controlled cohort (Prospective)	mTBI (n= 670) ECI Controls (n= 197)	Cases: 7.62 (6.61) [0–17.9); Controls: 9.44 (4.40); [0–17.8]	57.5% of cases; 46.7% of control subjects	ED (PCSI), follow-up at 2 wks if symptomatic, and monthly until resolution (PCSI).	PCSI, RPQ, BSI, FAD; PCS defined as > 3 symptoms on the PCSI at 3 months.	GCS score 13–15 with LOC or altered status < 20 min; no focal neurologic deficits; amnesia <24 h.	Among children with mTBI, 58.5% were symptomatic at 1 month and 13.7% were symptomatic 3 months after injury. Predictors include severity of injury and age> 6 years.	3
Barlow 2011 (98)	Chart Review (Retrospective)	(n= 106)	15.38 (1.70) [11–19]	65%	Enrolled patients needed minimum of two clinic visits (average (SD) 15.5 (14.1) days between initial and final visit	PCSS, BESS, ImPACT	Physician diagnosis of concussion; Excluded history of ADHD, seizures, depression, anxiety, headaches, brain surgery, meningitis, or a documented learning disability.	55% male with PCS 46% female with PCS No evidence that baseline score predicts if PCS will occur.	4
Barr 2012 (99)	Controlled cohort (Prospective)	mTBI (n= 59) Non-injured controls (n= 31)	Not reported (“eight high schools and two colleges”)	100%	Day of injury, 8 and 45 days	CSI, SAC, BESS, ANAM, resting EEG recording	> 1 symptoms from the AAN Guideline for Management of Sports Concussion; Control subjects (non-injured athletes) matched based on age, years of education, cumulative grade point average, and baseline performance on concussion assessment measures.	While group differences for CSI and SAC at time of injury, no significant difference at day 8 or day 45 between cases and controls. mTBI-DS (EEG Index score) showed more injury at time of injury and at day 8, but no significant difference at day 45.	4

Paper	Study design	N	Age: mean (SD) [range]	Male %	Time points	Measures	Concussion definition/ inclusion	Main finding	LoE
Grubenhoff 2014 (100)	Cohort (Prospective)	(n= 234); (179 completed follow-up)	[8–18]	70%	ED and 30 days after injury	CSI	International Statistical Classification of Diseases and Related Health Problems. GCS score of 13 or 14, or at least 2 of the following symptoms occurring after a direct blow to or rapid acceleration/ deceleration of the head: bystander-witnessed LOC; PTA; disorientation to person, place, or time; subjective feelings of slowed thinking; perseveration; vomiting/nausea; headache; diplopia/blurry vision; dizziness; or somnolence.	21% had delayed recovery greater than one month, and 13% met PCS criteria (3+ symptoms at one month). Greater initial symptom totals measured at ED presentation was associated with PCS.	3
Korinthenberg 2004 (101)	Cohort (Prospective)	(n= 98)	[3–13]	60	24h, 4–6 weeks post-injury	EEG and psychological investigation	Minor head injury; excluded if: LOC <10 min; any overt neurologic symptoms, cerebral haemorrhage, or ICU stay. Note: skull fractures were eligible.	At baseline there was a correlation between EEG and somatic symptom score (headache, dizziness, nausea, vomiting, fatigue). At 4–6 week follow-up, 23% still had somatic symptoms, 18% with psychiatric symptoms, and 10% with neurological symptoms. However, baseline EEG did not predict follow-up symptoms persistence.	3
Lau 2011 (102)	Cohort (Prospective)	(n= 107)	16.02 (1.22) [13–19]	100	On-field signs and symptoms of concussion recorded; Neuro-cognitive test done at 2.23 days	ImPACT, PCSS	Diagnosed concussion by trained medical personnel with documented, observed on-field signs and symptoms by trained sports medicine staff at the time of injury.	Dizziness at time of injury was associated with prolonged recovery (OR= 6.34 [95% CI: 1.34–29.91]). No other on-field symptoms were associated with increased risk. The combination of 4 symptom clusters and 4 neurocognitive composite scores had highest sensitivity (65%), specificity (80%) in predicting protracted recovery.	3

Paper	Study design	N	Age: mean (SD) [range]	Male %	Time points	Measures	Concussion definition/ inclusion	Main finding	LoE
Lee 2010 (103)	Chart review (Retrospective)	(n= 774)	15.0 (1.8) [11–19]	62.6	Patients seen every 7–10 days until resolution	ImPACT, Mechanism of injury, symptom inventory (self-report), physical examination	Physician diagnosed.	24.4% of patients with persistent symptoms beyond 4 weeks. A history of receiving multiple hits to the head in the same game was most predictive of persistent symptoms (33% vs. 23%, p = 0.01).	4
Lee 2013 (104)	Observational (Retrospective)	(n= 184); 13–16yrs (n= 92) 18–22yrs (n= 92); Groups were matched	Younger group = 15.0 (0.8); Older group = 19.1 (1.1)	56.5% male in each group	Baseline before head injury and during post-concussion visit	Baseline symptom inventory, TSS, ImPACT.	On-field or side-line signs or symptoms: 1) lethargy, fogginess, headache, and such; 2) alteration in mental status; 3) loss of consciousness; or 4) amnesia. Diagnosis made by trainers.	No significant differences between the age groups at baseline or at post-concussion testing.	4
Meehan 2013 (105)	Cohort (Prospective)	(n= 182)	15.2 (3.04)	64	Initial visit time points vary. Average period of time between injury and first visit was 11 d for group 1 (persistent symptom > 28 d) and 13 d for group 2 (symptoms resolved <28 d).	BESS, neurocognitive assessment ImPACT, PCSS	International Consensus on Concussion in Sport. Patients with injury mechanisms and forces similar to sports injuries were also included.	PCSS score was independently associated with prolonged symptom duration predictor. All other predictors were not associated with prolonged symptoms (age, verbal memory, visual memory, visual motor speed, reaction time).	3
Merritt 2014 (106)	Cohort (Retrospective)	Baseline athletes (n= 702) Post-concussion athletes (n= 55)	Baseline group 18.44 (0.93); Post-concussion 19.91 (1.40)	Baseline group = 74.5% Post-concussion group = 85.5%	Baseline and after concussion	PCSS, Previous Head Injury Questionnaire. Neurocognitive battery: BVMT-R, HVLT-R, Digit Span Test, SDMT, Comprehensive TMT, PSU Cancellation Task, the Vigil/W CPT, Stroop Color–Word Test, ImPACT, WTAR.	Defined by experiencing PTA lasting < 24 h), LOC (lasting 30 min or less), or any alteration in mental status and/or post-concussion signs or symptoms at the time of injury.	On factor analysis, physical and affective symptom clusters, sex and neurocognitive composite score were associated with PCS.	3
Morgan 2015 (107)	Case-control (Retrospective)	PCS cases (n= 40) matched with sport-related concussion group (n= 80)	Cases 14.9(2.1); Control 14.8 (2.0); [9–18]	Case = 47.5%; Control = 50%		PCSS; PCS defined as patients experiencing post-concussion symptoms > 3 months.	Physician diagnosed.	Risk for PCS higher in patients with an individual or family history of preinjury psychiatric illness and migraines, number of previous concussions, and delay in symptom onset.	4

Paper	Study design	N	Age: mean (SD) [range]	Male %	Time points	Measures	Concussion definition/ inclusion	Main finding	LoE
Ponsford 1999 (108)	Controlled cohort (Prospective)	mTBI cases (n= 130); Orthopaedic injury controls (n= 96)	Cases: 11.3 (2.9); Control subjects: 11.6 (2.4); [6–15]	Cases = 76%; Control subjects = 65%	1 week, 3 months	PCSC, WPTAS kids > 7yrs (orientation, memory), COAT < 7yrs, CBCL, Rowe BRI, PPTV, Vineland Adaptive Behavior Scale	American Congress of Rehabilitation Medicine (LOC <30 min, GCS score 13–15, amnesia <24 h); no CT or MRI performed.	1-week post-injury, headache best differentiated between cases and controls. 3 months post injury, mTBI cases had significantly lower memory and verbal scores compared to controls. Pre-morbid Rowe Behavior Rating Inventory total score was predictive of symptoms at 3 months.	3
Thomas 2011 (109)	Cohort (Prospective)	(n= 60)	15 [11–17]	78%	Follow-up telephone surveys at 3-day, 2-week, 6-week, and 3-month post-injury.	ACE and ImPACT	Concussion defined by ACE; ineligible if GOAT score 75; patients with history of ADHD or developmental delays were excluded.	ED-obtained symptom measures (ACE and ImPACT PCSS) did not correlate with symptom duration or time to return to normal activity.	3
Yeates 1999 (110)	Controlled cohort (Prospective)	Cases (n= 26) Uninjured sibling controls (n= 8) Orthopedic injury controls (n= 99)	Cases: 10.85 (2.22); Control subjects: 12.38 (2.13); [8–15]	Cases = 58% Sibling Control subjects = 87% Control subjects = 65%	Baseline and 3 months	MRI, Neuro-psychological testing, HBI (62 items)	Children with mild closed head injuries with GCS score 13–15, LOC 30 min, amnesia, alteration of mental state, headache, recurrent emesis, or transient neurologic deficits; positive CT or skull fracture excluded	Children with head injury had more PCS symptoms compared to siblings. Cases also had more attention problems and tiredness than siblings. Premorbid and post-injury factors are believed to contribute to PCS.	3
Yeates 2009 (111)	Controlled cohort (Prospective)	mTBI cases (n= 186) Orthopaedic controls (n= 99)	Cases: 11.96 (2.22); Control subjects: 11.76 (2.23); [8–15]	Cases = 71% Control subjects = 65%	Baseline, 1, 3, and 12 months	HBI (50-item), Post-Concussive Symptom Interview	Blunt head trauma and evidence for at least 1 of the following indications of concussion: observed LOC or GCS score 13 or 14; or note of at least 2 of the following acute signs and symptoms of concussion: persistent PTA, transient neurologic deficits, vomiting, nausea, headache, diplopia, dizziness, disorientation, and other mental status changes	LOC was associated with PCS. The presence of headaches, being forgetful, having difficulty in concentrating, and tiring easily scores were most discriminant between mTBI and orthopaedic injury.	2

Paper	Study design	N	Age: mean (SD) [range]	Male %	Time points	Measures	Concussion definition/ inclusion	Main finding	LoE
Zemek 2013 (112)	Observational cohort (Prospective)	(n= 98); 27% developed PPCS	12 (3) [5–17]	58%	ED, 3 days, 7 days, 2 week and 1 month	STAI-S and PCSI; PPCS defined as 3 or more symptoms on the PCSI.	Head injury within 48 hours of presenting at ED; met concussion diagnostic criteria consistent with Zurich consensus statement	Parental anxiety at time of acute presentation was not associated with PCS.	3
Zemek 2016 (95)	Cohort (Prospective)	(n= 3063) Derivation = 2006 Validation = 1057	Derivation Median = 11.8 (Interquartile range = 8.9–14.6) [5–18] Validation Median = 12.3 (Interquartile range = 9.6–14.8) [5–18]	60.7%	ED, 1,2,4,8,12 weeks	PCSI; PPCS defined as 3 or more symptoms on the PCSI.	Head injury within 48 hours of presenting at ED; met concussion diagnostic criteria consistent with Zurich consensus statement	30.0% had PPCS (derivation). 47 predictor variables were associated with PPCS on bivariable analysis. Multivariable analysis yielded 9 predictor variables: female sex, age 13+, personal migraine history, prior concussion with symptoms lasting > 1 week, answering questions slowly, 4+ errors on the BESS tandem stance, headache, sensitivity to noise, and fatigue. A 12-point risk score was derived and validated to predict PPCS.	2

Source: Berlin Guideline (2017) Online Supplementary Table 5

Abbreviations: AAN, American Academy of Neurology; ACE, Acute Concussion Evaluation; ADHD, Attention Deficit Hyperactivity Disorder; ANAM, Automated Neuropsychological Assessment Metrics; BESS, Balance Error Scoring System; BSI, Brief Symptom Inventory; BVMT-R, Brief Visuospatial Memory Test – Revised; CBCL, Child Behavior Checklist; COAT, Children's Orientation and Amnesia Test; CSI, Concussion Symptom Inventory; ECI, Extracranial Injury; ED, Emergency Department; EEG, Electroencephalography; FAD, Family Assessment Device; GCS, Glasgow Coma Scale; HBI, Health Behaviour Inventory; HVLT-R, Hopkins Verbal Learning Test – Revised; ImPACT, Immediate Post-Concussion Assessment and Cognitive Test; LOC, Loss of Consciousness; LoE, level of evidence; mTBI, Mild Traumatic Brain Injury; mTBI-DS, Mild Traumatic Brain Injury – Discriminant Score; PCS, Post-concussion Syndrome; PCSC, Post-Concussion Syndrome Checklist; PCSI, Post-Concussion Symptom Inventory; PCSS, Post-Concussion Symptom Scale; PPCS, Persistent Post-concussive Symptoms; PSU, Pennsylvania State University Cancellation Task; PPVT, Peabody Picture Vocabulary Test; PTA, Post Traumatic Amnesia; Rowe BRI, Rowe Behavior Rating Inventory; RPQ, Rivermead Post Concussion Symptoms Questionnaire; SAC, Standardised Assessment of Concussion; SDMT, Symbol Digit Modalities Test; sport-related concussion, Sport-Related Concussion; STAI-S, Spielberger State-Trait Anxiety Inventory – State Anxiety Scale; TMT, Trail Making Test; TSS, Total Symptom Scale; Vigil/W CPT, Vigil/W Continuous Performance Test; WPTAS, Westmead PTA Scale; WTAR, Wechsler Test of Adult Reading

6.3.8 New evidence

Fifty-two studies relevant to this question were identified in the PREDICT Guideline literature search (Table 6.3.8). Five key studies (95, 113-116) (were selected.

Table 6.3.8 New evidence identified for discharge Q2 (a) and Q2 (b)

Ref #	Citation	Relevant PREDICT question
2.	Alsalaheen B, Stockdale K, Pechumer D, Broglio SP, Marchetti GF. A Comparative Meta-Analysis of the Effects of Concussion on a Computerized Neurocognitive Test and Self-Reported Symptoms. Journal of Athletic Training. 2017;52(9):834–46.	DISCHARGE Q4a
3.	Anderson V, Beauchamp MH, Yeates KO, Crossley L, Ryan N, Hearps SJC, et al. Social Competence at Two Years after Childhood Traumatic Brain Injury. Journal of Neurotrauma. 2017;34(14):2261–71.	DISCHARGE Q4a
46.	Babcock L, Kurowski BG, Zhang N, Dexheimer JW, Dyas J, Wade SL. Adolescents with mild traumatic brain injury get SMART: An analysis of a novel web-based intervention. Telemedicine and e-Health. 2017;23(7):600–7.	DISCHARGE Q4b
4.	Babl FE, Dionisio D, Davenport L, Baylis A, Hearps SJC, Bressan S, et al. Accuracy of Components of SCAT to Identify Children with Concussion. Pediatrics. 2017;140(2).	DISCHARGE Q4a
43.	Baker JG, Leddy JJ, Darling SR, Shucard J, Makdissi M, Willer BS. Gender Differences in Recovery from Sports-Related Concussion in Adolescents. Clinical Pediatrics. 2016;55(8):771–5.	DISCHARGE Q4a – sex difference
5.	Baker JG, Leddy JJ, Darling SR, Rieger BP, Mashtare TL, Sharma T, et al. Factors Associated with Problems for Adolescents Returning to the Classroom After Sport-Related Concussion. Clinical Pediatrics. 2015;54(10):961–8.	DISCHARGE Q4a
6.	Bakker K, Catroppa C, Anderson V. Anosmia and olfactory outcomes following paediatric traumatic brain injury. Brain Injury. 2016;30(2):191–8.	DISCHARGE Q4a
7.	Beauchamp MH, Aglipay M, Yeates KO, Desire N, Keightley M, Anderson P, et al. Predictors of neuropsychological outcome after pediatric concussion. Neuropsychology. 2018;32(4):495–508.	DISCHARGE Q4a
8.	Beauchamp MH, Tang K, Yeates KO, Anderson P, Brooks BL, Keightley M, et al. Predicting Wellness After Pediatric Concussion. Journal of the International Neuropsychological Society. 2019;25(4):375–89.	DISCHARGE Q4a
9.	Bernard CO, Ponsford JA, McKinlay A, McKenzie D, Krieser D. Predictors of post-concussive symptoms in young children: Injury versus non-injury related factors. Journal of the International Neuropsychological Society. 2016;22(8):793–803.	DISCHARGE Q4a
10.	Bernard CO, Ponsford JL, McKinlay A, McKenzie D, Krieser D. Do concussive symptoms really resolve in young children? The Journal of Head Trauma Rehabilitation. 2017;32(6):413–24.	DISCHARGE Q4a
11.	Boutis K, Gravel J, Freedman SB, Craig W, Tang K, DeMatteo CA, et al. The Diagnosis of Concussion in Pediatric Emergency Departments: A Prospective Multicenter Study. Journal of Emergency Medicine. 2018;54(6):757–65.	DISCHARGE Q4a
12.	Boutis K, Weerdenburg K, Koo E, Schneeweiss S, Zemek R. The diagnosis of concussion in a pediatric emergency department. Journal of Pediatrics. 2015;166(5):1214–1.22E+04.	DISCHARGE Q4a
47.	Briet C, Braun K, Lefranc M, Toussaint P, Boudailliez B, Bony H. Should We Assess Pituitary Function in Children After a Mild Traumatic Brain Injury? A Prospective Study. Frontiers in Endocrinology. 2019;10:149.	DISCHARGE Q4b
13.	Briggs R, Brookes N, Tate R, Lah S. Duration of post-traumatic amnesia as a predictor of functional outcome in school-age children: A systematic review. Developmental Medicine & Child Neurology. 2015;57(7):618–27.	DISCHARGE Q4a
14.	Brooks BL, Daya H, Khan S, Carlson HL, Mikrogianakis A, Barlow KM. Cognition in the emergency department as a predictor of recovery after pediatric mild traumatic brain injury. Journal of the International Neuropsychological Society. 2016;22(4):379–87.	DISCHARGE Q4a
15.	Brooks BL, Plourde V, Beauchamp MH, Tang K, Yeates KO, Keightley M, et al. Predicting Psychological Distress after Pediatric Concussion. Journal of Neurotrauma. 2019;36(5):679–85.	DISCHARGE Q4a
44.	Brown DA, Elsass JA, Miller AJ, Reed LE, Reneker JC. Differences in symptom reporting between males and females at baseline and after a sports-related concussion: A systematic review and meta-analysis. Sports Medicine. 2015;45(7):1027–40.	DISCHARGE Q4a – sex difference
45.	Cancelliere C, Donovan J, Cassidy JD. Is Sex an Indicator of Prognosis After Mild Traumatic Brain Injury: A Systematic Analysis of the Findings of the World Health Organization Collaborating Centre Task Force on Mild Traumatic Brain Injury and the International Collaboration on Mild Traumatic Brain Injury Prognosis. Archives of Physical Medicine & Rehabilitation. 2016;97(2 Suppl):S5–18.	DISCHARGE Q4a – sex difference
16.	Catroppa C, Crossley L, Hearps SJC, Yeates KO, Beauchamp M, Rogers K, et al. Social and behavioral outcomes: Pre-injury to six months following childhood traumatic brain injury. Journal of Neurotrauma. 2015;32(2):109–15.	DISCHARGE Q4a
17.	Catroppa C, Hearps S, Crossley L, Yeates K, Beauchamp M, Fusella J, et al. Social and behavioral outcomes following childhood traumatic brain injury: What predicts outcome at 12 months post-insult? Journal of Neurotrauma. 2017;34(7):1439–47.	DISCHARGE Q4a
18.	Chasle V, Riffaud L, Longuet R, Martineau-Curt M, Collet Y, Le Fournier L, et al. Mild head injury and attention deficit hyperactivity disorder in children. Childs Nervous System. 2016;32(12):2357–61.	DISCHARGE Q4a

Ref #	Citation	Relevant PREDICT question
19.	Chin EY, Nelson LD, Barr WB, McCrory P, McCrea MA. Reliability and Validity of the Sport Concussion Assessment Tool-3 (SCAT3) in High School and Collegiate Athletes. American Journal of Sports Medicine. 2016;44(9):2276–85.	DISCHARGE Q4a
48.	Choe MC, Valino H, Fischer J, Zeiger M, Breault J, McArthur DL, et al. Targeting the Epidemic: Interventions and Follow-up Are Necessary in the Pediatric Traumatic Brain Injury Clinic. Journal of Child Neurology. 2016;31(1):109–15.	DISCHARGE Q4b
49.	Creasey N, Benger J, Wright I, Lyttle M. Non-pharmacological interventions to reduce psychological sequalae of mild traumatic brain injury in adults and children: a systematic review. Brain Injury. 2016;30(5-Jun):709–10.	DISCHARGE Q4b
20.	Chrisman SPD, Lowry S, Herring SA, Kroshus E, Hoopes TR, Higgins SK, et al. Concussion Incidence, Duration, and Return to School and Sport in 5- to 14-Year-Old American Football Athletes. Journal of Pediatrics. 2019;207:176–1.84E+03.	DISCHARGE Q4a
21.	Crichton A, Oakley E, Babl FE, Greenham M, Hearps S, Delzoppo C, et al. Predicting Fatigue 12 Months after Child Traumatic Brain Injury: Child Factors and Postinjury Symptoms. Journal of the International Neuropsychological Society. 2018;24(3):224–36.	DISCHARGE Q4a
22.	Crichton AJ, Babl F, Oakley E, Greenham M, Hearps S, Delzoppo C, et al. Prediction of multidimensional fatigue after childhood brain injury. The Journal of Head Trauma Rehabilitation. 2017;32(2):107–16.	DISCHARGE Q4a
50.	Dachtyl SA, Morales P. A collaborative model for return to academics after concussion: Athletic training and speech-language pathology. American Journal of Speech-Language Pathology. 2017;26(3):716–28.	DISCHARGE Q4b
23.	Evans E, Asuzu D, Cook NE, Caruso P, Townsend E, Costine-Bartell B, et al. Traumatic Brain Injury-Related Symptoms Reported by Parents: Clinical, Imaging, and Host Predictors in Children with Impairments in Consciousness Less than 24 Hours. Journal of Neurotrauma. 2018;35(19):2287–97.	DISCHARGE Q4a
24.	Ewing-Cobbs L, Cox CS, Jr., Clark AE, Holubkov R, Keenan HT. Persistent Postconcussion Symptoms After Injury. Pediatrics. 2018;142(5):11.	DISCHARGE Q4a
25.	Grubenhoff JA, Currie D, Comstock RD, Juarez-Colunga E, Bajaj L, Kirkwood MW. Psychological Factors Associated with Delayed Symptom Resolution in Children with Concussion. Journal of Pediatrics. 2016;174:27–3.0E+02.	DISCHARGE Q4a
26.	Hang B, Babcock L, Hornung R, Ho M, Pomerantz WJ. Can Computerized Neuropsychological Testing in the Emergency Department Predict Recovery for Young Athletes with Concussions? Pediatric Emergency Care. 2015;31(10):688–93.	DISCHARGE Q4a
27.	Heyer GL, Young JA, Fischer AN. Lightheadedness After Concussion: Not All Dizziness is Vertigo. Clinical Journal of Sport Medicine. 2018;28(3):272–7.	DISCHARGE Q4a
28.	Howell DR, O'Brien MJ, Beasley MA, Mannix RC, Meehan WP, 3rd. Initial somatic symptoms are associated with prolonged symptom duration following concussion in adolescents. Acta Paediatrica. 2016;105(9):e426–32.	DISCHARGE Q4a
29.	Howell DR, Potter MN, Kirkwood MW, Wilson PE, Provance AJ, Wilson JC. Clinical predictors of symptom resolution for children and adolescents with sport-related concussion. Journal of Neurosurgery 2019; Pediatrics 43678.	DISCHARGE Q4a
30.	Iverson GL, Gardner AJ, Terry DP, Ponsford JL, Sills AK, Broshek DK, et al. Predictors of clinical recovery from concussion: a systematic review. British Journal of Sports Medicine. 2017;51(12):941–8.	DISCHARGE Q4a
51.	Kania K, Shaikh KA, White IK, Ackerman LL. Follow-up issues in children with mild traumatic brain injuries. Journal of Neurosurgery Pediatrics. 2016;18(2):224–30.	DISCHARGE Q4b
31.	Kassam I, Gagnon F, Cusimano MD. Association of the APOE-4 allele with outcome of traumatic brain injury in children and youth: A meta-analysis and meta-regression. Journal of Neurology, Neurosurgery and Psychiatry. 2016;87(4):433–40.	DISCHARGE Q4a
52.	Mortenson P, Singhal A, Hengel AR, Purtzki J. Impact of Early Follow-Up Intervention on Parent-Reported Postconcussion Pediatric Symptoms: a Feasibility Study. Journal of Head Trauma Rehabilitation. 2016;31(6):E23-E32.	DISCHARGE Q4b
32.	Moser RS, Davis GA, Schatz P. The age variable in childhood concussion management: A systematic review. Archives of Clinical Neuropsychology. 2018;33(4):417–26.	DISCHARGE Q4a
33.	Nelson LD, Furger RE, Gikas P, Lerner E, Barr WB, Hammeke TA, et al. Prospective, head-to-head study of three computerized neurocognitive assessment tools part 2: Utility for assessment of mild traumatic brain injury in emergency department patients. Journal of the International Neuropsychological Society. 2017;23(4):293–303.	DISCHARGE Q4a
34.	Nelson LD, Tarima S, LaRoche AA, Hammeke TA, Barr WB, Guskiewicz K, et al. Preinjury somatization symptoms contribute to clinical recovery after sport-related concussion. Neurology. 2016;86(20):1856–63.	DISCHARGE Q4a
53.	Nowacki R, van Eldik N, Eikens M, Roijen R, Haga N, Schott D, et al. Evaluation of a follow-up program for mild traumatic brain injury in schoolchildren. European Journal of Paediatric Neurology. 2017;21(2):382–7.	DISCHARGE Q4b
35.	Pearce KL, Sufrinko A, Lau BC, Henry L, Collins MW, Kontos AP. Near Point of Convergence After a Sport-Related Concussion: Measurement Reliability and Relationship to Neurocognitive Impairment and Symptoms. American Journal of Sports Medicine. 2015;43(12):3055–61.	DISCHARGE Q4a
36.	Ritchie EV, Emery C, Debert CT. Analysis of serum cortisol to predict recovery in paediatric sport-related concussion. Brain Injury. 2018;32(4):523–8.	DISCHARGE Q4a

Ref #	Citation	Relevant PREDICT question
37.	Shim J, Smith DH, Van Lunen BL. On-field signs and symptoms associated with recovery duration after concussion in high school and college athletes: a critically appraised topic. Journal of Sport Rehabilitation. 2015;24(1):72–6.	DISCHARGE Q4a
38.	Slovis JC, Gupta N, Li NY, Kernie SG, Miles DK. Assessment of Recovery Following Pediatric Traumatic Brain Injury. Pediatric Critical Care Medicine. 2018;19(4):353–60.	DISCHARGE Q4a
39.	Teel EF, Marshall SW, Shankar V, McCrea M, Guskiewicz KM. Predicting Recovery Patterns After Sport-Related Concussion. Journal of Athletic Training. 2017;52(3):288–98.	DISCHARGE Q4a
40.	Terry DP, Huebschmann NA, Maxwell BA, Cook NE, Mannix R, Zafonte R, et al. Preinjury migraine history as a risk factor for prolonged return to school and sports following concussion. Journal of Neurotrauma. 2019;36(1):142–51.	DISCHARGE Q4a
41.	Zemek R, Barrowman N, Freedman SB. Erratum: Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED (JAMA – Journal of the American Medical Association (2016) 315:10 (1014–1025)). JAMA – Journal of the American Medical Association. 2016;315(23):2624.	DISCHARGE Q4a
42.	Zemek R, Barrowman N, Freedman SB, Gravel J, Gagnon I, McGahern C, et al. Clinical Risk Score for Persistent Postconcussion Symptoms Among Children with Acute Concussion in the ED. JAMA. 2016;315(10):1014–25.	DISCHARGE Q4a

Shading indicates key studies

6.3.8.1 Rationale for selection of key evidence

Five of the 52 new studies were selected as key evidence for these questions based on the following rationale: The studies were high quality systematic reviews (115) or large prospective cohort studies (95) addressing question 4a regarding which children require follow-up; or small prospective cohort studies, or pilot RCTs, addressing question 4b regarding what type of follow-up should be provided (113, 114, 116).

6.3.8.2 Key evidence data extraction

Table 6.3.9 Data from key evidence for discharge Q2

Study details	Participants	Intervention, methods and outcomes	Results	Comments (quality)
Full citation **Iverson GL**, Gardner AJ, Terry DP, Ponsford JL, Sills AK, Broshek DK, et al. Predictors of clinical recovery from concussion: a systematic review. British Journal of Sports Medicine. 2017;51(12):941–8. **Country** NA **Study type** Systematic review **Aim** A systematic review of factors that might be associated with, or influence, clinical recovery from sport-related concussion.	A total of 7617 articles were identified using the search strategy, and 101 articles were included. **Inclusion criteria** Articles that examined factors that may be associated with outcome from concussion and were conducted with humans.	**Search** Data sources PubMed, PsycINFO, MEDLINE, CINAHL, Cochrane Library, EMBASE, SPORTDiscus, Scopus and Web of Science. **Eligibility criteria for selecting studies** Studies published by June of 2016 that addressed clinical recovery from concussion. **Outcomes** Clinical recovery was defined functionally as a return to normal activities, including school and sports, following injury. Many different clinical outcomes were measured, such as symptoms, cognition, balance, return to school and return to sports, although symptom outcomes were the most frequently measured.	The most consistent predictor of slower recovery from concussion is the severity of a person's acute and subacute symptoms. The development of subacute problems with headaches or depression is likely a risk factor for persistent symptoms lasting greater than a month. Those with a preinjury history of mental health problems appear to be at greater risk for having persistent symptoms. Those with attention deficit hyperactivity disorder (ADHD) or learning disabilities do not appear to be at substantially greater risk. There is some evidence that the teenage years, particularly high school, might be the most vulnerable time period for having persistent symptoms—with greater risk for girls than boys.	

Study details	Participants	Intervention, methods and outcomes	Results	Comments (quality)
Full citation **Zemek** R, Barrowman N, Freedman SB, Gravel J, Gagnon I, McGahern C, et al. Clinical Risk Score for Persistent Postconcussion Symptoms Among Children with Acute Concussion in the ED. JAMA. 2016;315(10):1014–25. **Country** Canada **Study type** Prospective, multicenter cohort study **Aim** To derive and validate a clinical risk score for PPCS among children presenting to the emergency department.	Eligible patients were aged 5 years through younger than 18 years, presented to a participating ED with a head injury within the preceding 48 hours, and met concussion diagnostic criteria consistent with the fourth Zurich consensus statement. Concussion was defined as a complex pathophysiological process caused by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head (which may or may not have involved loss of consciousness), resulting in a brain injury with 1 or more symptoms in 1 or more of the following clinical domains: somatic, cognitive, emotional or behavioural, or sleep. Patients were excluded for (1) a Glasgow Coma Scale score of 13 or less, (2) a structural abnormality on neuroimaging (if performed), (3) a neurosurgical intervention, (4) intubation or intensive care unit admission, (5) multisystem injury requiring hospitalization, (6) procedural sedation, (7) severe pre-existing neurological developmental delay resulting in communication difficulties, intoxication, absence of trauma as primary event, previously enrolled in this same study, insurmountable language barrier, or the inability to follow-up by telephone or email. 3063 patients (median age, 12.0 years [interquartile range, 9.2–14.6 years];1205 [39.3%] girls) were enrolled (n = 2006 in the derivation cohort; n = 1057 in the validation cohort) and 2584 of whom (n = 1701 [85%] in the derivation cohort; n = 883 [84%] in the validation cohort) completed follow-up at 28 days after the injury.	**Study design** Multivariable prediction model **Outcomes** The primary outcome was PPCS risk score at 28 days, which was defined as 3 or more new or worsening symptoms using the patient-reported Post-concussion Symptom Inventory compared with recalled state of being prior to the injury.	Persistent post-concussion symptoms were present in 801 patients (31.0%) (n = 510 [30.0%] in the derivation cohort and n = 291 [33.0%] in the validation cohort). The 12-point PPCS risk score model for the derivation cohort included the variables of female sex, age of 13 years or older, physician-diagnosed migraine history, prior concussion with symptoms lasting longer than 1 week, headache, sensitivity to noise, fatigue, answering questions slowly, and 4 or more errors on the Balance Error Scoring System tandem stance. The area under the curve was 0.71 (95%CI, 0.69–0.74) for the derivation cohort and 0.68 (95%CI, 0.65–0.72) for the validation cohort. Assesses static postural stability. In tandem stance, the participant is instructed to stand heel to toe with the nondominant foot in the back and to hold this stance for 20 seconds with hands on hips and eyes closed. The modified version of this test is calculated by adding 1 error point for each error during the 20-second test; total scores range from 0 to 10. A higher score indicates poorer postural stability.	**Conclusion** Clinical risk score developed among children presenting to the emergency department with concussion and head injury within the previous 48 hours had modest discrimination to stratify PPCS risk at 28 days. Before this score is adopted in clinical practice, further research is needed for external validation, assessment of accuracy in an office setting, and determination of clinical utility.

Study details	Participants	Intervention, methods and outcomes	Results	Comments (quality)
Full citation **Babcock L**, Kurowski BG, Zhang N, Dexheimer JW, Dyas J, Wade SL. Adolescents with mild traumatic brain injury get SMART: An analysis of a novel web-based intervention. Telemedicine and e-Health. 2017;23(7):600–7. **Country** USA **Study type** Open-label, single arm study **Aim** Developed and piloted a novel web-based intervention, entitled Self-Management Activity Restriction and Relaxation Training (SMART), and examined its impact on symptom burden, functional disability, and executive functioning during the month following mTBI in adolescents.	Adolescents with recent mTBI and a parent were recruited from the emergency department and provided access upon discharge to SMART—a Web-based program designed to facilitate recovery via self-management and education about symptoms and sequelae associated with mTBI.	The program, entitled Self-Management Activity Restriction and Relaxation Training (SMART) is comprised of two components: (1) daily symptom and activity monitoring, along with personalized feedback and probes to promote tailored self-management of symptoms, and (2) educational modules incorporating principles of anticipatory guidance, problem-solving training, and stress management/ relaxation training. **Study design** Open-label, single arm study.	Symptom burden, functional disability, and executive functioning were rated by both the adolescent and the parent initially and at assessments at 1-, 2- and 4-weeks postinjury. Of the 21 adolescent/parent dyads enrolled, 13 engaged in the program and reported significant improvement in symptoms over the 4-week program (adolescent, $p = 0.0005$; parent, $p = 0.004$). Adolescents spent a median of 35.5 min (range 1.1–107.6) using the program. Parent ratings of the adolescent's functional disability and executive functioning significantly improved over the 4-week period from baseline ($p = 0.009$ and $p = 0.03$, respectively), whereas adolescents themselves did not report significant changes in either outcome. All participants improved and there were no adverse outcomes.	**Limitations** Pilot study – small numbers
Full citation **Mortenson P**, Singhal A, Hengel AR, Purtzki J. Impact of Early Follow-Up Intervention on Parent-Reported Postconcussion Pediatric Symptoms: a Feasibility Study. Journal of Head Trauma Rehabilitation. 2016;31(6):E23-E32. **Country** Canada **Study type** Pilot, randomized controlled study to investigate the effectiveness and feasibility of early intervention telephone counselling with parents in limiting post-concussion symptoms and impacts on children and youth.	Sixty-six parents of children aged 5 to 16 years with a diagnosis of a concussion injury.	Telephone counselling (reviewing symptom management and return to activity with parents at 1 week and 1 month postinjury) with usual care (no formalized follow-up). **Study design** A single, masked, block randomized controlled trial design was conducted at a Canadian, acute care, tertiary paediatric hospital. Recruitment occurred from September 2012 until February 2014. All parents understood that they would receive telephone follow-up from an occupational therapist (OT) at some point in the next 3 months. Parents enrolled in the interventional arm of the study received structured follow-up and symptom counselling at both 1 week (range = 6–12 days postinjury; median = 9) and 1 month postinjury (range = 29–48 days postinjury; median = 33).	The Post-Concussion Symptom Inventory and the Family Burden of Injury Interview administered with parents by a blinded therapist at 3 months postinjury. **Results** No significant difference between the groups at 3 months postinjury in post-concussion symptoms ($p = .67$) and family stress ($p = .647$).	**Conclusion** The findings suggest that the early counselling intervention strategy trailed herein may not be effective for children and youth who experience significant postconcussion symptoms. Further research is needed to determine whether more intensive and integrated care would better serve children

Study details	Participants	Intervention, methods and outcomes	Results	Comments (quality)
Full citation **Nowacki R**, van Eldik N, Eikens M, Roijen R, Haga N, Schott D, et al. Evaluation of a follow-up program for mild traumatic brain injury in schoolchildren. European Journal of Paediatric Neurology. 2017;21(2):382–7 **Country** The Netherlands **Study type** Cohort **Aim** We developed a follow up program to screen for persistent symptoms and if necessary, refer patients for further medical assistance.	Children between 4 and 18 years of age who were presented with mild traumatic brain injury according to the WHO classification were evaluated, either in the emergency department or the neurologic or paediatric outpatient clinic. Depending on their clinical status they were either hospitalised or discharged immediately in accordance with the pertinent Dutch Guideline. Patients were included in the follow-up program through consulting the hospital registration system and daily reports from the paediatric and neurology department. Children were excluded from analysis if they had a significant medical condition such as pre-existent psychomotor retardation, neurological and psychiatric problems or severe behavioural problems. Nonetheless, each of these cases was discussed by the multidisciplinary team to evaluate whether follow-up was useful/indicated. The program started in July 2010, and we evaluated our results in January 2014.	From July 2010 until December 2013, eligible children aged 4–18 years who presented after sustaining a mild traumatic brain injury were included. All patients received a phone call after 6 weeks. After a period of 3 months, both their schoolteacher and parents were asked to complete in a questionnaire. The results were discussed monthly by a multidisciplinary team. **Study methods:** Upon discharge, these patients were given patient information describing mild traumatic brain injury, possible long-term effects and our follow-up program. Six weeks after the trauma occurred, parents received a phone call from our research nurse to determine if any problems were evident. Results of these phone calls were reported to a multidisciplinary team. If necessary, a visit to the paediatrician, neurologist, psychologist or paediatric rehabilitation physician was planned. Three months after the trauma the patients' parents and primary school teacher or high school mentor received the “Screening tool for Cognitive, Emotional and Social consequences of brain injury in children ” (SCES), a questionnaire used as an identification tool for problems in the aforementioned areas. A psychologist evaluated all questionnaires. Results of the follow-up by phone and the questionnaires were discussed in monthly meetings of a multi-disciplinary team consisting of a paediatrician, paediatric rehabilitation physician, psychologist, paediatric neurologist and a research nurse. During these meetings, every patient with reported problems related to the traumatic brain injury was discussed to determine if these patients required further medical assistance. Children were referred to a specialist according to the nature of their problem	Results: A total of 305 children were enrolled in our follow-up program. Headache was the most common acute symptom upon presentation (63%). Overall, 19% of all patients had problems, either at 6 weeks or 3 months. 14% of these patients were referred for special care. Most common persistent post-concussive symptoms were headache (32%), cognitive problems (23%) and behavioural problems (16%). After a period of two years, a review of patient charts revealed that all of the problems were resolved.	**Conclusion** One fifth of the children exhibit post-concussive symptoms after mild traumatic brain injury. Education of patients and caregivers and a follow up visit if needed applied appropriate care at an early stage to minimise physical and mental problems.

6.3.9 Key considerations for assessing the evidence

None.

6.3.10 Working Group recommendation deliberations

Table 6.3.10 Clinical judgement form for discharge Q2 (a), discharge Q2 (b) and discharge Q2 (c)

PREDICT Guideline discharge Q4 (a)	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, which require follow-up for post-concussive symptoms?**
Discharge Q4 (b)	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, what type of follow-up should it be?**
Discharge Q4 (c)	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, when should they be followed-up?**
Source recommendation/s	
CDC (2018) USA 4 recommendations: Recs 9A, 9B, 11A, 11B	**PROGNOSTIC FACTORS** **Recommendation 9A** Health care professionals should screen for known risk factors for persistent symptoms in children with mTBI. **Recommendation 9B** Health care professionals may use validated prediction rules, which combine information about multiple risk factors for persistent symptoms, to provide prognostic counselling to children with mTBI evaluated in ED settings. **FOLLOW UP FOR PATIENTS WITH POOR PROGNOSIS** **Recommendation11A** Health care professionals should closely monitor children with mTBI who are determined to be at high risk for persistent symptoms based on their premorbid history, demographics, and/or injury characteristics. **Recommendation 11B** For children with mTBI whose symptoms do not resolve as expected with standard care (i.e., within 4–6 weeks), health care professionals should provide or refer for appropriate assessments and/or interventions.
Notes on wording changes	

GENERALISABILITY of the source recommendation/s

Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?	If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☒ Yes ☐ No ☐ Unsure ☐ N/A	☐ Yes ☐ No ☐ Unsure ☒ N/A

Comment:

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☒ Yes ☐ No ☐ Unsure ☐ N/A

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

CDC (2018) Recommendation 9A	CDC (2018) Recommendation 9B	CDC (2018) Recommendation 11A
☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance

CDC (2018) Recommendation 11B

☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☒ Not applicable

Comment:

PREDICT Guideline discharge Q4 (a)	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, which require follow-up for post-concussive symptoms?**
Discharge Q4 (b)	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, what type of follow-up should it be?**
Discharge Q4 (c)	**In infants and children with mild to moderate head injury presenting within 72 hours of injury and discharged from the ED or hospital, that require follow up for post-concussive symptoms, when should they be followed-up?**

PREDICT guidance	
PREDICT evidence-informed recommendation 36	All parents and caregivers of children discharged from hospital after presenting within 72 hours of mild to moderate head injury should be advised that their child should attend primary care 1–2 weeks post injury for assessment of post-concussive symptoms and to monitor clinical status.
PREDICT evidence-informed recommendation 37	In children at high risk of persistent post concussive symptoms (more than 4 weeks) (see Practice point O), clinicians should consider provision of referral to specialist services for post-concussive symptom management.
PREDICT practice point O	For children presenting within 72 hours of mild to moderate head injury, emergency department clinicians should consider factors known to be associated with an increased risk of developing post-concussive symptoms. Examples include, but are not restricted to, a high degree of symptoms at presentation, girls aged over 13 years, previous concussion with symptoms lasting more than a week, or past history of learning difficulties or attention deficit hyperactivity disorder (ADHD). There are validated prediction rules (e.g. Predicting Persistent Post-concussive Problems in Pediatrics (5P) clinical risk score) or risk tables to provide prognostic counselling and follow-up advice to children and their caregivers on their potential risk of developing post-concussive symptoms (see Tables 6.3.3 and 6.3.4 above for further details*)*.
PREDICT evidence-informed recommendation 38	In children whose post concussive symptoms do not resolve within 4 weeks, clinicians should provide or refer the child to specialist services for persistent post-concussive symptom management.

Rationale

The PREDICT GWG **adapted evidence-informed recommendations** 9A and 9B of the CDC 2018 Guideline and **created a new evidence-informed recommendation** (Rec 36) for question 4a: which children require follow-up for post-concussive symptoms?

The CDC Guideline recommendations were derived from a systematic review (33) addressing prognostic factors for poor outcome grouped into i) follow-up of less than 12 months and ii) follow-up of 12 months or longer. A total of 27 studies (19 for less than 12 months and 15 for greater than 12 months follow-up) were identified exploring associations between candidate factors and various post-concussive outcomes.

The PREDICT literature search identified 52 new studies, of these 2 studies were deemed key to inform this question (95, 115). Iverson 2017 is a systematic review of 101 studies and identified the following as potential predictors of persistent symptoms greater than one month: severity of a person's acute and subacute symptoms, development of subacute problems such as headaches or depression, preinjury history of mental health problems. The teenage years, particularly high school, were the most vulnerable time period for having persistent symptoms—with greater risk for girls than boys. Zemek 2016 (95) is a multicentre prospective cohort study of 3,063 patients who presented to the ED with head injury and developed a 12 point clinical risk score for persistent post-concussive symptoms at 28 days including: female sex, age of 13 years or older, physician-diagnosed migraine history, prior concussions with symptoms lasting longer than 1 week, headache, sensitivity to noise, fatigue, answering questions slowly, and 4 or more errors on the Balance Error Scoring System tandem stance (area under the curve in validation cohort 0.68 [95% CI, 0.65–0.72]). Other studies identified in the PREDICT literature search did not contribute significantly to these recommendations.

The PREDICT GWG **adapted evidence-informed recommendations** 11A and 11B of the CDC 2018 Guideline and **created a new evidence-informed recommendation** (Rec 36) for questions 4b: what type of follow-up for post-concussive symptoms (PCS) and question 4c: when should children be followed-up? The CDC Guideline recommendations for follow-up of patients with poor prognosis were derived from one study (97), a cohort study of 670 children who presented to a tertiary referral emergency department with mTBI and 197 children who presented with extracranial injury to investigate the epidemiology and natural history of PCS symptoms. Among school-aged children with mTBI, 13.7% were symptomatic 3 months after injury and provided support for the validity of diagnosis of PCS in children.

The PREDICT literature search identified 3 new studies to inform question 4b, what type of follow up (113, 114, 116). These studies were however small in size. Babcock 2017 (116) was a single arm study of 21 adolescent/parent dayads to pilot a Web-based intervention to improve PCS symptoms post mTBI. Mortenson 2016 (114) is a pilot RCT of 65 parents of children with concussion that found early intervention telephone counselling with parents did not significantly improve PCS in children and youth. Nowacki 2017 (113) was a cohort of 305 children who presented with mild TBI and were enrolled in a follow-up program to screen for persistent PCS and referred if necessary. Overall, 19% of children had problems, 14% were referred for special care.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☒ Yes ☐ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure

Comment: Evidence shows (Zemek *et al.*) that the sensitivity and specificity of determining children at risk of persistent post concussive symptoms following a head injury in an acute care facility is moderate at best. In light of this the Guideline Working Group have recommended that all children presenting within 72 hours of a head injury are reviewed in primary care at 1–2 weeks to determine the presence of post concussive symptoms. This may have resource implications. However, conversely not managing, or not identifying, persistent post concussive symptoms appropriately also has resource implications. Throughout Australia and New Zealand there is considerable heterogeneity with regards to the provision of health care for patients with persistent post concussive symptoms. Further work needs to be undertaken by the appropriate national and state-based health systems to address this access.

6.4 Discharge Q5 (a) – In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to sport should be provided to children and their caregivers?

6.4.1 PREDICT question

PREDICT Guideline discharge Q5 (a)

In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to sport should be provided to children and their caregivers?

6.4.2 Source question

Berlin (2017) Question 8

When should children with concussion return to sport?

6.4.3 Source recommendations

A systematic review of sports concussion management in children (Davis et al, 2017) was conducted for the International Concussion in Sport Group (CISG) to inform the 5th International Consensus Conference on Concussion in Sport (24). This systematic review also provided recommendations, and this guidance is referred to here as the Berlin Guideline.

Berlin Guideline (2017) Return to sport – Recommendation 1

Children and adolescents should not return to sport until they have successfully returned to school, however early introduction of symptom-limited physical activity is appropriate.

Berlin Guideline (2017) Return to sport – Recommendation 2

Children and adolescents with sport-related concussion should commence a modified non-contact exercise programme, supervised by qualified personnel, before full contact training and/or game day play can resume.

6.4.4 Source evidence

Five studies relevant to review Question 8 were identified in Berlin Guideline (2017). The Berlin Guideline (2017) authors noted that these studies were 'typically observational cohorts with either prospective or retrospective data acquisition'. Synopses and citations are shown in Table 6.4.1 while study characteristics and summary of findings are presented in Table 6.4.2.

Table 6.4.1 Studies identified for return to sport – Question 8 in Berlin (2017)

Ref No	Citation	Synopsis
26	Kerr ZY, Zuckerman SL, Wasserman EB, et al. Concussion symptoms and return to play time in youth, high school, and college American football Athletes. JAMA Pediatr 2016; 170:647–53	Kerr reported on over 1400 concussions from three different cohorts, in which more youth athletes (10%) return to sport in <1 day compared with high school (1%) or collegiate athletes (5%), and the authors offer several potential reasons for athletes returning to sport prematurely, such as failure to report symptoms and delayed onset of symptoms. Fewer collegiate athletes (7%) had prolonged return to sport (> 1 month) than youth (16%) or high school athletes (20%).
85	Purcell L, Harvey J, Seabrook JA. Patterns of recovery following Sport-Related concussion in children and adolescents. Clin Pediatr 2016; 55:452–8.	A retrospective cohort comparing children (8–12 years) with adolescents (13–17 years) demonstrated a trend for more symptoms and greater symptom severity in adolescents. Younger children became symptom-free significantly faster than adolescents (12 days vs 14 days, $p = 0.04$), had a lower likelihood of persistent (> 30 days) symptoms (11.3% vs 30.3%) and trended towards a more rapid return to sport (14 days vs 19.5 days, $p = 0.06$). Only 14.5% of children took longer than 1 month to return to sport, compared with 35.3% of adolescents.
89	McClincy MP, Lovell MR, Pardini J, et al. Recovery from sports concussion in high school and collegiate Athletes. Brain Inj 2006;20: 33–9.	A study of high school and collegiate athletes found that symptoms, visual memory and speed composite scores were worse than baseline on postinjury day (PID) 2 and 7, with resolution by PID 14. Verbal memory composite scores continued to show deficits at PID 14. This study emphasises the need for multimodality clinical assessment but did not distinguish recovery curves for high school and collegiate athletes.
112	Carson JD, Lawrence DW, Kraft SA, et al. Premature return to play and return to learn after a sport-related concussion: physician's chart review. Can Fam Physician 2014;60: e310–e12–5.	A retrospective cohort of 159 clinic patients showed that elementary school athletes returned to play faster (11.6 days) than high school (25.1 days) or collegiate athletes (23.6 days; $p < 0.02$). This study documented symptom exacerbation in over 43% of the entire cohort after return to learn or return to sport
117	McKeon JM, Livingston SC, Reed A, et al. Trends in concussion return-to-play timelines among high school Athletes from 2007 through 2009. J Athl Train 2013;48: 836–43.	McKeon found that 35% of high school students with concussion return to sport in 3–6 days, 71% in 7–9 days and 89% by 21 days. No comparison was made to adults or younger children.

Table 6.4.2 Study characteristics and findings for return to sport – Question 8 in Berlin (2017)

Paper	Journal	Design	N	Age groups	Time points	Outcome	Main findings	Notes/Limitations	LoE
Kerr 2016 (117)	JAMA Pediatrics	Prospective cohort	sport-related concussion (n= 1429) RTsp (n= 1409)	Youth, High school, College	<1d, <1w, 1–2w, 2–4w, > 4w	RTsp (clinically determined)	RTsp<1d: Youth 10% > High school 1%.No signif difference between youth & College or High School & College. RTsp > 30d: Youth 16% & High school 20% > college 7%	Concussion diagnosed clinically by ATC, MD 3 different cohorts (YFSS, NATIO, NCAA) each slightly different RTsp determination by clinician, differed by cohort	3
McClincy 2006 (118)	Brain Injury	Prospective cohort	(n= 104)	High school, College	PID2, 7, 14	ImPACT: Symptom, Verbal Memory, Visual Memory & Speed composite scores	Compared to baseline: Symptoms, Visual Memory, Speed worse PID2, 7, recover by PID14. Verbal Memory impaired all time-points.	Unable to separate high school from college Retrospective look at prospectively acquired data. Unclear how 104 were selected from larger dataset	3
McKeon 2013 (119)	Journal of Athletic Training	Descriptive cohort	(n= 81)	High school	<1d, 1–2d, 3–6d, 7–9d, 10–21d, > 21d, no return	RTsp (clinically determined by MD, DO)	<1d 1.3%; 1–2d 2.5%; 3–6d 35%; 7–9d 71%; 10–21 & > 21d 89%; 6 seasons ended	No comparison to youth or adult/college data RTsp differed by clinician, uncertain what criteria used.	3
Purcell 2016 (120)	Clinical Pediatrics	Retrospective cohort	Patients (n= 198) Concussion (n= 220)	(Child= C) 8–12yrs (Adol= A) 13–17yrs	From chart (rounded to week/ month)	Symptom-free, RTL (with or without accommodations) , RTsp (full game play)	Trend for Adolescents more symptoms, more severe than Child Symptom-free: C 12d; A 14d (.04); > 1m C 11%; A 30% RTL: C 4d, A 2.5d (NS); 73% C & A RTL <7d RTsp: C 14d, A 19.5d (.06); > 1m C 15%; A 36%	Retrospective review; time points rounded to nearest week/month Different practitioners, different documentation No adult comparison group	3
Carson 2014 (121)	Canadian Family Physician	Retrospective cohort	Patients (n= 159) sport-related concussion (n= 170)	Elementary, High school, College	From chart	Premature RTL, RTsp (worsened sx at return)	All groups: Premature RTL 44%; premature RTsp 43%. RTsp: Elementary 11.6d, High school 25.1d, College 23.6d (.02)	No analysis of premature RTL/RTsp by age group Different data abstractors	3

Source: Berlin (2017) Online Supplementary Table 8

Abbreviations: LOE, level of evidence; NATIO, The National Athletic Treatment Injury and Outcomes Network; NCAA, The National Collegiate Athletic Association; PID, Post Injury Day; RTL, Return to Learn; RTSp, Return to Sport; sport-related concussion, Sports-Related Concussion; YFSS, Youth Football Surveillance System.

The following overview provides context for the recommendations and is reproduced from The Berlin (2017) Guideline. It does not refer to the five studies identified in the systematic review for this topic:

> *Current recommendations for return to sport for children have been extrapolated from the adult return to sport consensus guidelines. Adult guidelines have been based on resolution of markers of impaired neurological function (symptoms, cognitive dysfunction, impaired balance) at rest and with gradually increasing exertion. This is primarily to avoid increased risk for repeat injury and potentially worse outcome after repeat injury in those returning prior to full recovery. The relationship between return to sport and return to school is another critical element in management of sport-related concussion in children.*
>
> *Return to contact risk prior to full recovery may predispose to repeat injury and therefore is not recommended. Cognitive or non-contact physical activity might increase symptoms, but it is likely that cognitive activity and gentle, non-contact, aerobic exercise would not predispose to worsened or repeat brain injury. In addition, prolonged inactivity is known to result in greater symptom reporting and delayed recovery.*[68]
>
> *No consistent evidence is available to indicate optimal timing for children or adolescents to return to sport compared with adults. In general, age appears to be an important variable, and studies not limited to sport-related concussion show symptom resolution among high school athletes taking longer than collegiate athletes.*[69] *These have led to more conservative recommendations for return to sport in youth athletes, but specific criteria are lacking. When limited to sport-related concussion studies, return to sport in childhood age groups have demonstrated that adolescents had more symptoms, longer return to sport and higher proportions of slow-to-recover individuals than younger school children.*
>
> *Children requiring regular medication use to control symptoms require expert clinical assessment before return to sport decisions can be made.*

6.4.5 New evidence

Two new studies relevant to this question were identified in the PREDICT Guideline literature search (Table 6.4.3). One study was selected as key to this question (122).

Table 6.4.3 New evidence identified for discharge Q5 (a)

Ref #	Citation
62.	Elbin RJ, Sufrinko A, Schatz P, French J, Henry L, Burkhart S, et al. Removal from Play After Concussion and Recovery Time. Pediatrics. 2016;138(3):9.
63.	McLendon LA, Kralik SF, Grayson PA, Golomb MR. The Controversial Second Impact Syndrome: A Review of the Literature. Pediatric Neurology. 2016;62:42979.

Shading indicates key study

6.4.5.1 Rationale for selection of key evidence

One of the two new studies was selected as key evidence for this question based on the following rationale: McLendon *et al.* was a systematic literature review of the evidence regarding second impact syndrome. Only 17 cases were identified in 7 publications (low quality evidence). While second impact syndrome is rare in the literature, care should be taken to avoid second impact syndrome.

[68] Thomas DG, Apps JN, Hoffmann RG, et al. Benefits of strict rest after acute concussion: a randomized controlled trial. Pediatrics 2015; 135:213–23.

[69] Williams RM, Puetz TW, Giza CC, et al. Concussion recovery time among high school and collegiate Athletes: a systematic review and meta-analysis. Sports Med 2015; 45:893–903.

6.4.5.2 Key evidence data extraction

Table 6.4.4 Data from key evidence for discharge Q5(a)

Study details	Participants	Methods	Outcomes/results
Full citation **McLendon LA**, Kralik SF, Grayson PA, Golomb MR. The Controversial Second Impact Syndrome: A Review of the Literature. Pediatric Neurology. 2016;62:42979 **Country** All **Study type** Literature review Aim To review previous literature on second impact syndrome, discuss possible mechanisms and risk factors, and propose directions for future research.	**Inclusion criteria** (1) observed second head impact with immediate neurological deterioration (seconds to minutes) and (2) cerebral oedema that could not fully be explained by structural pathology, together with (3) verification of continuous post-concussive symptoms after the first impact up to the time of the second impact or (4) evaluation by trained medical professional after observed first impact.	Searched Ovid and PubMed searches from 1946 to July 2015 using the terms "second impact syndrome," "repeat concussion," and "catastrophic brain injury." In addition, review articles were found using a combination of the terms, "concussion," "second impact syndrome," and "repetitive head trauma."	Seventeen patients in seven publications met the criteria of having two witnessed hits and persistent symptoms from the first to the second concussion. Ten of the 17 (59%) included individuals were football players. All were male. Ages ranged from 13 to 23 years. All children with poor outcomes (death or permanent disability) were younger than 20 years, while four of the five players with good outcomes were older than 19 years. The lag time from first to second concussion ranged from one hour to four weeks, and in many cases, at least one of the two hits appeared minor. **Conclusion** American football, male gender, and young age appear to be associated with second impact syndrome. Controversies surrounding this syndrome are discussed. There is a need for prospective studies to clarify risk factors and outcomes of second impact syndrome to guide return-to-play recommendations for young athletes.

6.4.6 Key considerations for assessing the evidence

None.

6.4.7 Working Group recommendation deliberations

Table 6.4.5 Clinical judgement form for discharge Q5 (a)

PREDICT Guideline discharge Q5 (a)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to sport should be provided to children and their caregivers?**
Source recommendation/s	
Berlin (2017) Australia, USA, Canada 2 recommendations: Return to sport recs 1 and 2	**Berlin (2017) Return to sport – Recommendation 1** Children and adolescents should not return to sport until they have successfully returned to school, however early introduction of symptom-limited physical activity is appropriate. **Berlin (2017) Return to sport – Recommendation 2** Children and adolescents with sport-related concussion should commence a modified non-contact exercise programme, supervised by qualified personnel, before full contact training and/or game day play can resume.
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☒ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☒ Yes ☐ No ☐ Unsure ☐ N/A
Comment: Berlin (2017) Guidelines address a select patient population in whom their head injury occurred while participating in sport. Although this population is a selective population of all children who receive a head injury there is no consistent evidence that the return to sport recommendations developed from Berlin (2017) are not generalisable to all child with head injury, regardless of mechanism.	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	

PREDICT Guideline discharge Q5 (a)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to sport should be provided to children and their caregivers?

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

Berlin (2017) Return to sport – Rec 1	Berlin (2017) Return to sport – Rec 2
☐ Adopt source guidance	☐ Adopt source guidance
☒ Adapt source guidance	☒ Adapt source guidance
☐ Create new guidance	☐ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☒ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance

PREDICT evidence-informed recommendation 39	Children with mild to moderate head injury should not return to contact sport until they have successfully returned to school. Early introduction (after 24 hours) of gradually increasing, low to moderate physical activity is appropriate, provided it is at a level that does not result in exacerbation of post-concussive symptoms.
PREDICT evidence-informed recommendation 40	Children with post-concussive symptoms should avoid activities with a risk of contact, fall or collisions that may increase the risk of sustaining another concussion during the recovery period.
PREDICT evidence-informed recommendation 41	Children with post-concussive symptoms who play sport should commence a modified non-contact exercise program and must subsequently be asymptomatic before full contact training or game day play can resume.
PREDICT practice point P	A modified non-contact exercise program can be supervised by a parent (for younger children) or sports or health personnel (for children with ongoing significant symptoms or older children wanting to resume contact sport).

Rationale

The PREDICT GWG **adapted evidence-informed recommendations Return to Sport 1 and 2 from the Berlin Guideline** and developed a **new Practice Point**. The Berlin Guideline recommendations were derived from a systematic review of sports concussion management in children (24, 29) and contained 5 studies that were observational cohorts with either prospective or retrospective data acquisition. Although this Guideline focuses on a select population of children who receive a head injury while participating in sport, there is no consistent evidence that the return to sport recommendations are not generalisable to all children with head injuries.

The PREDICT literature search identified 2 new studies, of these, 1 study was deemed key to inform this question (122). McLendon et al. was a systematic literature review of the evidence regarding second impact syndrome. Only 17 cases were identified in 7 publications (low quality evidence). While second impact syndrome is rare in the literature, care should be taken to avoid second impact syndrome.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure

Comment: These recommendations need to be made widely available to education authorities and institutions, and sport and recreation clubs.

6.5 Discharge Q5 (b) – In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning physical activity or play should be provided to children and their caregivers?

6.5.1 PREDICT question

PREDICT Guideline discharge Q5 (b)

*In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning **physical activity or play** should be provided to children and their caregivers?*

6.5.2 Source question

Berlin Guideline (2017) Question 6

How long should children with sport-related concussion rest?

6.5.3 Source recommendations

Berlin Guideline (2017) Rest – Recommendation 1

Similar to adults, a brief period of cognitive and physical rest is advised following sport-related concussion in children. Symptom-limited physical and cognitive activity should then be gradually introduced.

Berlin Guideline (2017) Rest – Recommendation 2

Prolonged rest may prolong symptoms following sport-related concussion in children, and is therefore not recommended.

6.5.4 Source evidence

Ten studies relevant to review Question 6 were identified in the literature search for the Berlin (2017) Guideline, and an additional study presented is also included. The Berlin (2017) Guideline authors made the following general observation about the identified evidence:

> *Several studies had very small samples, and the larger studies were limited by issues with definitions, compliance, selection bias and recall bias. There were no validated data demonstrating the appropriate duration of cognitive or physical rest in children with sport-related concussion.*

Study synopses, where available, and citations are shown in Table 6.5.1 while study characteristics and summary of findings are presented in Table 6.5.2 for all studies except Winkler et al 2015, which is a systematic review.

Table 6.5.1 Studies identified for rest – Question 6 in Berlin Guideline (2017)

Ref No	Citation	Synopsis
77	Brown NJ, Mannix RC, O'Brien MJ, et al. Effect of cognitive activity level on duration of Post-Concussion symptoms. Pediatrics 2014;133:e299–e304	No synopsis
101	Brooks BL, Low TA, Daya H, et al. Test or rest? computerized cognitive testing in the emergency department after pediatric mild traumatic brain injury does not delay symptom recovery. J Neurotrauma 2016;33:2091–6.	No synopsis
102	Gibson S, Nigrovic LE, O'Brien M, et al. The effect of recommending cognitive rest on recovery from sport-related concussion. Brain Inj 2013;27:839–42	No synopsis
103	Howell DR, Mannix RC, Quinn B, et al. Physical activity level and symptom duration are not associated after concussion. Am J Sports Med 2016;44:1040–6.	Exercise at mild or self-selected levels does not appear to prolong symptoms and may shorten symptom duration, and may be particularly beneficial for adolescent athletes. Small amounts of cognitive activity in the acute setting do not appear to substantially prolong symptoms. High levels of cognitive activity may be associated with longer symptom duration, but athletes engaging in minimal, mild and moderate cognitive activity seem to recover at a similar rate.
104	Moor HM, Eisenhauer RC, Killian KD, et al. The relationship between adherence behaviours and recovery time in adolescents after a sports-related concussion: an observational study. Int J Sports Phys Ther 2015;10:225–33.	No synopsis
105	Moser RS, Schatz P, Glenn M, et al. Examining prescribed rest as treatment for adolescents who are slow to recover from concussion. Brain Inj 2015;29:58–63.	No synopsis
106	Renjilian C, Basta L, Wiebe D, et al. Physical activity in pediatric concussion: using accelerometers to evaluate how total daily activity or physical exertion relate to symptoms. Clinical J Sport Med 2015;25:211	No synopsis
107	Thomas DG, Apps JN, Hoffmann RG, et al. Benefits of strict rest after acute concussion: a randomized controlled trial. Pediatrics 2015;135:213–23.	While the results were variable, the single RCT assessing rest post-sport-related concussion in 11–22-year-olds (median age 13.7 years) demonstrated no significant difference in neurocognitive or balance outcomes between those receiving prescribed rest and those receiving usual care, however, those receiving strict rest reported more symptoms and longer symptom duration
108	Winkler R, Taylor NF, Children D. Do children and adolescents with mild traumatic brain injury and persistent symptoms benefit from treatment? A systematic review. J Head Trauma Rehabil 2015;30:324–33	No synopsis
109	Moser RS, Glatts C, Schatz P. Efficacy of immediate and delayed cognitive and physical rest for treatment of sports-related concussion. J Pediatr 2012;161:922–6.	No synopsis
110	Grool AM, Aglipay M, Momoli F, et al; Pediatric Emergency Research Canada (PERC) Concussion Team. Association between early participation in physical activity following acute concussion and persistent postconcussive symptoms in children and adolescents. JAMA 2016;316:2504–14	A recent study presented at the Berlin meeting, included a secondary analysis of 2413 children presenting to ED with concussion, which demonstrated that children who participated in physical activity within 7 days of presentation had a reduced rate of PPCS at 28 days compared with those who participated in no physical activity. The study had many limitations, including an observational trial design, with self-reported questionnaires and inability to control for other factors such as cognitive load, and the authors stated that a well-designed RCT is required to determine the role of early physical activity following sport-related concussion.

Table 6.5.2 Study characteristics and findings for rest – Question 6 in Berlin Guideline (2017)

Paper	Design	Participants (n, age, sex)	Exposure/ intervention (definition)	Outcome (definition)	Results (including statistical outcomes)	Main limitations	LoE
Brooks et al., 2016 (123)	Controlled without randomization	(n= 154); 8–17yrs; 90 male, 64 female	Cognitive exertion in form of CNT while in ED at diagnosis	PCSI score at pre-injury (estimate); 7–10 days; 1 month; 2 month; 3 month	No significant difference in % symptomatic at any of the time points.	Selection bias, participants self-selected whether or not to undergo testing	3
Howell et al., 2016 (124)	Observational cohort study	(n= 364); 8–27yrs (some analyses for <19yrs separated out); 222 male, 142 female	Physical activity level	Duration of symptoms (days)	Pediatrics/ Adolescents – higher levels of physical activity were associated with shorter symptom duration	Patients self-selected activity level	3
Moor et al., 2015 (125)	Observational cohort study	(n= 56); 12–19yrs; 30 male, 26 female	Adherence to treatment recommendation (modified Sport Injury Rehab Adherence Scale)	Duration of treatment	No significant association between adherence and duration of treatment	50% response rate, self-report,	3
Thomas et al., 2015 (126)	Randomized controlled trial	(n= 88); 11–22 years. 34 female, 65 male	Strict rest	Symptom duration, neurocognitive function, balance	Strict rest associated with higher symptom score and longer duration of symptoms	Unclear if "usual care group" also employed strict rest	2
Moser et al., 2015 (127)	Descriptive natural history	(n= 13); 12–17yrs; 7 male, 6 female	Cognitive and physical rest	CNT scores	Rest between visits resulted in greater improvement	No control group	3
Brown et al., 2014 (128)	Observational cohort study	(n= 355); 8–23yrs, 220 male, 135 female	Level of cognitive activity between visits	Symptom duration	Highest levels of cognitive activity associated with prolonged recovery; other levels of cognitive activity showed similar recovery	Self selected activity levels	3
Gibson et al., 2013 (129)	Retrospective cohort study	(n= 184); 8–26yrs; 50 female 134 male	Recommendation for cognitive rest	Symptom duration (> 30 days)	No effect of recommendation for cognitive rest on symptoms > 30 days	Confounding by indication	4
Moser et al., 2012 (130)	Descriptive natural history	(n= 49); 14–23yrs; 33 male, 16 female	Timing of recommendation for physical and cognitive rest (1–7d, 8–30d, > 30d post injury)	CNT scores	Rest was associate with improvement in scores regardless of timing	No control group	3
Renjilian et al., 2015 (131)	Prospective cohort study	(n= 34); 11–17yrs	Physical activity (accelerometry measured)	Symptom scores	Early in recovery (< 5 days) rest appeared beneficial in decreasing symptoms	Self-selected activity level	3

Paper	Design	Participants (n, age, sex)	Exposure/ intervention (definition)	Outcome (definition)	Results (including statistical outcomes)	Main limitations	LoE
Grool et al 2016 (132)	Observational Cohort Study	(n= 2413); 5–17.99 yrs	Self-report questionnaire on physical activity in first 7 days post enrolment.	Presence of PPCS, at 28 days. (≥ 3 new or worsening individual symptoms compared with the pre-concussion status)	At 7 days 69.5% reported participating in physical activity, 30.5% reported no physical activity. Early participation in any type of physical activity compared with no physical activity was associated with lower risk of PPCS 24.6% vs 43.5% at 28 days.	Observational, Unmeasured confounders, Self report, No record of duration/frequency of physical activity, No record of cognitive load, Treatment varied across sites/physicians, Activity between 7–28 days not recorded.	3

Source: Berlin (2017) Online Supplementary Table 6

Abbreviations: CNT, Computerised Neuropsychological Tests; ED, Emergency Department; LoE, level of evidence; PCSI, Post-Concussion Symptom Inventory, PPCS, persistent Post-concussive symptoms

The following overview provides context for the recommendations and is reproduced from The Berlin (2017) Guideline. It refers to only one of the studies identified in the systematic review for this topic:

> *Previous Berlin statements have identified rest, both cognitive and physical, as 'the cornerstone of management of concussion', until an athlete is asymptomatic. However, the evidence for this recommendation is not strong, and in particular, the optimal duration of rest in children has not been clearly articulated. We found that, while rest in the first few days following sport-related concussion in children may be beneficial, prolonged rest has not demonstrated any advantage and may even delay recovery. This applies to both physical and cognitive rest.*
>
> *The intensity of physical and cognitive activity does seem to correlate with recovery. Mild to moderate levels of both cognitive and physical activity are correlated with improved outcomes compared with high-intensity levels of activity. These effects may be age-dependent,[103] with some evidence suggesting greater response to mild-to-moderate exercise in adolescents compared with other age groups.[103]*

Note: citation 103 refers to Howell et al 2016 in Table 6.5.2.

6.5.5 New evidence

Fourteen studies relevant to this question were identified in the PREDICT Guideline literature search (Table 6.5.3). Of these, one study was selected as key for this question (132); however, on further inspection this study had been included in the Berlin Guideline.

Table 6.5.3 New evidence identified for discharge Q5 (b)

Ref #	Citation
64.	Anderson V, Manikas V, Babl FE, Hearps S, Dooley J. Impact of Moderate Exercise on Post-concussive Symptoms and Cognitive Function after Concussion in Children and Adolescents Compared to Healthy Controls. International Journal of Sports Medicine. 2018;39(9):696–703.
65.	Buckley TA, Munkasy BA, Clouse BP. Acute cognitive and physical rest may not improve concussion recovery time. The Journal of Head Trauma Rehabilitation. 2016;31(4):233–41.
66.	DiFazio M, Silverberg ND, Kirkwood MW, Bernier R, Iverson GL. Prolonged Activity Restriction After Concussion: Are We Worsening Outcomes? Clinical Pediatrics. 2016;55(5):443–51.
67.	Grool AM, Aglipay M, Momoli F, Meehan WP, 3rd, Freedman SB, Yeates KO, et al. Association Between Early Participation in Physical Activity Following Acute Concussion and Persistent Postconcussive Symptoms in Children and Adolescents. JAMA. 2016;316(23):2504–14.
68.	Harriss A, Woehrle E, Barker A, Moir ME, Fischer L, Fraser D, et al. The impact of aerobic exercise training on autonomic function in adolescent sport-related concussion. FASEB journal. 2018;32(1).
69.	Howell DR, Mannix RC, Quinn B, Taylor JA, Tan CO, Meehan WP, 3rd. Physical Activity Level and Symptom Duration Are Not Associated After Concussion. American Journal of Sports Medicine. 2016;44(4):1040–6.
70.	Howell DR, Taylor JA, Tan CO, Orr R, Meehan WP, 3rd. The Role of Aerobic Exercise in Reducing Persistent Sport-related Concussion Symptoms. Medicine & Science in Sports & Exercise. 2019;51(4):647–52.
71.	Leddy JJ, Haider MN, Hinds AL, Darling S, Willer BS. A Preliminary Study of the Effect of Early Aerobic Exercise Treatment for Sport-Related Concussion in Males. Clinical Journal of Sport Medicine. 2018;19:19.
72.	Micay R, Richards D, Hutchison MG. Feasibility of a postacute structured aerobic exercise intervention following sport concussion in symptomatic adolescents: a randomised controlled study. BMJ Open Sport & Exercise Medicine. 2018;4(1):e000404.
73.	O'Brien MJ, Howell DR, Pepin MJ, Meehan WP, 3rd. Sport-Related Concussions: Symptom Recurrence After Return to Exercise. Orthopaedic Journal of Sports Medicine. 2017;5(10).
74.	Sufrinko AM, Howie EK, Elbin RJ, Collins MW, Kontos AP. A Preliminary Investigation of Accelerometer-Derived Sleep and Physical Activity Following Sport-Related Concussion. Journal of head trauma rehabilitation. 2018;33(5):E64-E74.
75.	Taubman B, Rosen F, McHugh J, Grady MF, Elci OU. The timing of cognitive and physical rest and recovery in concussion. Journal of Child Neurology. 2016;31(14):1555–60.
76.	Worts PR, Burkhart SO, Kim JS. A Physiologically Based Approach to Prescribing Exercise Following a Sport-Related Concussion. Sports Medicine. 2019;49(5):683–706.
77.	Zemek R, Grool AM, Barrowman N, Freedman SB, Gravel J, Gagnon I, et al. Early resumption of physical activities and persistent post-concussive symptoms following paediatric concussion. Brain Injury. 2016;30(5-Jun):771.

Shading indicates key studies.

6.5.5.1 Rationale for selection of key studies and relevance to overall evidence

One of the 14 new studies was selected as key evidence for this question based on the following rationale: Grool *et al.* was a secondary analysis from a large prospective cohort study addressing the question of early versus delayed return to physical activity following head injury and risk of persistent concussion symptoms and was included as a study in the Berlin Guideline.

6.5.5.2 Key evidence data extraction

Table 6.5.4 Data from key evidence for discharge Q5(b)

Study details	Participants	Methods	Outcomes/results	Comments (quality)
Full citation **Grool AM**, Aglipay M, Momoli F, Meehan WP, 3rd, Freedman SB, Yeates KO, et al. Association Between Early Participation in Physical Activity Following Acute Concussion and Persistent Postconcussive Symptoms in Children and Adolescents. JAMA. 2016;316(23):2504–14 **Country**: Canada **Study type** Prospective, multicenter cohort study **Aim** To investigate the association between participation in physical activity within 7 days postinjury and incidence of persistent postconcussive symptoms (PPCS).	**Inclusion criteria** ED presentation for acute head injury occurring within the preceding 48 hours, who met concussion diagnosis criteria according to the 2012 Zurich consensus statement. Exclusion criteria were a Glasgow Coma Scale score of 13 or less; any abnormality on brain computed tomography or magnetic resonance imaging; neurosurgical intervention, intubation, or intensive care unit admission; multisystem injury requiring hospitalization; severe pre-existing neurological developmental delay resulting in communication difficulties; intoxication; absence of trauma as the primary event; previously enrolled in this same study; insurmountable language barrier; or inability to follow-up by phone or electronic-mail.	This research comprises a planned secondary analysis of the Predicting Persistent Postconcussive Problems in Pediatrics (5P) study, a prospective, multicenter cohort study that recruited participants from August 2013 until June 2015 at 9 Pediatric Emergency Research Canada (PERC) network tertiary pediatric emergency departments (EDs).	Physical activity participation and post-concussive symptom severity were rated using standardized questionnaires in the ED and at days 7 and 28 postinjury. PPCS (≥3 new or worsening symptoms on the Post-Concussion Symptom Inventory) was assessed at 28 days post enrolment. Early physical activity and PPCS relationships were examined by unadjusted analysis, 1:1 propensity score matching, and inverse probability of treatment weighting (IPTW). Sensitivity analyses examined patients (≥3 symptoms) at day 7. Among 2,413 participants who completed the primary outcome and exposure, (mean [SD] age, 11.77 [3.35] years; 1205 [39.3%] females), PPCS at 28 days occurred in 733 (30.4%); 1677 (69.5%) participated in early physical activity including light aerobic exercise (n = 795 [32.9%]), sport-specific exercise (n = 214 [8.9%]), noncontact drills (n = 143 [5.9%]), full-contact practice (n = 106 [4.4%]), or full competition (n = 419 [17.4%]), whereas 736 (30.5%) had no physical activity. On unadjusted analysis, early physical activity participants had lower risk of PPCS than those with no physical activity (24.6% vs 43.5%; Absolute risk difference [ARD], 18.9% [95%CI, 14.7%-23.0%]). Early physical activity was associated with lower PPCS risk on propensity score matching (n = 1108 [28.7% for early physical activity vs 40.1% for no physical activity]; ARD, 11.4% [95%CI, 5.8%-16.9%]) and on inverse probability of treatment weighting analysis (n = 2099; relative risk [RR], 0.74 [95% CI, 0.65–0.84]; ARD, 9.7%[95%CI, 5.7%-13.7%]). Among only patients symptomatic at day 7 (n = 803) compared with those who reported no physical activity (n = 584; PPCS, 52.9%), PPCS rates were lower for participants of light aerobic activity (n = 494 [46.4%]; ARD, 6.5% [95%CI, 5.7%-12.5%]), moderate activity (n = 176 [38.6%]; ARD, 14.3% [95%CI, 5.9%-22.2%]), and full-contact activity (n = 133 [36.1%]; ARD, 16.8% [95%CI, 7.5%-25.5%]). No significant group difference was observed on propensity-matched analysis of this subgroup (n = 776 [47.2% vs 51.5%]; ARD, 4.4% [95%CI, −2.6% to 11.3%]).	Among participants aged 5 to 18 years with acute concussion, physical activity within 7 days of acute injury compared with no physical activity was associated with reduced risk of PPCS at 28 days. Although this evidence is from a large, well designed observational study the outcome was self-reported and there was limited ability to adjust for factors such as cognitive load. A well-designed randomized clinical trial is needed to determine the benefits of early physical activity following concussion.

6.5.6 Key considerations for assessing the evidence

None.

6.5.7 Working Group recommendation deliberations

Table 6.5.5 Clinical judgement form for discharge Q5 (b)

PREDICT Guideline discharge Q5 (b)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning physical activity or play should be provided to children and their caregivers?**
Source recommendation/s	
Berlin (2017) Australia, USA, Canada 2 recommendations: Rest recs 1 and 2	**Berlin Guideline (2017) Rest – Recommendation 1** Similar to adults, a brief period of cognitive and physical rest is advised following sport-related concussion in children. Symptom-limited physical and cognitive activity should then be gradually introduced. **Berlin Guideline (2017) Rest – Recommendation 2** Prolonged rest may prolong symptoms following sport-related concussion in children, and is therefore not recommended.

GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?	If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☐ Yes ☒ No ☐ Unsure ☐ N/A	☒ Yes ☐ No ☐ Unsure ☐ N/A
Comment: Berlin (2017) Guidelines address a select patient population in whom their head injury occurred while participating in sport. Although this population is a selective population of all children who receive a head injury there is no consistent evidence that the return to activity recommendations developed from Berlin (2017) are not generalisable to all child with head injury, regardless of mechanism.	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☒ Yes ☐ No ☐ Unsure ☐ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?	
Berlin Guideline (2017) Rest – Rec 1 ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance	Berlin Guideline (2017) Rest – Rec 2 ☐ Adopt source guidance ☒ Adapt source guidance ☐ Create new guidance
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☒ Evidence-informed recommendation/s ☐ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT evidence-informed recommendation 42	Children with mild to moderate head injury should have a brief period of physical rest post injury (not more than 24–48 hours post injury).
PREDICT evidence-informed recommendation 43	Following a mild to moderate head injury, children should be introduced to early (between 24 and 48 hours post injury), gradually increasing, low to moderate physical activity, provided that it is at a level that does not result in significant exacerbation of post-concussive symptoms. Physical activities that pose no or low risk of sustaining another concussion can be resumed whenever symptoms improve sufficiently to permit activity, or even if mild residual post-concussive symptoms are present.

PREDICT Guideline discharge Q5 (b)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning physical activity or play should be provided to children and their caregivers?

Rationale

The PREDICT GWG **adapted evidence-informed recommendations Rest-1 and Rest-2 from the Berlin Guideline**. The Berlin Guideline recommendations were derived from a systematic review of sports concussion management in children (29) and contained 10 studies that had either small samples or larger studies with limitations such as compliance, selection and recall bias. Although this Guideline focuses on a select population of children who receive a head injury while participating in sport, there is no consistent evidence that the return to physical activity or play recommendations are not generalizable to all children with head injuries.

The PREDICT literature search identified 14 new studies, 1 was selected as key evidence for this question (132). Grool et al. was a secondary analysis from a large prospective cohort study addressing the question of early versus delayed return to physical activity following head injury and risk of persistent concussion symptoms and was also included as a study in the Berlin Guideline. Of the 2,413 participants in the study those who undertook early physical activity (69.5%) had less persistent concussion symptoms (24.6% vs. 43.5%, absolute risk difference 18.9% [95% CI 14.7% to 23.0%]). Results from a recently published randomised clinical trial (133) of 103 adolescent athletes (age 13–18 years) presenting within 10 days of sports related concussion (SRC) supports these conclusions. Individualised sub-symptom threshold aerobic exercise treatment prescribed to adolescents with concussion symptoms during the first week after SRC resulted in faster recovery (median 13 vs. 17 days). Previous recommendations regarding rest following head injury were based mainly on conservative expert opinion.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure

Comment: These recommendations need to be made widely available to education authorities and institutions, and sport and recreation clubs.

6.6 Discharge Q5 (c,f) In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to school and cognitive activity should be provided to children and their caregivers? and In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child’s school?

6.6.1 PREDICT question

PREDICT Guideline discharge Q5 (c)

In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning ***return to school and cognitive activity*** *should be provided to children and their caregivers?*

PREDICT Guideline discharge Q5 (f)

In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child’s school?

6.6.2 Source question

Berlin Guideline (2017) Question 7

What factors must be considered in ‘return to school’ following concussion and what strategy or accommodations should be followed?

6.6.3 Source recommendations

Berlin Guideline (2017) Return to school – Recommendation 1

All schools are encouraged to have a concussion policy that includes education on sport-related concussion prevention and management for teachers, staff, students and parents, and should offer appropriate academic accommodations and support to students recovering from sport-related concussion.

Berlin Guideline (2017) Return to school – Recommendation 2

Students should have regular medical follow-up following a sport-related concussion to monitor recovery and help with return to school.

Berlin Guideline (2017) Return to school – Recommendation 3

Students may require temporary absence from school after injury.

Berlin Guideline (2017) Return to school – Recommendation 4

Clinicians should assess risk factors/modifiers that may prolong recovery and require more/prolonged/formal academic accommodations. In particular, adolescents may require more academic support during concussion recovery.

6.6.4 Source evidence

Eleven studies relevant to review Question 7 were identified in the literature search for the Berlin (2017) Guideline. As each study reported a range of factors relevant to returning to school, results are summarised by these factors rather than by study. The overall synopsis is therefore reproduced here, and the study citations are shown in Table 6.6.1. Study characteristics and summary of findings are presented in Table 6.6.2.

> *Five factors were found to influence return to school following a concussion:*
>
> ***1. Age****: Adolescents tend to have a greater number of and more severe post-concussion symptoms than younger children; tend to take longer to recover and return to school and sport than younger children; and tend to be more concerned about the academic effects of concussion than younger children.*[36 50 85 112]
>
> ***2. Symptom load/severity****: Students with a greater number of symptoms and more severe symptoms tend to take longer to return to school and require more academic accommodations, as well as taking longer to recover and to return to sport.*[19 36 85 111 113 114]
>
> ***3. School resources****: Schools with concussion policies that include student and parent education about concussion tend to practise best-practice guidelines for concussion management; tend to provide more accommodations and greater variety of accommodations to students following concussions; are more likely to form concussion management teams at school to facilitate return to school for concussed students; and have students and parents who are more knowledgeable about concussion.*[115]

***4. Medical follow-up after injury**: Students who receive medical follow-up after an initial assessment in an ED are more likely to receive academic accommodations on return to school following a concussion.*[116]

***5. Certain subjects**: Math poses greater problems for students returning to school after a concussion, followed by reading/ language, arts, science and social studies.*[36]

Between 35% and 73% of students required academic accommodations and/or experience school difficulty after concussion.[19 85 111 114 116] *The literature did not assess specific academic accommodations other than temporary school absence. Post-concussion symptoms such as memory complaints, headache, visual disturbances and vestibular abnormalities may require students to miss some days of school initially after a concussion.*[19 36 50 85 111 113 114 116] *Most students require only a few days off school (2–5 days),*[85 116] *although some evidence suggests that a significant number of students (45%) may return prematurely, resulting in exacerbation or recurrence of post-concussion symptoms.*[112] *Academic accommodations were more likely to be offered to students post-concussion in schools with concussion policies, although mostly informal, and for students who received outpatient medical follow-up after initial assessment in an ED.*[115 116]

Table 6.6.1 Citations of studies identified for return to school – Question 7 in Berlin Guideline (2017)

Ref No	Citations
19	Corwin DJ, Zonfrillo MR, Master CL, et al. Characteristics of prolonged concussion recovery in a pediatric subspecialty referral population. J Pediatr 2014;165:1207–15
36	Ransom DM, Vaughan CG, Pratson L, et al. Academic effects of concussion in children and adolescents. Pediatrics 2015;135:1043–50.
50	Lovell MR, Collins MW, Iverson GL, et al. Recovery from mild concussion in high school Athletes. J Neurosurg 2003;98:296–301.
77	Brown NJ, Mannix RC, O'Brien MJ, et al. Effect of cognitive activity level on duration of Post-Concussion symptoms. Pediatrics 2014;133:e299–e304
85	Purcell L, Harvey J, Seabrook JA. Patterns of recovery following Sport-Related concussion in children and adolescents. Clin Pediatr 2016;55:452–8.
111	Baker JG, Leddy JJ, Darling SR, et al. Factors associated with problems for adolescents returning to the classroom after Sport-Related concussion. Clin Pediatr 2015;54:961–8.
112	Carson JD, Lawrence DW, Kraft SA, et al. Premature return to play and return to learn after a sport-related concussion: physician's chart review. Can Fam Physician 2014;60:e310–e12–5.
113	Corwin DJ, Wiebe DJ, Zonfrillo MR, et al. Vestibular deficits following youth concussion. J Pediatr 2015;166:1221–5.
114	Darling SR, Leddy JJ, Baker JG, et al. Evaluation of the Zurich Guidelines and exercise testing for return to play in adolescents following concussion. Clin J Sport Med 2014;24:128–3
115	Glang AE, Koester MC, Chesnutt JC, et al. The effectiveness of a web-based resource in improving postconcussion management in high schools. J Adolesc Health 2015;56:91–7.
116	Grubenhoff JA, Deakyne SJ, Comstock RD, et al. Outpatient follow-up and return to school after emergency department evaluation among children with persistent postconcussion symptoms. Brain Inj 2015;29:1186–91.

Table 6.6.2 Study characteristics and findings for return to school – Question 7 in Berlin Guideline (2017)

Paper	Study design, Duration, Country	Participants (n, age, sex)	Exposure/ intervention (definition)	Outcome (definition)	Results (including statistical outcomes)	Main limitations	LoE
Baker,2015 (134)	Retrospective, descriptive study (telephone interview of cohort); 2010–2012; USA	Student athletes (n= 91), Aged 13–19yrs	sport-related concussion observed by athletic trainer & assessed by sports medicine physician/ telephone follow-up/ SCAT2, BCTT & ANAM or ImPACT	Factors associated with school difficulties following concussion and school days missed	• Problems with RTS = 35/91 (38.5%) • Age, gender, previous concussions not associated with school problems • Days to recover > 10= 57%, > 21= 29% • Recovery <10 days = less likely to report school problems (p < .01) • Students who reported school problems: (a) longer to become asymptomatic (p <.005) or pass BCTT (p < .03), (b) more symptoms (p <.021), (c) higher severity scores SCAT2 (p < .023) (d) blurred vision (2.5 times) (e) difficulty remembering (1.8 times), (f) ANAM/ ImPACT borderline score (BS) BS= 49% v no-BS= 26% (p < .03) • Missed days of school: higher symptom severity scores (p < .032)	• Significant delay for phone follow-up; mean of 14.4 +/- 9.6 months • Two different CNT used for assessment	4
Brown 2014 (128)	Single Center, prospective cohort Oct 2009 – Jul 2011 USA	Patients (n= 335) Mean age 15 (8–23) yrs 62% male	Concussed patients seen at a sports concussion clinic ≤3 weeks post injury. PCSS & cognitive activity scale	Determine effect of cognitive load on duration of post-concussion symptoms	• Mean PCSS score at initial visit was 30 • Mean duration of symptoms 43 days; no difference between age groups • Total symptom burden at initial visit and cognitive activity independently associated with duration of symptoms • Highest cognitive activity associated with prolonged symptom duration; but no difference between mild or moderate cognitive activity and cognitive rest.	• Included non-sport-related concussions • Cognitive activity scale not validated • Includes adult patients • Specialty sport medicine clinic • Retrospective assessment of pre-existing PCSS symptoms	3
Carson 2014 (121)	Retrospective EMR review April 2006 – March 2011 Canada	Patients (n= 159) from elementary (24.1%), secondary (55.9%) to college/ university (20.0%) Ages not specified 170 concussions 61.8% male	sport-related concussion student-athletes assessed by same family and sport medicine physician who gave advice regarding cognitive and physical rest post-concussion	Premature RTP/RTL defined as recurrence or worsening of symptoms upon RTL or RTP using SCAT and self-report	• Premature return in RTP = 43.5% & RTL = 44.7% • Prior concussion associated with more rest days before return to activity (RTA) (p <.001) • Elementary school patients required fewer rest days to RTA (11.6 days) v High school (25.1) v College/University (23.6) (p = .0163)	• Did not state reasons for going back too soon: ? against medical advice or prior to receiving medical advice • Mixed age cohort – 20% college/university students • Does not explicitly state ages, just level of school	4

Paper	Study design, Duration, Country	Participants (n, age, sex)	Exposure/ intervention (definition)	Outcome (definition)	Results (including statistical outcomes)	Main limitations	LoE
Corwin 2014 (135)	Retrospective EMR review Jul 2010 – Dec 2011 USA	Convenience sample patients (n= 247) (selected from 3740) Median age 14 (7–18) yrs with concussion seen at a tertiary pediatric hospital-affiliated Sports Medicine Clinic 58% male	Concussion – 77% sports related	Identify pre-existing characteristics associated with prolonged recovery	• RTS (median time) Part-time= 12 days (IQR 6–21); Full time w/o accommodations= 35 days (IQR 11–105); symptom-free 64 days (IQR 18–119); full RTP 76 days (IQR 30–153) • 73% symptomatic > 4weeks; 73% prescribed school accommodations; 61% had decline in grades • Associated with prolonged recovery: History of depression or anxiety, dizziness at time of injury; abnormal convergence or symptom provocation on oculomotor exam, history of prior concussion • Symptom provocation with eye exam more likely to have accommodations (p = .0001), take longer to RTS full-time (p = .050), be Symptom free (p = .048), more likely to have decline in grades (p = .035) • Patients with abnormal convergence more likely to have accommodations (p = .038) • RTS full time compared with ages 17–18 yrs: 13–14 yrs= 1.8 times, 15–16 yrs = 1.6 times • Age > 12 years: almost 2 × longer to be symptom-free • History ≥ 2 concussions more than twice as long to become symptom-free (p = .039)	• Relatively small sample size, • Selection bias due to referral of more severe concussions, • Delayed presentation • Retrospective review • 23% not sports related.	4
Corwin 2015 (136)	Retrospective EMR review Jul 2010 – Dec 2011 USA	(n= 247) (NB: same data set as Corwin 2014) Aged 7–18yrs Male 58%	Concussion, 77% sports related. Vestibular deficit classified if abnormalities on VOR and/or tandem gait.	Prevalence & recovery of patients with concussion & vestibular deficits, & correlate with ImPACT results	• 81% had vestibular abnormality on initial exam; took significantly longer to return to school (59 v 6 days p = .001) and be fully cleared (106 v 29 days p = .001); scored more poorly on ImPACT and took longer to recover from deficits • History ≥ 3 concussions had 100% prevalence of vestibular deficits and took longer to resolve.	• Relatively small sample size • Selection bias due to referral of more severe concussions • Delayed presentation • Retrospective review • 23% not sports related.	4
Darling, 2014 (137)	Retrospective chart review and telephone follow-up 2010–2012 USA	Athletes (n= 117) Aged 13–19yrs (75% male) for chart review Patients & parents (n= 91) (77.8%) for telephone follow-up 76.9% male	sport-related concussion; Once asymptomatic (SCAT2), then completed CNT (ANAM or ImPACT) then BCTT, then Zurich Guidelines for RTP	Evaluate success of RTP and return to classroom	• All athletes RTP without exacerbation of symptoms • Telephone follow-up indicated that 38.5% had new issues upon return to the classroom • 48% had 1 or more CNT below average when asymptomatic • Performance on CNT was not predictive of RTL issues	• 2 different CNTs • Last CNT prior to RTP used on average 3 weeks post-injury – school problems could have already resolved • Heterogeneous time of initial evaluation (some day of injury, some not for weeks after injury) • University sport medicine clinic • 2 month period following RTP for phone follow-up – recall bias • Did not describe issues encountered upon RTL or length of issues • No baseline data	4

Paper	Study design, Duration, Country	Participants (n, age, sex)	Exposure/ intervention (definition)	Outcome (definition)	Results (including statistical outcomes)	Main limitations	LoE
Glang, 2015 (138)	Randomised Control Trial Aug-Nov 2011 USA (Knowledge transfer)	High schools in Oregon (n= 25) (13 intervention, 12 control)	*Brain 101* website (intervention), CDC material on safety (not concussion) - Pre-test and post-test	Effect on parents' and athletes' concussion knowledge, behavioural intention and concussion management	• Pre-test/post-test intervention group significantly outperformed controls on sports concussion knowledge p <.0001 • No significant difference between groups in number of school days missed or whether accommodations provided • More intervention schools implemented best- practise guidelines • More test schools formed a concussion management team (CMT) (p = .007) with a coordinator (p = .005) • More students in test schools received a variety of accommodations compared to controls although not statistically significant	• Small sample size • Did not assess other groups (teachers, coaches, etc.) • Outcome primarily RTA, not specifically RTS • Lack of control for other sources of concussion knowledge	2
Grubenhoff, 2015 (139)	Secondary analysis of a prospective longitudinal cohort observational study Oct 2010-Mar 2013 USA	Patients (n= 234) Aged 8–18yrs enrolled, 179 completed follow-up Urban ED 70% male (no PPCS) 66% male (PPCS)	Concussion, prolonged symptoms (≥3 new symptoms > 1 month post-injury)/ sport-related concussion in 49%	Number of follow-up visits after ED visit; number of school days missed; receipt of academic accommodations	• No significant differences in demographic or injury characteristics between no PPCS and PPCS • PPCS occurred in 21% • Only 45% of patients had follow-up appointments after ED visit • Children with PPCS missed twice as many school days (p <.0001) but did not differ in academic accommodations • Outpatient follow-up was associated with receiving academic accommodations • Most academic accommodations were informal • 72% missed at least 1 day of school • 40% received academic accommodations – 53% of patients with PPCS received accommodations	• Secondary data analysis • Urban population only • Short follow-up of only 30 days • Didn't account for reasons for school days missed	4
Lovell, 2003 (140)	Case-control Baseline data collected prior to 2000 and 2001 seasons USA	Concussed high school athletes (n= 64) 94% male 24 controls (67% male)	ImPACT before and after sport-related concussion (36 hours, days 4, 7) compared to non-injured controls	Evaluate memory dysfunction and self- reporting of symptoms in high school athletes with concussion	• Significant decline in memory in concussed athletes compared to controls • Significant differences between preseason and post-injury memory test results at day 4 and day 7 post-injury • Self-reported symptoms resolved by day 4 • Duration of on-field mental status changes was related to memory impairment at 36 hours day 4 and 7 post-injury; also related to slower resolution of self-reported symptoms	• Study and control groups not equivalent in number, gender or sport • Excluded those with LOC • Very short study duration (up to 7 days post-injury) • Ages of athletes not specified	4
Purcell, 2016 (120)	Retrospective chart review Sep 2009 – Dec 2012 Canada	Patients (n= 198) Aged 8–17yrs, 220 sport-related concussion 72.7% male	sport-related concussion assessed at a university sport medicine clinic	Time to symptom-free, RTL and RTP; comparison of children 8–12yrs with adolescent aged 13–17yrs	• Symptom-free (days) 8–12yo = 12 vs 13–17yo = 14 (p = .04) • RTL (days) 8–12yo = 4 vs 13–17yo = 2.5 (p = .86) • RTP (days) 8–12yo = 14 vs 13–17yo= 19.5 (p = .06) • 31.3% were aged 8–12 years • Initial SCAT2 symptom scores higher in adolescents (12.3 vs 10.6 in 8–12yo) (p = .07) • Symptom severity score higher in adolescents (19.0 in 8–12yo vs 27 in 13–17yo) (p = .08) • 39.5% of patients symptom-free at 10 days • 16% still symptomatic 4 weeks after injury • 40.3% required academic accommodations • 81.8% of 8–12yo RTP by 4 weeks vs 62.6% of 13–17yo • RTL within 5 days: children 60%, adolescents 71.8%	• Retrospective chart review • SCAT2 not validated in pediatric patients • Patients seen at sport medicine clinic – care may not be applicable to community as a whole	4

Paper	Study design, Duration, Country	Participants (n, age, sex)	Exposure/ intervention (definition)	Outcome (definition)	Results (including statistical outcomes)	Main limitations	LoE
Ransom, 2015 (141)	Case review-structured school questionnaire Dates not specified USA	Patients (n= 349) Aged 5–18yrs 67% male	Concussion - symptomatic vs recovered/ outpatient concussion clinic large regional medical centre, assessed within 28 days of injury. Parent & child report (69%), parent-only report (31%)	Nature and severity of symptoms and the extent of adverse academic effects of concussion Using PCSI, RBL, CLASS	• Symptomatic students and parents reported higher levels of concern for impact of concussion on school performance ($p < .05$); more school-related problems (Symptoms interfering, diminished academic skills) ($p < .001$) • Symptomatic high school students reported more adverse academic effects than younger students ($p < .05$) • Greater severity of PCS associated with more school-related problems and worse academic effects ($p < .001$) • Higher frequency of impaired neurocognitive scores in symptomatic group ($p < .001$) • High school students more concerned about academic effects ($p < .01$) • Math most problematic class all grade levels followed by reading/language, arts, science, social studies.	• Study Selection bias, does not describe how patients were selected or over what time period • Does not discuss sample size • Outcomes were self reported, neurocognitive testing was not undertaken • Demographics varied between groups (more males and older children in recovered group) – no objective data on academic effects, only parent/ child reports, which may be influenced by other variables.	4

Source: Berlin Guideline (2017) Online Supplementary Table 7.

Abbreviations: ANAM, Automated Neuropsychological Assessment Metrics; BCTT, Buffalo Concussion Treadmill Test; BS, Borderline Score; CLASS, Concussion Learning Assessment and School Survey; CMT, Concussion Management Team; CNT, Computerised Neuropsychological Tests; ED, Emergency Department; EMR, Electronic Medical Record; ImPACT, Immediate Post-Concussion Assessment and Cognitive Test; LOC, Loss of Consciousness; PCS, Post-Concussion Symptoms; PCSI, Post-Concussion Symptom Inventory; PCSS, Post-Concussion Symptom Scale; PPCS, Persistent Post-concussive Symptoms; RBL, Retrospective Baseline; RTA, Return to Activity; RTL, Return to Learn; RTP, Return to Play; RTS, Return to School; SCAT, Sports Concussion Assessment Tool; sport-related concussion, Sport-Related Concussion; VOR, Vestibular Ocular Reflex

The following overview provides context for the recommendations and is reproduced from the Berlin (2017) Guideline. It refers to none of the studies identified in the systematic review for this topic:

> *Children face different issues than adults following sport-related concussion, with return to school/learning being a key goal in the management paradigm. For children and adolescents with rapid recovery from sport-related concussion, returning to school may be straightforward and require a minimum of support. However, students with more symptoms or severe symptoms may have greater difficulty with return to school. Adolescents tend to have more symptoms, greater severity of symptoms, greater academic demands and are more concerned about the academic impact of concussions than younger children and may have more difficulty getting back to school.*
>
> *Initially, students may require a temporary absence from school, usually no more than a few days. However, the optimal length of school absence is unknown, and is likely to vary depending on persistence of symptoms. Most guidelines for return to school recommend minimising the length of time away from school and state that students do not need to be symptom- free to resume school, although there are no validated data available to support this assertion.*[70,71]
>
> *Upon return to school, approximately 35%–73% of children may require academic accommodations to avoid exacerbation of symptoms. The research examined for this review did not specify the types of academic accommodations, but many review articles outline symptom-specific accommodations that can be instituted, such as reduced school attendance, frequent breaks, more time for tests and assignments, preferential seating in the classroom and shorter assignments.*[72,73,74,75] *Academic accommodations are more likely to be offered to children who have regular medical follow-up in the first month after injury, and in schools with a concussion policy.*

6.6.5 New evidence

Eight studies relevant to this question were identified in the PREDICT Guideline literature search (Table 6.6.3). Of these, four were selected as key studies for this question (5, 123, 139, 142).

Table 6.6.3 New evidence identified for discharge Q5 (c)

Ref #	Citation	Note
54.	Andersson K, Bellon M, Walker R. Parents' experiences of their child's return to school following acquired brain injury (ABI): A systematic review of qualitative studies. Brain injury. 2016;30(7):829–38.	Relevant to DISCHARGE Q5 (f) – advice to schools
65.	Buckley TA, Munkasy BA, Clouse BP. Acute cognitive and physical rest may not improve concussion recovery time. The Journal of Head Trauma Rehabilitation. 2016;31(4):233–41.	–
78.	Brooks BL, Low TA, Daya H, Khan S, Mikrogianakis A, Barlow KM. Test or rest? Computerized cognitive testing in the emergency department after pediatric mild traumatic brain injury does not delay symptom recovery. Journal of Neurotrauma. 2016;33(23):2091–6.	–
79.	DeMatteo C, Stazyk K, Giglia L, Mahoney W, Singh SK, Hollenberg R, et al. A Balanced Protocol for Return to School for Children and Youth Following Concussive Injury. Clinical Pediatrics. 2015;54(8):783–92.	Relevant to DISCHARGE Q5 (f) – advice to schools

[70] CanChild McMaster University. Return to activity and school Guidelines for children and youth.
[71] Halstead ME, McAvoy K, Devore CD, et al; Council on Sports Medicine and Fitness Council on School Health. Returning to learning following a concussion. Pediatrics 2013;132:948–57.
[72] Gioia GA. Multimodal evaluation and management of children with concussion: using our heads and available evidence. Brain Inj 2015;29:195–206.
[73] Master CL, Gioia GA, Leddy JJ, et al. Importance of 'return-to-learn' in pediatric and adolescent concussion. Pediatr Ann 2012;41:e160–e166
[74] McGrath N. Supporting the student-athlete's return to the classroom after a sport-related concussion. J Athl Train 2010;45:492–8.
[75] Sady MD, Vaughan CG, Gioia GA. School and the concussed youth: recommendations for concussion education and management. Phys Med Rehabil Clin N Am 2011;22:701–19.

Ref #	Citation	Note
80.	Glang A, Todis B, Ettel D, Wade SL, Yeates KO. Results from a randomized trial evaluating a hospital-school transition support model for students hospitalized with traumatic brain injury. Brain injury. 2018;32(5):608–16.	Relevant to DISCHARGE Q5 (f) – advice to schools
81.	Grady MF, Master CL. Return to School and Learning After Concussion: Tips for Pediatricians. Pediatric Annals. 2017;46(3):e93-e8.	–
82.	Grubenhoff JA, Deakyne SJ, Comstock RD, Kirkwood MW, Bajaj L. Outpatient follow-up and return to school after emergency department evaluation among children with persistent post-concussion symptoms. Brain Injury. 2015;29(10):1186–91.	–
83.	O'Neill JA, Cox MK, Clay OJ, Johnston JM, Jr., Novack TA, Schwebel DC, et al. A review of the literature on pediatric concussions and return-to-learn (RTL): Implications for RTL policy, research, and practice. Rehabilitation Psychology. 2017;62(3):300–23.	–

Shading indicates key studies.

6.6.5.1 Rationale for selection of key evidence

Four of the eight new studies were selected as key evidence for this question based on the following rationale: two were systematic reviews (5, 142) and two were prospective cohort studies (123, 139). Grubenhoff was included in the Berlin Guideline therefore the 3 other studies are discussed below.

Anderson *et al.* was a systematic review of parental experiences during their child's return to school following a head injury. The authors included six qualitative studies in the review. Ten themes were identified and grouped into three clusters: influencing factors (environment, school, parent and child factors); features of interaction (information, communication and collaboration); and quality levels of outcome (conflict, coping and construction of new roles and identities).

O'Neill *et al.* was a systematic review of the range of themes and gaps in the current body of return to learn research. The authors included 35 studies in the review. Key themes identified from the return to learn literature centred on academic outcomes, physician recommendations, length of time to complete return to learn, concussion-related symptom difficulties, and academic accommodations/guidelines. Across these areas, the research identified was inconsistent in terms of providing clear conclusions.

Brooks *et al.* was a matched cohort study of 77 children with mild traumatic brain injury who undertook formal computerised cognitive testing in the emergency department as part of their assessment, compared with 77 children with mild traumatic brain injury who did not undertake the cognitive testing. Participants who underwent cognitive testing did not differ from those who did not undergo acute cognitive testing on mean symptom ratings or the proportion who were not recovered at 7–10 days, 1 month, 2 months, or 3 months

6.6.5.2 Key evidence data extraction

Study details	Participants	Intervention/control	Methods	Outcomes/results	Comments (quality)
Full citation **Andersson K**, Bellon M, Walker R. Parents' experiences of their child's return to school following acquired brain injury (ABI): A systematic review of qualitative studies. Brain Injury. 2016;30(7):829–38 **Country** NA **Study type** Systematic review **Aim** To examine parents' experiences during their child's return to school following ABI. The second aim is to identify themes arising from this review and map the factors and qualities of interaction which influence successful school reintegration.	**Inclusion criteria** Qualitative studies, therefore studies using interviews or focus groups to explore the experiences of parents of children re-entering primary or secondary school following ABI were included.	NA	Six electronic databases relevant to the fields of brain injury and education were searched between 1980–2015. In addition, two qualitative journals and references from articles were hand-searched for further literature. Search results were screened independently by two reviewers for relevance. Studies meeting the inclusion criteria were analysed using the McMasters Critical Review Form for Qualitative Studies.	Two hundred and sixteen articles were screened after duplicates had been removed and 11 were assessed for relevance, resulting in six full text articles for review. The quality of studies was mixed, with only two presenting a high number of quality indicators for qualitative research. Ten themes were identified and grouped into three clusters: influencing factors (environment, school, parent and child factors); features of interaction (information, communication and collaboration); and quality levels of outcome (conflict, coping and construction of new roles and identities).	**Conclusions** Parents' experiences are influenced by the quality of information, communication and collaboration between the school, health professionals and the family. Further well designed qualitative studies examining parents' experiences and support needs are required

Study details	Participants	Intervention/control	Methods	Outcomes/results	Comments (quality)
Full citation **Brooks BL**, Low TA, Daya H, Khan S, Mikrogianakis A, Barlow KM. Test or rest? Computerized cognitive testing in the emergency department after pediatric mild traumatic brain injury does not delay symptom recovery. Journal of Neurotrauma. 2016;33(23):2091–6 **Country** Canada **Study type** controlled cohort **Aim** The objective of this study was to determine if computerized cognitive testing in the emergency department alters symptom outcome from mTBI.	Participants included children and adolescents who presented to the ED of a tertiary care pediatric hospital following mTBI. **Inclusion** criteria were 8–17 years of age, sustained an external force to head or body leading to neurological symptoms, at least one reported symptom attributed to the injury (e.g., dizziness, confusion, headache, balance issues, nausea), and a diagnosis of mTBI or concussion by the emergency physician. **Exclusion** criteria included loss of consciousness exceeding 30 min, Glasgow Coma Scale (GCS) score <13/15, abnormal neuroimaging attributed to the traumatic injury, suspected child abuse, alcohol or drug use at the time of injury, the administration of analgesics that can potentially alter cognition (e.g., codeine, morphine, ketamine), English as a second language, or an upper extremity injury that would have prevented responding on the computerized tests.	Cognitive testing included the CNS Vital Signs computerized battery.	Participants were recruited and tested within the ED. Parents completed the PCSI in the ED to indicate their child's baseline (pre-injury) level of functioning Cognitive testing in the ED was introduced for the final phase of a larger study's data collection on epidemiological outcome from mTBI. Cognitive testing was offered to all participants from this point forward, so those who agreed were not randomly assigned. Computerized cognitive testing was completed with the research assistant in a designated room in the ED. Due to the relatively higher level of noise within an ED environment, compared with a typical neuropsychological testing laboratory, all participants who participated in the cognitive testing wore noise-dampening ear muffs while being tested). Follow-up ratings of post-concussive symptoms, which serve as an indicator of outcome and recovery from mTBI, were completed over the phone using the PCSI as a semi-structured interview at 7–10 days, 1 month, 2 months, and 3 months post-injury.	The primary outcome measure was the Post-Concussion Symptom Inventory (PCSI) Participants included 77 youth with mTBI who underwent computerized cognitive testing (mean age, 13.6; 95% confidence interval [CI] = 13.0–14.2) and were matched to 77 youth with mTBI who did not participate in cognitive testing (mean age, 13.5; 95% CI = 12.9–14.0). Participants who underwent cognitive testing did not differ from those who did not undergo acute cognitive testing on mean symptom ratings or the proportion who were not recovered at 7–10 days, 1 month, 2 months, or 3 months. There also was no difference in symptom outcome for those who underwent a shortened (four subtests, mean time = 16 min) or full-length (seven subtests, mean time = 28 min) version of the computerized test Brief cognitive exertion using a computerized cognitive assessment after mTBI in youth does not result in worse symptoms at these follow-up periods, does not prolong symptom recovery, should not be considered contraindicated to recovery, and could be considered as another tool to aid in the management of these injuries.	

Study details	Participants	Intervention/control	Methods	Outcomes/results	Comments (quality)
Full citation **Grubenhoff JA**, Deakyne SJ, Comstock RD, Kirkwood MW, Bajaj L. Outpatient follow-up and return to school after emergency department evaluation among children with persistent post-concussion symptoms. Brain Injury. 2015;29(10):1186–91. **Country** USA **Study type** Observational **Aim** To describe differences in outpatient follow-up and academic accommodations received by children with and without persistent post-concussion symptoms (PPCS) after emergency department (ED) evaluation.	Children aged 8–18 years with acute (≤6 hours) concussion at time of presentation to a paediatric ED were enrolled in an observational study.	NA	Outcomes were assessed though telephone survey 30 days after injury.	Of 234 enrolled participants, 179 (76%) completed follow-up. PPCS occurred in 21%. Only 45% of subjects had follow-up visits after ED discharge. Follow-up visit rates were similar for those with and without PPCS (58% vs. 41% respectively; p= 0.07). Children with PPCS missed twice as many school days as those without (3 vs 1.5; p<0.001) but did not differ in receiving academic accommodations (36% vs 53%; p= 0.082). Outpatient follow-up was associated with receiving academic accommodations (RR 2.2; 95% CI 1.4–3.5).	**Conclusions** Outpatient follow-up is not routine for concussed children. Despite missing more school days, children with PPCS do not receive academic accommodations more often. Outpatient follow-up may facilitate academic accommodations.

Study details	Participants	Intervention/control	Methods	Outcomes/results	Comments (quality)
Full citation **O'Neill JA**, Cox MK, Clay OJ, Johnston JM, Jr., Novack TA, Schwebel DC, et al. A review of the literature on pediatric concussions and return-to-learn (RTL): Implications for RTL policy, research, and practice. Rehabilitation Psychology. 2017;62(3):300–23. **Country** NA **Study type** Systematic review Aim To identify the full range of themes and gaps in the current body of RTL research.	Inclusion criteria for the search were as follows: (1) publication date between January 2000 and May 2016, (2) publication in a peer reviewed scholarly journal, and (3) publication in English. Studies included diagnostic labels of concussion or mTBI. Results excluded moderate to severe TBI but did not exclude by mechanism of injury (sports, falls, motor vehicle accidents). "Youth" was defined as children or adolescents ages 18 years and under or high school grade levels and below. We excluded articles that focused on individuals in college or above unless they also included data on adolescents in high school or younger. Case studies were excluded, as were studies without empirical data collection. Opinion papers that described RTL protocols and/or yielded qualitative information were also excluded.	NA	Researchers analysed PubMed, PsycINFO, and ERIC databases to identify all recent (January 2000 through May 2016) empirical publications on the RTL process following youth concussions. In addition to the database searches, bibliographies of selected manuscripts were handsearched for additional sources.	A total of 35 articles met inclusion criteria. Key themes identified from the RTL literature centred on academic outcomes, physician recommendations, length of time to complete RTL, concussion-related symptom difficulties, and academic accommodations/ guidelines. Across these areas, the research was fairly inconsistent in terms of providing clear conclusions, likely because of the small number of studies conducted within these areas as well as variability in methodology and terminology. Gaps in the research include a lack of the following: consensus on RTL protocols, agreement on prescription of cognitive rest, guidance for RTL legislation, understanding of communication between systems of care, concussion-related education for systems of care, evidence based programs or interventions for RTL, and the impact on RTL outcomes.	

6.6.6 Key considerations for assessing the evidence

None.

6.6.7 Working Group recommendation deliberations

Table 6.6.4 Clinical judgement form for discharge Q5 (c) and discharge Q5 (f)

PREDICT Guideline discharge Q5 (c)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to school and cognitive activity should be provided to children and their caregivers?**
Discharge Q5 (f)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child's school?**
Source recommendation/s	
Berlin Guideline (2017) Australia, USA, Canada 4 recommendations: Return to school recs 1, 2, 3 and 4	**Berlin Guideline (2017) Return to school – Recommendation 1** All schools are encouraged to have a concussion policy that includes education on sport-related concussion prevention and management for teachers, staff, students and parents, and should offer appropriate academic accommodations and support to students recovering from sport-related concussion. **Berlin Guideline (2017) Return to school – Recommendation 2** Students should have regular medical follow-up following a sport-related concussion to monitor recovery and help with return to school. **Berlin Guideline (2017) Return to school – Recommendation 3** Students may require temporary absence from school after injury. **Berlin Guideline (2017) Return to school – Recommendation 4** Clinicians should assess risk factors/modifiers that may prolong recovery and require more/prolonged/formal academic accommodations. In particular, adolescents may require more academic support during concussion recovery.

GENERALISABILITY of the source recommendation/s

Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question?	If not, is the recommendation generalisable/ transferable to the settings and patients of interest?
☐ Yes ☒ No ☐ Unsure ☐ N/A	☒ Yes ☐ No ☐ Unsure ☐ N/A

Comment: Berlin (2017) Guidelines address a select patient population in whom their head injury occurred while participating in sport. Although this population is a selective population of all children who receive a head injury there is no consistent evidence that the return to school recommendations developed from Berlin (2017) are not generalisable to all child with head injury, regardless of mechanism.

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☒ Yes ☐ No ☐ Unsure ☐ N/A

Comment:

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

Berlin (2017) Return to school – Rec 1	Berlin (2017) Return to school – Rec 2	Berlin (2017) Return to school – Rec 3
☐ Adopt source guidance	☐ Adopt source guidance	☒ Adopt source guidance
☒ Adapt source guidance	☒ Adapt source guidance	☐ Adapt source guidance
☐ Create new guidance	☐ Create new guidance	☐ Create new guidance

Berlin (2017) Return to school – Rec 4

☒ Adopt source guidance
☐ Adapt source guidance
☐ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☒ Not applicable

Comment:

PREDICT Guideline discharge Q5 (c)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to school and cognitive activity should be provided to children and their caregivers?**
Discharge Q5 (f)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child's school?**

PREDICT guidance

PREDICT evidence-informed recommendation 44	Children with mild to moderate head injury should have a brief period of cognitive rest[76] post injury (not more than 24–48 hours post injury).
PREDICT evidence-informed recommendation 45	Following a mild to moderate head injury, children should be introduced to early (between 24 and 48 hours post injury), gradually increasing, low to moderate cognitive activity, at a level that does not result in significant exacerbation of post-concussive symptoms.
PREDICT evidence-informed recommendation 46	Children with post-concussive symptoms should gradually return to school at a level that does not result in significant exacerbation of post-concussive symptoms. This may include temporary academic accommodations and temporary absences from school.
PREDICT evidence-informed recommendation 47	All schools should have a concussion policy that includes guidance on sport-related concussion prevention and management for teachers and staff, and should offer appropriate short-term academic accommodations and support to students recovering from concussion.
PREDICT evidence-informed recommendation 48	Clinicians should assess risk factors and modifiers that may prolong recovery and may require more, prolonged or formal academic accommodations. In particular, adolescents recovering from concussion may require more academic support during the recovery period.
PREDICT practice point Q	Protocols for return to school should be personalised and based on severity of symptoms with the goal being to increase student participation without exacerbating symptoms. Academic accommodations and modifications after concussion may include a transition plan and accommodations designed to reduce demands, monitor recovery and provide emotional support (see Box B).

Rationale

The PREDICT GWG **adapted evidence-informed recommendations Return to school-1 to 4 from the Berlin Guideline** and developed two new recommendations (recs 44,45). The Berlin Guideline recommendations were derived from a systematic review of sports concussion management in children (29) and contained 11 studies, the majority were observational cohorts with either prospective or retrospective data acquisition. Although this Guideline focuses on a select population of children who receive a head injury while participating in sport, there is no consistent evidence that the return to school recommendations are not generalizable to all children with head injuries.

The PREDICT literature search identified 8 new studies, 4 studies were deemed key to inform this question (5, 123, 139, 142). Grubenhoff 2015 was included in the Berlin Guideline therefore was not deemed new. Andersson 2016 (142) is a systematic review of parental experiences during the child's return to school following a head injury. Six qualitative studies identified key themes such as influencing factors (environment, school, parent and child factors), features of interaction (information, collaboration and communication) and quality levels of outcome (conflict, coping and construction of new roles and identities). O'Neill 2017 (5) is a systematic review of the range of themes and gaps in the current body of return to learn research. The authors included 35 studies in the review. Key themes identified from the return to learn literature centred on academic outcomes, physician recommendations, length of time to complete return to learn, concussion-related symptom difficulties, and academic accommodations/guidelines. Across these areas, the research identified was fairly inconsistent in terms of providing clear conclusions. Brooks, Low (123) was matched cohort study of 77 children with mild traumatic brain injury who undertook formal computerised cognitive testing in the emergency department as part of their assessment, compared with 77 children with mild traumatic brain injury who did not undertake the cognitive testing. Participants who underwent cognitive testing did not differ from those who did not undergo acute cognitive testing on mean symptom ratings or the proportion who were not recovered at 7–10 days, 1 month, 2 months, or 3 months.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☒ Yes ☐ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure	☒ Yes ☐ No ☐ Unsure

Comment: These recommendations (particularly PREDICT recommendation 52) requires education resources at both a national and state level.

[76] Low level cognitive activity, in appropriate short periods, that does not exacerbate symptoms.

6.7 Discharge Q5 (d) – In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning screen time should be provided to children and their caregivers?

6.7.1 PREDICT question

PREDICT Guideline discharge Q5 (d)

In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning ***screen time*** *should be provided to children and their caregivers?*

6.7.2 Source question

No source guidelines were identified that address this question.

6.7.3 Source recommendation

No source guidelines were identified that make recommendations about screen time for children after mild to moderate head injury.

6.7.4 Source evidence

Not applicable.

6.7.5 New evidence

No new evidence was identified for this topic in literature search for the PREDICT Guideline.

6.7.6 Key considerations for assessing the evidence

N/A

6.7.7 Working Group recommendation deliberations

Table 6.7.1 Clinical judgement form for discharge Q5 (d)

PREDICT Guideline discharge Q5 (d)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning screen time should be provided to children and their caregivers?**
Source recommendation/s	
None available	
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☐ No ☐ Unsure ☒ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☒ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☐ Yes ☐ No ☐ Unsure ☒ N/A	
Comment:	

PREDICT Guideline discharge Q5 (d)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning screen time should be provided to children and their caregivers?

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

☐ Adopt source guidance
☐ Adapt source guidance
☒ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☒ Consensus-based recommendation/s
☐ Practice point/s
☐ Not applicable

Comment:

PREDICT guidance

PREDICT consensus-based Recommendation 49	Following a mild to moderate head injury, children's use of screens should be consistent with the recommendation for gradually increasing, low to moderate cognitive activity; that is, activity at a level that does not result in significant exacerbation of post-concussive symptoms.
PREDICT practice point R	Parents and caregivers should be aware of general recommendations for screen use in children aged 2–5 years; that is, limiting screen use to 1 hour per day; no screens 1 hour before bed, and devices to be removed from bedrooms before bedtime.
PREDICT practice point S	Parents and caregivers should be aware of general recommendations for screen use in children aged over 5 years; that is, promote that children get adequate sleep (8–12 hours, depending on age), recommend that children not sleep with devices in their bedrooms (including TVs, computers and smartphones) and avoid exposure to devices or screens for 1 hour before bedtime.

Rationale

The PREDICT GWG developed a **new consensus-based recommendation** for question 5d: what discharge advice should be provided concerning screen time. There was no Guideline evidence source to inform these recommendations and the PREDICT literature search did not identify any new studies.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

6.8 Discharge Q5 (e) – In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to driving/operating machinery should be provided to children and their caregivers?

6.8.1 PREDICT question

PREDICT Guideline discharge Q5 (e)

In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to driving/operating machinery should be provided to children and their caregivers?

6.8.2 Source question

No question specific to discharge advice regarding driving was included in the NICE (2014) Guideline, but the following question about discharge advice in general was included.

NICE CG176 Section 10.8

What information and support do patients with head injury say they want? What discharge information should be given to patients with head injury?

6.8.3 Source recommendation

The NICE (2014) Guideline includes a recommendation that advice be given regarding driving but does not specify what that advice should be. However, a suggested written discharge advice card of specific advice about driving is included in the appendix to the Guideline.

NICE CG176 Recommendation 87

Printed advice for patients, family members and carers should be age-appropriate and include:

- *Details of the nature and severity of the injury.*
- *Risk factors (see recommendation 4 and 5) that mean patients need to return to the emergency department.*
- *A specification that a responsible adult should stay with the patient for the first 24 hours after their injury.*
- *Details about the recovery process, including the fact that some patients may appear to make a quick recovery, but later experience difficulties or complications.*
- *Contact details of community and hospital services in case of delayed complications.*
- *Information about return to everyday activities, including school, work, sports and **driving**.*
- *Details of support organisations.*

Developed: 2014

Excerpt from **Suggested written discharge advice** (NICE 2014 Appendices, Section O.6.1, pp295–6)

Things that will help you get better

If you follow this advice you should get better more quickly, and it may help any symptoms you have to go away:

- *DO NOT stay at home alone for the first 48 hours after leaving hospital*
- *DO make sure you stay within easy reach of a telephone and medical help*
- *DO have plenty of rest and avoid stressful situations*
- *DO NOT take any alcohol or drugs*
- *DO NOT take sleeping pills, sedatives or tranquilisers unless they are given by a doctor*
- *DO NOT play any contact sport (for example, rugby or football) for at least 3 weeks without talking to your doctor first*
- *DO NOT return to your normal school, college or work activity until you feel you have completely recovered*
- *DO NOT **drive a car**, motorbike or bicycle or operate machinery unless you feel you have completely recovered.*

6.8.4 Source evidence

6.8.4.1 Recommendation

As presented for DISCHARGE Q2, Recommendation 87 was one of a selection of recommendations derived from three qualitative studies and six surveys about requirements for, and patient preferences regarding, discharge advice (Section 6.2.4, Table 6.2.1). Various themes were identified across patient information and patient support. Neither age nor injury severity were used to stratify the themes, but were indicated within the text, where applicable.

Driving was not discussed in the evidence presented for this question in the NICE (2014) Guideline, nor in the subsequent surveillance report in 2017.

6.8.4.2 Suggested written discharge advice

The suggested written discharge advice was included in the NICE (2014) Appendices as relevant information taken from the appendices of the 2003 and 2007 version of the Guideline. No information was provided regarding its development and is presumably a consensus document.

6.8.5 New evidence

No new evidence was identified for this topic in literature search for the PREDICT Guideline.

6.8.6 Key considerations for assessing the evidence

None.

6.8.7 Working Group recommendation deliberations

Table 6.8.1 Clinical judgement form for discharge Q5 (e)

PREDICT Guideline discharge Q5 (e)	**In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to driving/operating machinery should be provided to children and their caregivers?**
Source recommendation/s	
NICE CG176 (2014) UK 1 recommendation and 1 example discharge notice Rec 87	**NICE CG176 Recommendation 87** Printed advice for patients, family members and carers should be age-appropriate and include: • Details of the nature and severity of the injury. • Risk factors (see recommendation 4 and 5) that mean patients need to return to the emergency department. • A specification that a responsible adult should stay with the patient for the first 24 hours after their injury. • Details about the recovery process, including the fact that some patients may appear to make a quick recovery, but later experience difficulties or complications. • Contact details of community and hospital services in case of delayed complications. • Information about return to everyday activities, including school, work, sports and driving. • Details of support organisations Excerpt from **Suggested written discharge advice** (NICE 2014 Appendices, Section O.6.1, pp295–6) <u>Things that will help you get better</u> If you follow this advice you should get better more quickly, and it may help any symptoms you have to go away: • DO NOT stay at home alone for the first 48 hours after leaving hospital • DO make sure you stay within easy reach of a telephone and medical help • DO have plenty of rest and avoid stressful situations • DO NOT take any alcohol or drugs • DO NOT take sleeping pills, sedatives or tranquilisers unless they are given by a doctor • DO NOT play any contact sport (for example, rugby or football) for at least 3 weeks without talking to your doctor first • DO NOT return to your normal school, college or work activity until you feel you have completely recovered • DO NOT drive a car, motorbike or bicycle or operate machinery unless you feel you have completely recovered.
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☒ Yes ☐ No ☐ Unsure ☐ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☒ Yes ☐ No ☐ Unsure ☐ N/A
Comment:	

PREDICT Guideline discharge Q5 (e)	In infants and children with mild to moderate head injury discharged from the ED or hospital, what discharge advice concerning return to driving/operating machinery should be provided to children and their caregivers?

APPLICABILITY of the source recommendation/s

Is the recommendation relevant to the Australian health care setting?

☐ Yes ☐ No ☒ Unsure ☐ N/A

Comment: The recommendation does not take into consideration relevant Australian and New Zealand legislation.

Adapt, adopt or new guidance

Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline?

NICE CG176 (2014) Rec 87

☐ Adopt source guidance
☒ Adapt source guidance
☐ Create new guidance

Comment:

If new guidance needs to be developed, what type of guidance is appropriate?

☐ Evidence-informed recommendation/s
☐ Consensus-based recommendation/s
☐ Practice point/s
☒ Not applicable

Comment:

PREDICT guidance

PREDICT consensus-based recommendation 50	Adolescents (and children as appropriate) who have had a mild to moderate head injury causing loss of consciousness must not drive a car, motorbike or bicycle, or operate machinery for at least 24 hours.
PREDICT consensus-based recommendation 51	Adolescents (and children as appropriate) who have had a mild to moderate head injury should not drive a car or motorbike, or operate machinery until completely recovered or, if persistent post-concussive symptoms are present, until they have been assessed by a medical professional.

Rationale

The GWG **adapted evidence-based recommendation** 87 from the NICE CG176 Guideline. Recommendation 87 was one of a selection of recommendations derived from three qualitative studies and six surveys about requirements for, and patient preferences regarding, discharge advice. Various themes were identified across patient information and patient support; however, driving was not discussed in the evidence presented for this question in the NICE (2014) Guideline, nor in the subsequent surveillance report in 2017. The PREDICT literature search did not identify any new studies to inform this recommendation.

FEASIBILITY of draft recommendation/s

Will this recommendation result in changes in usual care?	Are there any resource implications associated with implementing this recommendation?	Are there barriers to the implementation of this recommendation?
☐ Yes ☐ No ☒ Unsure	☐ Yes ☒ No ☐ Unsure	☐ Yes ☒ No ☐ Unsure

Comment:

6.9 Discharge Q5 (f) – In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child's school?

6.9.1 PREDICT question

PREDICT Guideline discharge Q5 (f)

In infants and children with mild to moderate head injury discharged from the ED or hospital, what information/advice should be provided to the child's school?

This question is a sub-question of DISCHARGE Q5 (c), and all recommendations and relevant evidence are covered off in that question.

6.10 Discharge Q5 (g) – In children diagnosed with repeat concussion who are discharged from the ED or hospital, what distinct discharge advice should be provided to children and their caregivers?

6.10.1 PREDICT question

PREDICT Guideline discharge Q5 (g)
In children diagnosed with repeat concussion who are discharged from the ED or hospital, what distinct discharge advice should be provided to children and their caregivers?

6.10.2 Source question

No guidelines were identified that posed a question about discharge advice for patients with repeat concussion.

6.10.3 Source recommendation

N/A – a de novo recommendation or practice point would be required for this PREDICT Guideline question.

6.10.4 Source evidence

N/A

6.10.5 New evidence

Five studies relevant to this question were identified in the PREDICT Guideline literature search (Table 6.10.1). No key studies were selected.

Table 6.10.1 New evidence identified for discharge Q5 (g)

Ref ID	Citation
84.	Alsalaheen B, Stockdale K, Pechumer D, Giessing A, He X, Broglio SP. Cumulative Effects of Concussion History on Baseline Computerized Neurocognitive Test Scores: Systematic Review and Meta-analysis. Sports & Health. 2017;9(4):324–32.
85.	Brooks BL, Mannix R, Maxwell B, Zafonte R, Berkner PD, Iverson GL. Multiple Past Concussions in High School Football Players: Are There Differences in Cognitive Functioning and Symptom Reporting? American Journal of Sports Medicine. 2016;44(12):3243–51.
86.	Brooks BL, Silverberg N, Maxwell B, Mannix R, Zafonte R, Berkner PD, et al. Investigating Effects of Sex Differences and Prior Concussions on Symptom Reporting and Cognition Among Adolescent Soccer Players. American Journal of Sports Medicine. 2018;46(4):961–8.
87.	Currie DW, Comstock RD, Fields SK, Cantu RC. A Paired Comparison of Initial and Recurrent Concussions Sustained by US High School Athletes Within a Single Athletic Season. Journal of Head Trauma Rehabilitation. 2017;32(2):90–7.
88.	Curry AE, Arbogast KB, Metzger KB, Kessler RS, Breiding MJ, Haarbauer-Krupa J, et al. Risk of Repeat Concussion Among Patients Diagnosed at a Pediatric Care Network. Journal of Pediatrics. 2019; 4:4

6.10.5.1 Rationale for selection of key evidence

N/A

6.10.5.2 Key evidence data extraction

N/A

6.10.6 Key considerations for assessing the evidence

N/A

6.10.7 Working Group recommendation deliberations

Table 6.10.2 Clinical judgement form for discharge Q5 (g)

PREDICT Guideline discharge Q5 (g)	**In children diagnosed with repeat concussion who are discharged from the ED or hospital, what distinct discharge advice should be provided to children and their caregivers?**
Source recommendation/s	
None available	
Notes on wording changes	
GENERALISABILITY of the source recommendation/s	
Is the setting and patient population in the source recommendation/s representative of the target population in the PREDICT research question? ☐ Yes ☐ No ☐ Unsure ☒ N/A	If not, is the recommendation generalisable/ transferable to the settings and patients of interest? ☐ Yes ☐ No ☐ Unsure ☒ N/A
Comment:	
APPLICABILITY of the source recommendation/s	
Is the recommendation relevant to the Australian health care setting? ☐ Yes ☐ No ☐ Unsure ☒ N/A	
Comment:	
Adapt, adopt or new guidance	
Considering the degree to which the PREDICT clinical question is addressed by the source guideline question and recommendations, and the nature of any new evidence, what type of guidance should be developed for the PREDICT Guideline? ☐ Adopt source guidance ☐ Adapt source guidance ☒ Create new guidance	
Comment:	
If new guidance needs to be developed, what type of guidance is appropriate? ☐ Evidence-informed recommendation/s ☒ Consensus-based recommendation/s ☐ Practice point/s ☐ Not applicable	
Comment:	
PREDICT guidance	
PREDICT consensus-based recommendation 52	Children diagnosed with a repeat concussion soon after the index injury (within 12 weeks), or after multiple repeat episodes are at increased risk of persistent post-concussive symptoms. Parents and caregivers of children with repeat concussion should be referred for appropriate medical review (e.g. to a paediatrician).
Rationale The PREDICT GWG developed a **new consensus-based recommendation** for question 5g: what distinct discharge advice should be provided to children and their caregivers if diagnosed with repeat concussion. There was no Guideline evidence source to inform this recommendation and the PREDICT literature search did not identify any new studies.	

FEASIBILITY of draft recommendation/s		
Will this recommendation result in changes in usual care? ☐ Yes ☐ No ☒ Unsure	Are there any resource implications associated with implementing this recommendation? ☐ Yes ☒ No ☐ Unsure	Are there barriers to the implementation of this recommendation? ☐ Yes ☒ No ☐ Unsure
Comment:		

7 Appendices

Appendix A Membership of the PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children Working Group

Name	Expertise	Affiliation	Conflict of Interest Declaration
Prof Franz Babl (co- hair)	Emergency Physician	Department of Paediatrics, University of Melbourne Consultant, Emergency Department, Royal Children's Hospital Melbourne, Victoria Head, Emergency Research, Murdoch Children's Research Institute (MCRI)	• **Board memberships**: PREDICT has governance of project. PREDICT research may be included in guidelines. • **Memberships:** Royal Australasian College of Physicians, potential end-user of guideline. • **Employment**: Royal Children's Hospital, University of Melbourne – both potential end-users of guidelines. MCRI – research undertaken by me while employed by all three may be included.
Prof Stuart Dalziel (co-chair)	Emergency Physician	Paediatric Emergency Medicine Specialist Director of Emergency Medicine Research Children's Emergency Department Starship Children's Hospital, Auckland, New Zealand Cure Kids Chair of Child Health Research Dept of Paediatrics: Child and Youth Health, University of Auckland	• **Board memberships**: PREDICT has governance of project. PREDICT research may be included in guidelines. • **Memberships:** Royal Australasian College of Physicians, New Zealand Emergency Medicine Network – potential end-user of guideline. • **Employment**: Starship Children's Hospital and the University of Auckland – both potential end-users of guidelines. Research undertaken by me while employed by both may be included. • **Expert testimony:** *Ad hoc* for the New Zealand Coronial Service.
Prof Ed Oakley	Emergency Physician	Chief of Critical Care/ Emergency Physician Royal Children's Hospital Melbourne, Victoria	**Memberships:** • Member of Australasian College of Emergency Medicine Council of Advocacy, Practice and Partnership, Quality and Safety Committee, Research Committee, Clinical Trial Network. • Co-opted member of Executive Committee of PREDICT.
Prof Meredith Borland	Emergency Physician	Consultant, Emergency Department Director of Emergency Medicine Research Perth Children's Hospital, Western Australia School of Medicine, University of Western Australia	• **Board memberships**: PREDICT has governance of the project. PREDICT research may be included in guidelines. • **Memberships:** Australasian College for Emergency Medicine – potential end-user of Guideline. • **Employment**: Perth Children's Hospital – potential end-users of guidelines. Research undertaken by me while employed may be included.
A/Prof Peter Barnett	Sports Physician Emergency Physician	Emergency Consultant Emergency Department, RCH, Melbourne, Victoria	NIL
Dr Ben Lawton	Emergency Physician (mixed Metro)	Emergency Department, Logan Hospital, Queensland	**Board memberships**: PLX
Dr Jo Cole	Emergency Physician (mixed regional)	Emergency Department, Tauranga Hospital, New Zealand	NIL
Glenda Mullen	Nurse Practitioner	Emergency Department, Sydney Children's Hospital, New South Wales	**Memberships:** College of Emergency Nursing Australasia (CENA). Members are likely to be end-users of the Guideline.
Dr Lambros Halkidis	Emergency Physician (mixed regional)	Staff Specialist Emergency Medicine, Emergency Department, Cairns Hospital, Queensland	NIL

Name	Expertise	Affiliation	Conflict of Interest Declaration
A/Prof Elizabeth Cotterell	Paediatrician (Rural)	Director of Paediatrics, Armidale Rural Referral Hospital, New South Wales	• **Affiliations:** School of Rural Medicine, University of New England, Armidale. • **Memberships:** Royal Australasian College of Physicians. Potential end-user of Guideline. • **Employment**: Hunter New England Health. – potential end-user of Guideline.
Prof Gavin Davis	Neurosurgeon /Concussion	Cabrini Hospital, Victoria	**Memberships:** • Board member of the CISG and 9Lives. • Honorary member of AFL Concussion Working Group. • **Other:** Has received travel assistance for meetings from FIFA, NRL, NFL, but has never received any payment from any of these organisations.
Sharon O'Brien	Nurse	Paediatric Nurse and Research Coordinator Emergency Department Perth Children's Hospital, Western Australia	• **Board memberships:** PREDICT has governance of project. PREDICT research may be included in guidelines. • **Employment:** Perth Children's Hospital – potential end-user of guidelines. Research undertaken by me while employed may be included.
Libby Haskell	Nurse Practitioner	Emergency Department Starship Children's Hospital, Auckland, New Zealand	• **Memberships:** PREDICT (executive member 2020), College of Emergency Nurses NZ – potential end-users of Guideline. • **Employment**: Starship Children's Hospital – potential end-user of Guideline.
Prof Stacy Goergen	Radiologist	Director of Research, Monash Imaging, Victoria Clinical Adjunct Professor, Monash University, Melbourne, Victoria	• **Memberships:** Current Chair, Safety Quality and Standards Committee, Royal Australian and New Zealand College of Radiologists (RANZCR) and member of the RANZCR. • **Employment:** Monash Health.
Dr David Perry	Paediatric and Obstetric Radiologist	Radiology, Auckland City Hospital, New Zealand	• **Memberships:** Royal Australasian College of Physicians, New Zealand Emergency Medicine Network – potential end-user of Guideline. • **Employment:** Radiologist at Starship Children's Hospital, potential end-user of Guideline. • **Expert testimony:** Expert witness in abusive head injury cases.
Dr John Craven	Paediatrician/Emergency Physician/ Retrieval	Paediatric Emergency Consultant, Women's and Children's Hospital Adelaide, South Australia Head of Unit and Paediatric Retrieval Consultant SAAS MedSTAR Kids	**Employment:** SAAS MedSTAR, Flinders Medical Centre, Women's & Children's Hospital, Flinders University.
Scott Bennetts	Pre-Hospital – ambulance service	Manager of Clinical Effectiveness, Ambulance Victoria	NIL
Prof Vicki Anderson	Neuro-cognitive Specialist	Head of Psychology, Royal Children's Hospital, Melbourne, Victoria Theme Director, Clinical Sciences Research, MCRI	• **Expert testimony:** Medico legal assessment. • **Payment for lectures/educational tools:** Delivery of keynotes/workshops. • **Royalties:** For published texts.
Dr Anna Lithgow	Paediatrician (Indigenous Health)	Royal Darwin Hospital, Northern Territory	NIL

Name	Expertise	Affiliation	Conflict of Interest Declaration
A/Prof Karen Barlow	Concussion and Rehabilitation	Consultant Paediatric Neurologist, Queensland Children's Hospital, Queensland Child Health Research Centre	• **Memberships**: Royal Australasian College of Physicians - potential end-user of Guideline. • **Consultancy***:* Clinical Pathway for concussion care in Alberta. Paid to University of Calgary. • **Employment:** Chair of Acquired Brain Injury Rehabilitation Research, University of Qld. • **Expert testimony:** Occasional medicolegal work in TBI. • **Honorarium for manuscript prep:** Concussion management – AAN Continuum paper. • **Other grants:** Clinical care pathway for children with concussion. Financial Markets Foundation for Children Grant, Australia. **Board membership:** Highmark interactive, concussion assessment e-health tool.
Dr Roisin Bhamjee	General Practitioner Registrar in training	Clinical Lecturer, Department of General Practice University of Melbourne, Victoria	NIL
Dr Dustin Ballard	Emergency Physician (USA)	Kaiser Permanente, Northern California, USA Visiting scholar, University of Auckland School of Medicine, New Zealand	**Employment:** Work on the Guideline supported by a US/NZ Fulbright Scholarship.
Dr Emma Tavender	Knowledge Translation Co-ordinator	MCRI, Melbourne, Victoria	**Membership:** Co-opted member of PREDICT Executive, Associate Editor of Cochrane EPOC Group. **Employment:** MCRI and work on the Guideline supported by an NHMRC Centre of Research Excellence.
Cate Wilson	PREDICT Research Co-ordinator	MCRI, Melbourne, Victoria	NIL
Michelle Paproth	Consumer	Consumer Representative	NIL

Appendix B Terms of reference for the PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children Working Group

1. Background and objectives

The Guideline Working Group (GWG) was established under the umbrella of the Paediatric Research in Emergency Departments International Collaborative (PREDICT) network and the Murdoch Children's Research Institute.

The specific objective of this GWG was to **develop an evidence-based clinical practice guideline for the acute management of mild to moderate head injury (including concussion) in children** to;

- improve outcomes for children who present with mild and moderate head injuries
- identify all paediatric patients in need of intervention, such as neurosurgical and/or intensive care with an intracranial injury (critical patient-important outcome)
- promote consistency of management (standardisation of observation criteria and duration of hospital stay), and in doing so reduce unnecessary interventions including inappropriate use of cranial computed tomography (CT) scans of the brain in children at very low risk of intracranial injury.

2. Purpose of the PREDICT Guideline Working Group

- Provide advice and guidance on the scope and processes of developing the Guideline.
- Develop consensus around the clinical questions to be investigated and review the literature.
- Evaluate and consider the latest evidence-based literature and other relevant international paediatric head injury guidelines.
- Contribute to the development of content, recommendations and format of the Guideline and supporting material.
- Play a key role as implementers within their hospital/institutions.

3. Membership

Members were representative of emergency medicine, paediatrics, neurosurgery, radiology, pre-hospital care, nursing, psychology and consumers. Membership of the GWG was for the duration of the time to develop and finalise the clinical Guideline for the assessment and management of acute mild to moderate paediatric head injury.

4. Governance structure

The GWG was created and supported by the PREDICT Network as a voluntary collaboration to develop the Guideline. A Guideline Steering Committee convened the GWG and comprised the following members: Prof Franz Babl (Co-Chair), Prof Stuart Dalziel (Co-Chair), A/Prof Ed Oakley, A/Prof Liz Cotterell, Dr Emma Tavender, Professor Meredith Borland, Dr Dustin Ballard and Ms Cate Wilson. Functions of the Guideline Working Group were assisted by representatives from the PREDICT Network and the Murdoch Children's Research Institute Emergency Research Team.

5. Disclosure of interest

A conflict of interest form was completed by all members involved in the GWG to declare any conflicts. A reminder to declare any new conflicts was given throughout the Guideline development process.

6. Confidentiality obligations

Where a GWG member shared confidential information (of their employer organisation or of a third party) during their membership, they made it clear that the information being shared was confidential.

No GWG members could disclose any confidential information of another GWG member to any third party or use any confidential information other than for the purpose of collaborating and developing the Guideline, except for disclosures:

- required by law or government authorities
- to employees, students or financial or legal advisers on a need to know basis and provided they agree to be bound by obligations of confidentiality
- with the prior written consent of the other party.

For the purposes of this section, 'confidential information' means any information or knowledge, in any form or media relating to or representing the intellectual property or other confidential information of a party other than information which:

- was in the public domain at the time of its disclosure or subsequently comes into the public domain otherwise than through breach by the receiving party
- came into the hands of the receiving party by lawful means and without breach of any obligation of confidentiality by any third party
- was in fact known to the receiving party prior to its disclosure to that party.

In parallel any personal information, terms of reference and conflicts provided to the GWG Chair was held in confidence and not shared without consent from the member, unless required by applicable law.

7. Intellectual property

Each member acknowledged and agreed that a member's background (pre-existing) intellectual property would remain the property of the member who provided it.

Members acknowledged and agreed that any new intellectual property in material created or produced during the conduct of the GWG was owned jointly (and in equal shares) by all members.

All members were granted a non-exclusive, perpetual, royalty-free licence to use all new intellectual property in material created or produced during the conduct of the GWG for their internal research and education purposes. No member can commercialise the material created or produced during the conduct of the GWG without prior written consent from the Steering Committee.

8. Acknowledgment

All members must acknowledge the PREDICT network and the National Health and Medical Research Council (NHMRC) when internally and externally referring to the final developed Guideline.

9. Publication

The publication process and procedure were agreed upon and documented in the minutes of the first GWG meeting. In any published form the authorship is awarded to the PREDICT Australian and New Zealand

Guideline for Mild to Moderate Head Injuries in Children Working Group, and all efforts are made to list and acknowledge all members and their institutions.

10. Liability

Each member (and their employer organisation) is liable for their member's acts and omissions in relation to their conduct and work on the GWG.

Appendix C Declaration of interest for the PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children Working Group

The purpose of this declaration of interest was to identify any potential duality of interest in the context of membership of the PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children Working Group for the development of the clinical Guideline entitled **"PREDICT Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children"**. Members were provided with the information listed below.

What to declare

Declaring conflicts is a member's responsibility. A conflict can arise in any situation in which member's interests could influence or appear to influence the independent performance of the responsibilities in developing the guidelines.

Some examples of what should be disclosed are:

- *Interactions* with entities relevant to the Working Group's output. For example, any participation with other Guideline development groups, publications and editorial invites in the area of paediatric or adult head injury, or work with other organisations that have positions/recommendations on the assessment and management strategies in paediatric head injury.
- *Sources of revenues* paid or relevant financial relationships with entities that could be perceived to influence what is to be incorporated into the Guideline.
- *For grants received for your work, you only need to disclose support from entities perceived to be affected financially by the published work*. For example, drug companies and or foundations perceived to have a financial stake in the outcome of the developed recommendations. Public funding sources, such as government agencies, charitable foundations or academic institutions **do not** need to be disclosed.

Appendix D Search parameters for head injury and concussion clinical practice guidelines

The aim of the search for clinical practice guidelines was to identify high quality clinical practice guidelines (CPGs) for the initial management of mild and moderate head injury in children to identify potential questions/recommendations for the new adapted Guideline.

Search parameters
Clinical practice guideline (CPG) or equivalent
2013 onwards
Available in English
Freely accessible
Electronic sources as below
Targeting countries with developed trauma systems (First world) -- Europe and NZ/Aus

The retrieved clinical practice guidelines had to meet minimum quality criteria to be considered an evidence-based CPG (based on items 8 and 12 of the AGREE Instrument): 1) systematic methods were used to search for evidence and 2) there was an explicit link between the recommendations and the supporting evidence.

Data Sources
Electronic health databases
MEDLINE
EMBASE
The Cochrane Library
PsycINFO

Websites
National Guideline Clearinghouse
National Health and Medical Research Council (NHMRC) (Australia)
NHMRC Clinical Guideline Portal and Emergency Care Portal (Australia)
The National Electronic Library for Health (UK)
Guidelines International Network
Therapeutic Guidelines (Australia)
National Institute for Health and Clinical Excellence (England ⁄ Wales)
Medical Journal of Australia Clinical Guidelines (Australia)
Joanna Briggs Institute (Australia)
Guidelines Advisory Committee (Canada)
TRIP database (UK)
Canadian Medical Association Clinical Guidelines (Canada)
Australasian College of Emergency Medicine (ACEM) (Australia)
Canadian Association of Emergency Physicians (CAEP) (Canada)
Royal College of Emergency Medicine (UK)
Eastern Association for the Surgery of Trauma (EAST) (United States)
Society of Critical Care Medicine (SCCM) (United States)
Department of Veterans Affairs (Australia)
International Council of Nurses
Nursing Best Practice Guidelines (Canada)

Websites
Royal College of Nursing (UK)
American Academy of Pediatrics (United States)
National Health Service (NHS) Evidence (UK)
New Zealand Guidelines Group (New Zealand)
Scottish Intercollegiate Guidelines Network (Scotland)
Brain Trauma Foundation (United States)
American College of Radiology (United States)
American College of Emergency Physicians (United States)
World Health Organization
Australian Government Department of Health and Ageing (Australia)
Australian State Departments of Health and Ageing (Australia)

Internet search engines
• Google
• Google Scholar

Appendix E Search parameters for new evidence on head injury and concussion

The following describes the search parameters for new evidence on head injury and concussion.

All head injury papers restricted to those published after 2015.

Database(s): Ovid MEDLINE(R) ALL 1946 to May 24, 2019

Search date: Search was run 3 separate times: 18/9/2018, 12/10/2018 and 23/2/2019

Search Name: HI Guidelines-Medline

Search Strategy:

#	Searches	Results
1	craniocerebral trauma/ or brain injuries/ or exp brain hemorrhage, traumatic/ or exp brain injuries, diffuse/ or exp brain injuries, traumatic/ or epilepsy, post-traumatic/ or pneumocephalus/ or shaken baby syndrome/ or Coma, Post-Head Injury/ or exp Head Injuries, Closed/ or exp intracranial hemorrhage, traumatic/ or exp Skull Fractures/	110930
2	(intracranial-hemorrhage* or intracranial-haemorrhage* or tbi or tbis or concuss* or post-concuss* or postconcuss* or mtbi or mtbis or brain-contusion* or brain-trauma or brain-laceration* or cranio-cerebral-trauma or craniocerebral-trauma or traumatic-brain or commotion-cerebri or post-commotion or post-contusion or post-head-injur*).tw,kf.	59156
3	((head or brain or cerebral or craniocerebral or intracranial) adj3 (injur* or trauma or contusion)).tw,kf.	106959
4	(Skull adj3 (injur* or fracture*)).tw,kf.	4994
5	(infan* or toddler* or pre-schooler* or preschooler* or boy or boys or girl or girls or child or children or childhood or pediatric* or paediatric* or adolescen* or youth or youths or teen or teens or teenage* or school-age* or schoolage* or school-child* or schoolchild* or school-girl* or schoolgirl* or school-boy* or schoolboy*).af.	4336688
6	(1 or 2 or 3 or 4) and 5	56613
7	(warfare or armed-conflict* or war or wars or operation-iraqi-freedom or afghan-campaign or operation-enduring-freedom or military or battlefield or army or armed-forces or marine or marines or troop or troops or servicem#n or service-m#n or servicewom#n or service-wom#n or service-personnel or air-force or soldier or soldiers or OIF or OEF or combat-related or combat-disorder* or veteran* or active-duty or service-member*).tw,kf.	219793
8	exp "Warfare and Armed Conflicts"/ or Military Personnel/ or Military Medicine/ or Veterans/ or Combat Disorders/	104048
9	(7 or 8) not (military.tw,kf. and ((civilian* or sports or athlete* or sport-related or sports-related).tw,kf. or exp sports/ or athletes/))	249941
10	6 not 9	56064
11	exp animals/ not human*.sh.	4581079
12	10 not 11	53992
13	limit 12 to (case reports or comment or editorial or letter)	10023
14	12 not 13	43969
15	limit 14 to yr= "2015 -Current"	9056

Database(s): Embase 1974 to 2019 May 24

Search date: 28/5/19

Search Name: HI Guidelines-Embase

Search Strategy:

#	Searches	Results
1	head injury/ or brain injury/ or acquired brain injury/ or brain concussion/ or brain contusion/ or postconcussion syndrome/ or shaken baby syndrome/ or brain damage/ or traumatic brain injury/ or skull injury/ or skull fracture/ or skull base fracture/ or exp brain hemorrhage/ or second impact syndrome/ or concussion/	318734
2	(intracranial-hemorrhage* or intracranial-haemorrhage* or tbi or tbis or concuss* or post-concuss* or postconcuss* or mtbi or mtbis or brain-contusion* or brain-trauma or brain-laceration* or cranio-cerebral-trauma or craniocerebral-trauma or traumatic-brain or commotion-cerebri or post-commotion or post-contusion or post-head-injur*).tw,kw,dq.	89690
3	((head or brain or cerebral or craniocerebral or intracranial) adj3 (injur* or trauma or contusion)).tw,kw,dq.	141982
4	(Skull adj3 (injur* or fracture*)).tw,kw,dq.	5506
5	(infan* or toddler* or pre-schooler* or preschooler* or boy or boys or girl or girls or child or children or childhood or pediatric* or paediatric* or adolescen* or youth or youths or teen or teens or teenage* or school-age* or schoolage* or school-child* or schoolchild* or school-girl* or schoolgirl* or school-boy* or schoolboy*).af.	4291985
6	(1 or 2 or 3 or 4) and 5	85097
7	(warfare or armed-conflict* or war or wars or operation-iraqi-freedom or afghan-campaign or operation-enduring-freedom or military or battlefield or army or armed-forces or marine or marines or troop or troops or servicem#n or service-m#n or servicewom#n or service-wom#n or service-personnel or air-force or soldier or soldiers or OIF or OEF or combat-related or combat-disorder* or veteran* or active-duty or service-member*).tw,kw,dq.	236112

8 exp military phenomena/ or soldier/ or military medicine/ or veteran/ or posttraumatic stress disorder/ 163277

9 (7 or 8) not (exp military phenomena/ and ((civilian* or sports or athlete* or sport-related or sports-related).tw,kw,dq. or exp Sport/ or Athlete/)) 315041

10 6 not 9 84043

11 exp animal/ not human*.sh. 4500549

12 10 not 11 79167

13 limit 12 to (conference abstract or conference paper or "conference review" or editorial or letter or note or short survey) 18414

14 12 not 13 60753

15 limit 14 to yr= "2015 -Current" 13959

Ovid PsycInfo

Search date: 27/5/19

Search Name: HI Guidelines-PsycInfo

Search Strategy:

Searches Results

1 exp head injuries/ or exp traumatic brain injury/ or brain damage/ or cerebral hemorrhage/ or subarachnoid hemorrhage/ 40278

2 (intracranial-hemorrhage* or intracranial-haemorrhage* or tbi or tbis or concuss* or post-concuss* or postconcuss* or mtbi or mtbis or brain-contusion* or brain-trauma or brain-laceration* or cranio-cerebral-trauma or craniocerebral-trauma or traumatic-brain or commotion-cerebri or post-commotion or post-contusion or post-head-injur*).ti,ab,id. 19815

3 ((head or brain or cerebral or craniocerebral or intracranial) adj3 (injur* or trauma or contusion)).ti,ab,id. 34327

4 (Skull adj3 (injur* or fracture*)).ti,ab,id. 275

5 (infan* or toddler* or pre-schooler* or preschooler* or boy or boys or girl or girls or child or children or childhood or pediatric* or paediatric* or adolescen* or youth or youths or teen or teens or teenage* or school-age* or schoolage* or school-child* or schoolchild* or school-girl* or schoolgirl* or school-boy* or schoolboy*).af. 1797132

6 (1 or 2 or 3 or 4) and 5 21252

7 (warfare or armed-conflict* or war or wars or operation-iraqi-freedom or afghan-campaign or operation-enduring-freedom or military or battlefield or army or armed-forces or marine or marines or troop or troops or servicem#n or service-m#n or servicewom#n or service-wom#n or service-personnel or air-force or soldier or soldiers or OIF or OEF or combat-related or combat-disorder* or veteran* or active-duty or service-member*).ti,ab,id. 81468

8 exp war/ or exp military personnel/ or military veterans/ or exp posttraumatic stress disorder/ 61547

9 (7 or 8) not (military.ti,ab,id. and ((civilian* or sports or athlete* or sport-related or sports-related).ti,ab,id. or exp Sports/ or Athletes/)) 102140

10 6 not 9 20394

11 exp animals/ not human*.sh. 335803

12 10 not 11 18934

13 limit 12 to (chapter or "comment/reply" or dissertation or editorial or letter or review-book or review-media) 2894

14 12 not 13 16040

15 limit 14 to yr= "2015 -Current" 3647

PubMed

Search date: 28/5/19

#1

(tbi OR tbis OR concuss* OR postconcuss* OR mtbi OR mtbis OR brain-contusion* OR brain-trauma OR brain-laceration* OR cranio-cerebral-trauma OR craniocerebral-trauma OR traumatic-brain OR commotion-cerebri OR post-commotion OR post-contusion OR post-head-injur* OR intracranial-hemorrhage* OR intracranial-haemorrhage* OR ((head OR brain OR cerebral OR craniocerebral OR intracranial) AND (injur* OR trauma OR contusion)) OR (Skull AND (injur* OR fracture*))) AND (infan* OR toddler* OR pre-schooler* OR preschooler* OR boy OR boys OR girl OR girls OR child OR children OR childhood OR pediatric* OR paediatric* OR adolescen* OR youth OR youths OR teen OR teens OR teenage* OR school-age* OR schoolage* OR school-child* OR schoolchild* OR school-girl* OR schoolgirl* OR school-boy* OR schoolboy*) AND (*NOTNLM OR publisher[sb] OR inprocess[sb] OR pubmednotmedline[sb] OR indatareview[sb] OR pubstatusaheadofprint)*

#2

(warfare OR armed-conflict* OR war OR wars OR operation-iraqi-freedom OR afghan-campaign OR operation-enduring-freedom OR military OR battlefield OR army OR armed-forces OR marine OR marines OR troop OR troops OR serviceman OR servicemen OR service-man OR service-men OR servicewoman OR servicewomen OR service-woman OR service-women OR service-personnel OR air-force OR soldier OR soldiers OR OIF OR OEF OR combat-related OR combat-disorder* OR veteran* OR active-duty OR service-member*) NOT (military AND (civilian* OR sport OR sports OR athlete*))

#3 #1 NOT #2

NOT (Letter OR editorial OR Comments OR Case report)

Limit to 2015 onwards = 11025

Cochrane Library

Search date: 27/5/19

Search Name: HI Guidelines 2

ID Search

#1 MeSH descriptor: [Craniocerebral Trauma] this term only

#2 MeSH descriptor: [Brain Injuries] this term only

#3 MeSH descriptor: [Brain Hemorrhage, Traumatic] explode all trees

#4 MeSH descriptor: [Brain Injuries, Diffuse] explode all trees

#5 MeSH descriptor: [Brain Injuries, Traumatic] explode all trees

#6 MeSH descriptor: [Epilepsy, Post-Traumatic] this term only

#7 MeSH descriptor: [Pneumocephalus] this term only

#8 MeSH descriptor: [Shaken Baby Syndrome] this term only

#9 MeSH descriptor: [Coma, Post-Head Injury] this term only

#10 MeSH descriptor: [Head Injuries, Closed] explode all trees

#11 MeSH descriptor: [Intracranial Hemorrhage, Traumatic] explode all trees

#12 MeSH descriptor: [Skull Fractures] explode all trees

#13 (tbi OR tbis OR concuss* OR postconcuss* OR mtbi OR mtbis OR brain-contusion* OR brain-trauma OR brain-laceration* OR cranio-cerebral-trauma OR craniocerebral-trauma OR traumatic-brain OR commotion-cerebri OR post-commotion OR post-contusion OR post-head-injur* OR intracranial-hemorrhage* OR intracranial-haemorrhage*)

#14 ((head OR brain OR cerebral OR craniocerebral OR intracranial) NEAR/3 (injur* OR trauma OR contusion))

#15 (Skull NEAR/3 (injur* OR fracture*))

#16 (infan* OR toddler* OR pre-schooler* OR preschooler* OR boy OR boys OR girl OR girls OR child OR children OR childhood OR pediatric* OR paediatric* OR adolescen* OR youth OR youths OR teen OR teens OR teenage* OR school-age* OR schoolage* OR school-child* OR schoolchild* OR school-girl* OR schoolgirl* OR school-boy* OR schoolboy*)

#17 (#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15) AND #16

#18 ((warfare OR armed-conflict* OR war OR wars OR operation-iraqi-freedom OR afghan-campaign OR operation-enduring-freedom OR military OR battlefield OR army OR armed-forces OR marine OR marines OR troop OR troops OR serviceman OR servicemen OR service-man OR service-men OR servicewoman OR servicewomen OR service-woman OR service-women OR service-personnel OR air-force OR soldier OR soldiers OR OIF OR OEF OR combat-related OR combat-disorder* OR veteran* OR active-duty OR service-member*))

#19 MeSH descriptor: [Warfare and Armed Conflicts] explode all trees

#20 MeSH descriptor: [Military Personnel] this term only

#21 MeSH descriptor: [Military Medicine] this term only

#22 MeSH descriptor: [Veterans] this term only

#23 MeSH descriptor: [Combat Disorders] this term only

#24 (#18 or #19 or #20 or #21 or #22 or #23)

#25 (military)

#26 (civilian* or sports or athlete* or sport-related or sports-related)

#27 MeSH descriptor: [Sports] explode all trees

#28 MeSH descriptor: [Athletes] this term only

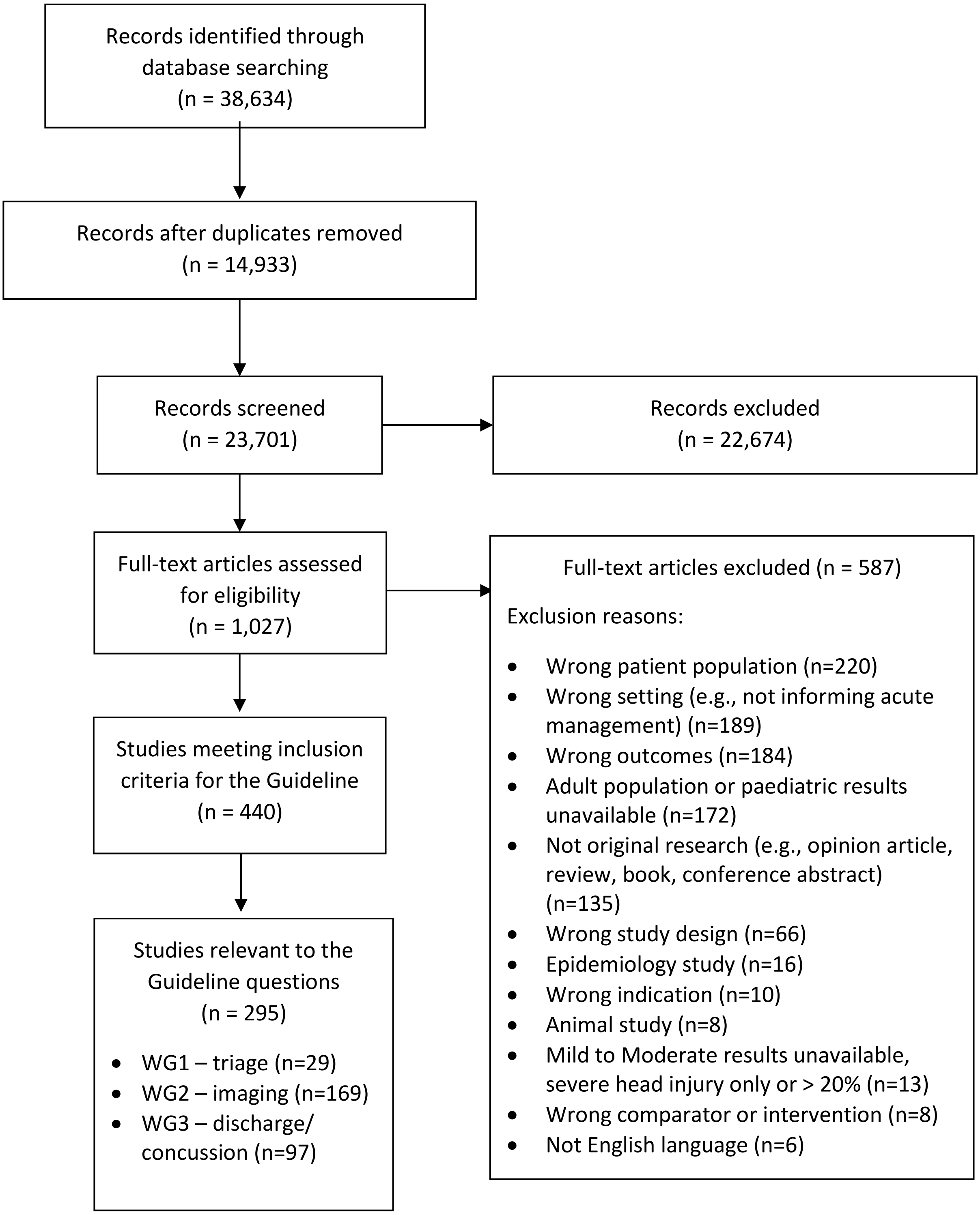
#29 (#25 and (#26 or #27 or #28))

#30 (#24 NOT #29)

#31 (#17 NOT #30) 2502

Limited from 2015-current= 947 (116 Reviews; 21 Protocols; 810 Trials)

Appendix F PRISMA diagram: PREDICT Literature Search



Appendix G References

1. Kuppermann N, Holmes JF, Dayan PS, Hoyle JD, Jr., Atabaki SM, Holubkov R, et al. Identification of Children at Very Low Risk of Clinically-Important Brain Injuries after Head Trauma: A Prospective Cohort Study. Lancet. 2009;374(9696):1160–70.
2. Chapter 8: The Child with a Decreased Conscious Level. In: Samuels M, Wieteska S, editors. Advanced Paediatric Life Support a Practical Approach to Emergencies (Sixth Edition): John Wiley and Sons; 2017.
3. National Health and Medical Research Council (NHMRC). Guidelines for Guidelines: Adopt, Adapt or Start from Scratch. Canberra: NHMRC; 2018. Available at: https://www.nhmrc.gov.au/guidelinesforguidelines/plan/adopt-adapt-or-start-scratch
4. Schünemann HJ, Wiercioch W, Brozek J, Etxeandia-Ikobaltzeta I, Mustafa RA, Manja V, et al. GRADE Evidence to Decision (EtD) Frameworks for Adoption, Adaptation, and De Novo Development of Trustworthy Recommendations: GRADE-Adolopment. J Clin Epidemiol. 2017;81:101–10.
5. O'Neill JA, Cox MK, Clay OJ, Johnston JM, Novack TA, Schwebel DC, et al. A Review of the Literature on Pediatric Concussions and Return-to-Learn (RTL): Implications for RTL Policy, Research, and Practice. Rehabil Psychol. 2017;62(3):300–23.
6. DeMatteo C, Bednar ED, Randall S, Falla K. Effectiveness of Return to Activity and Return to School Protocols for Children Postconcussion: A Systematic Review. BMJ Open Sport Exerc Med. 2020;6(1).
7. Babl FE, Borland ML, Phillips N, Kochar A, Dalton S, McCaskill M, et al. Accuracy of PECARN, CATCH, and CHALICE Head Injury Decision Rules in Children: A Prospective Cohort Study. Lancet. 2017;389(10087):2393–402.
8. Crowe LM, Hearps S, Anderson V, Borland ML, Phillips N, Kochar A, et al. Investigating the Variability in Mild Traumatic Brain Injury Definitions: A Prospective Cohort Study. Arch Phys Med Rehabil. 2018;99(7):1360–9.
9. Kochar A, Borland ML, Phillips N, Dalton S, Cheek JA, Furyk J, et al. Association of Clinically Important Traumatic Brain Injury and Glasgow Coma Scale Scores in Children with Head Injury. Emerg Med J. 2020;37(3):127–34.
10. Mathews JD, Forsythe AV, Brady Z, Butler MW, Goergen SK, Byrnes GB, et al. Cancer Risk in 680,000 People Exposed to Computed Tomography Scans in Childhood or Adolescence: Data Linkage Study of 11 Million Australians. BMJ. 2013;346:f2360.
11. Miglioretti DL, Johnson E, Williams A, Greenlee RT, Weinmann S, Solberg LI, et al. The Use of Computed Tomography in Pediatrics and the Associated Radiation Exposure and Estimated Cancer Risk. JAMA Pediatr. 2013;167(8):700–7.
12. Pearce MS, Salotti JA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation Exposure from CT Scans in Childhood and Subsequent Risk of Leukaemia and Brain Tumours: A Retrospective Cohort Study. Lancet. 2012;380(9840):499–505.
13. Goldwasser T, Bressan S, Oakley E, Arpone M, Babl FE. Use of Sedation in Children Receiving Computed Tomography after Head Injuries. Eur J Emerg Med. 2015;22(6):413–8.
14. Hoyle JD, Jr., Callahan JM, Badawy M, Powell E, Jacobs E, Gerardi M, et al. Pharmacological Sedation for Cranial Computed Tomography in Children after Minor Blunt Head Trauma. Pediatr Emerg Care. 2014;30(1):1–7.
15. Lyttle MD, Crowe L, Oakley E, Dunning J, Babl FE. Comparing Catch, Chalice and Pecarn Clinical Decision Rules for Paediatric Head Injuries. Emerg Med J. 2012;29(10):785–94.
16. Pickering A, Harnan S, Fitzgerald P, Pandor A, Goodacre S. Clinical Decision Rules for Children with Minor Head Injury: A Systematic Review. Arch Dis Child. 2011;96(5):414–21.
17. Kuppermann N, Holmes JF, Dayan PS. Head Injury Decision Rules in Children. Lancet. 2017;390(10101):1487–8.
18. Osmond MH, Klassen TP, Wells GA, Correll R, Jarvis A, Joubert G, et al. CATCH: A Clinical Decision Rule for the Use of Computed Tomography in Children with Minor Head Injury. CMAJ. 2010;182(4):341–8.
19. Dunning J, Daly JP, Lomas JP, Lecky F, Batchelor J, Mackway-Jones K. Derivation of the Children's Head Injury Algorithm for the Prediction of Important Clinical Events Decision Rule for Head Injury in Children. Arch Dis Child. 2006;91(11):885–91.

20. Babl F, Tavender E, Dalziel S. On Behalf of the Guideline Working Group for the Paediatric Research in Emergency Departments International Collaborative (PREDICT). Australian and New Zealand Guideline for Mild to Moderate Head Injuries in Children – Algorithm. Australia: PREDICT; 2020.
21. Borland ML, Dalziel SR, Phillips N, Lyttle MD, Bressan S, Oakley E, et al. Delayed Presentations to Emergency Departments of Children with Head Injury: A PREDICT Study. Ann Emerg Med. 2019;74(1):1–10.
22. Singh S, Hearps SJC, Borland ML, Dalziel SR, Neutze J, Donath S, et al. The Effect of Patient Observation on Cranial Computed Tomography Rates in Children with Minor Head Trauma. Acad Emerg Med. 2020; 27(9), 832-843.
23. Babl FE, Oakley E, Dalziel SR, Borland ML, Phillips N, Kochar A, et al. Accuracy of Clinician Practice Compared with Three Head Injury Decision Rules in Children: A Prospective Cohort Study. Ann Emerg Med. 2018;71(6):703–10.
24. McCrory P, Meeuwisse W, Dvořák J, Aubry M, Bailes J, Broglio S, et al. Consensus Statement on Concussion in Sport – the 5(Th) International Conference on Concussion in Sport Held in Berlin, October 2016. Br J Sports Med. 2017;51(11):838–47.
25. Tavender EJ, Wilson CL. Head Injuries in Children: What Influences your Decision Making? Clinical Session 2 - PREDICT Research Informing National Practice Change in Paediatric Emergencies. “The Changing Climate of Emergency Medicine”, ACEM 36th Annual Scientific Meeting; 2019 Nov 17-21; Hobart, Tasmania: Australiasian College of Emergency Medicine.
26. Wilson CL, Tavender EJ, Phillips NT, Hearps SJ, Foster K, O'Brien SL, et al. Variation in CT Use for Paediatric Head Injuries across Different Types of Emergency Departments in Australia and New Zealand. Emerg Med J. 2020;37(11):686–9.
27. Fervers B, Burgers J, Haugh M, Latreille J, Mlika-Cabanne N, Paquet L, et al. Adaptation of Clinical Guidelines: A Review of Methods and Experiences. Int J Health Care. 2006;18(30):167–76.
28. Astrand R, Rosenlund C, Undén J. Scandinavian Guidelines for Initial Management of Minor and Moderate Head Trauma in Children. BMC Med. 2016;14:33.
29. Davis GA, Anderson V, Babl FE, Gioia GA, Giza CC, Meehan W, et al. What Is the Difference in Concussion Management in Children as Compared with Adults? A Systematic Review. Br J Sports Med. 2017;51(12):949–57.
30. NICE: National Institute for Health and Care Excellence. Head Injury: Assessment and Early Management (NICE Guideline CG176). London: NICE; 2019.
31. Da Dalt L, Parri N, Amigoni A, Nocerino A, Selmin F, Manara R, et al. Italian Guidelines on the Assessment and Management of Pediatric Head Injury in the Emergency Department. Ital J Pediatr. 2018;44(1):7.
32. Ontario Neurotrauma Foundation (ONF). Guidelines for Diagnosing and Managing Pediatric Concussion. Toronto: ONF; 2014.
33. Lumba-Brown A, Yeates KO, Sarmiento K, Breiding MJ, Haegerich TM, Gioia GA, et al. Centers for Disease Control and Prevention Guideline on the Diagnosis and Management of Mild Traumatic Brain Injury among Children. JAMA Pediatr. 2018;172(11):e182853.
34. Ryan ME, Palasis S, Saigal G, Singer AD, Karmazyn B, Dempsey ME, et al. ACR Appropriateness Criteria Head Trauma – Child. J Am Coll Radiol. 2014;11(10):939–47.
35. Brouwers M KM, Browman GP, Burgers JS, Cluzeau F, Feder G, Fervers B, Graham ID, Grimshaw J, Hanna S, Littlejohns P, Makarski J, Zitzelsberger L for the AGREE Next Steps Consortium. Agree II: Advancing Guideline Development, Reporting and Evaluation in Healthcare. Can Med Assoc J 2010.
36. Reed N, Zemek R, Dawson J, Ledoux A, Provvidenza C, Paniccia M, et al. Guidelines for Diagnosing and Managing Pediatric Concussion. Toronto, ON: Ontario Neurotrauma Foundation; 2019
37. Giordano PNA, Lassandro G, Notarangelo LD, Bressan S, Ramenghi U, Saracco P, Da Dalt L, Molinari AC. Head Injury in Children with Coagulation Disorders a Position Paper by the Italian Society of Pediatric Emergency Medicine and the Italian Association of Pediatric Hematology and Oncology – Coagulation Disorders Working Group. Ital J Pediatr. In press.
38. National Institute for Health and Clinical Excellence. The Guidelines Manual. London 2012.
39. Yengo-Kahn AM, Hale AT, Zalneraitis BH, Zuckerman SL, Sills AK, Solomon GS. The Sport Concussion Assessment Tool: A Systematic Review. Neurosurg Focus. 2016;40(4):E6.

40. Parameswaran A, Heitner S, Thosar D, Fowler A, Marks S, O'Leary F. Trial of Life: Well Infants Presenting More Than 24 H after Head Injury with a Scalp Haematoma: A 10-Year Review. J Paediatr Child Health. 2018;54(11):1193–8.
41. Snyder CW, Danielson PD, Gonzalez R, Chandler NM. Computed Tomography Scans Prior to Transfer to a Pediatric Trauma Center: Transfer Time Effects, Neurosurgical Interventions, and Practice Variability. J Trauma Acute Care Surg. 2019;87(4):808–12.
42. Echemendia RJ, Meeuwisse W, McCrory P, Davis GA, Putukian M, Leddy J, et al. The Sport Concussion Assessment Tool 5th Edition (SCAT5): Background and Rationale. Br J Sports Med. 2017;51(11):848–50.
43. Davis GA, Purcell L, Schneider KJ, Yeates KO, Gioia GA, Anderson V, et al. The Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5): Background and Rationale. Br J Sports Med. 2017;51(11):859–61.
44. Bressan S, Marchetto L, Lyons TW, Monuteaux MC, Freedman SB, Da Dalt L, et al. A Systematic Review and Meta-Analysis of the Management and Outcomes of Isolated Skull Fractures in Children. Ann Emerg Med. 2018;71(6):714–24e2.
45. Arrey EN, Kerr ML, Fletcher S, Cox CS, Jr., Sandberg DI. Linear Nondisplaced Skull Fractures in Children: Who Should Be Observed or Admitted? J Neurosurg Pediatr. 2015;16(6):703–8.
46. Blanchard A, Cabrera KI, Kuppermann N, Dayan PS. Acute Outcomes of Isolated Pneumocephali in Children after Minor Blunt Head Trauma. Pediatr Emerg Care. 2018;34(9):656–60.
47. Hassan S, Alarhayema AQ, Cohn SM, Wiersch JC, Price MR. Natural History of Isolated Skull Fractures in Children. Cureus. 2018;10(7):e3078.
48. Kommaraju K, Haynes JH, Ritter AM. Evaluating the Role of a Neurosurgery Consultation in Management of Pediatric Isolated Linear Skull Fractures. Pediatr Neurosurg. 2019;54(1):21–7.
49. Lyons TW, Stack AM, Monuteaux MC, Parver SL, Gordon CR, Gordon CD, et al. A QI Initiative to Reduce Hospitalization for Children with Isolated Skull Fractures. Pediatrics. 2016;137(6):6.
50. Azim A, Jehan FS, Rhee P, O'Keeffe T, Tang A, Vercruysse G, et al. Big for Small: Validating Brain Injury Guidelines in Pediatric Traumatic Brain Injury. J Trauma Acute Care Surg. 2017;83(6):1200–4.
51. Burns EC, Burns B, Newgard CD, Laurie A, Fu R, Graif T, et al. Pediatric Minor Traumatic Brain Injury with Intracranial Hemorrhage: Identifying Low-Risk Patients Who May Not Benefit from ICU Admission. Pediatr Emerg Care. 2019;35(3):161–9.
52. Flaherty BF, Moore HE, Riva-Cambrin J, Bratton SL. Pediatric Patients with Traumatic Epidural Hematoma at Low Risk for Deterioration and Need for Surgical Treatment. J Pediatr Surg. 2017;52(2):334–9.
53. Tallapragada K, Peddada RS, Dexter M. Paediatric Mild Head Injury: Is Routine Admission to a Tertiary Trauma Hospital Necessary? ANZ J Surg. 2018;88(3):202–6.
54. Varano P, Cabrera KI, Kuppermann N, Dayan PS. Acute Outcomes of Isolated Cerebral Contusions in Children with Glasgow Coma Scale Scores of 14 to 15 after Blunt Head Trauma. J Trauma Acute Care Surg. 2015;78(5):1039–43.
55. Marincowitz C, Lecky FE, Townend W, Borakati A, Fabbri A, Sheldon TA. The Risk of Deterioration in Gcs13-15 Patients with Traumatic Brain Injury Identified by Computed Tomography Imaging: A Systematic Review and Meta-Analysis. J Neurotrauma. 2018;35(5):703–18.
56. Hentzen AS, Helmer SD, Nold RJ, Grundmeyer RW, 3rd, Haan JM. Necessity of Repeat Head Computed Tomography after Isolated Skull Fracture in the Pediatric Population. Am J Surg. 2015;210(2):322–5.
57. Plackett TP, Asturias S, Tadlock M, Wright F, Ton-That H, Demetriades D, et al. Re-Evaluating the Need for Hospital Admission and Observation of Pediatric Traumatic Brain Injury after a Normal Head CT. J Pediatr Surg. 2015;50(10):1758–61.
58. Bertsimas D, Dunn J, Steele DW, Trikalinos TA, Wang Y. Comparison of Machine Learning Optimal Classification Trees with the Pediatric Emergency Care Applied Research Network Head Trauma Decision Rules. JAMA Pediatr. 2019;13:13.
59. Dayan PS, Holmes JF, Schutzman S, Schunk J, Lichenstein R, Foerster LA, et al. Risk of Traumatic Brain Injuries in Children Younger Than 24 Months with Isolated Scalp Hematomas. Ann Emerg Med. 2014;64(2):153–62.

60. Ide K, Uematsu S, Tetsuhara K, Yoshimura S, Kato T, Kobayashi T. External Validation of the PECARN Head Trauma Prediction Rules in Japan. Acad Emerg Med. 2017;24(3):308–14.
61. Nigrovic LE, Schunk JE, Foerster A, Cooper A, Miskin M, Atabaki SM, et al. The Effect of Observation on Cranial Computed Tomography Utilization for Children after Blunt Head Trauma. Pediatrics. 2011;127(6):1067–73.
62. Fabbri A, Servadei F, Marchesini G, Dente M, Iervese T, Spada M, et al. Clinical Performance of NICE Recommendations Versus NCWFNS Proposal in Patients with Mild Head Injury. J Neurotrauma. 2005;22(12):1419–27.
63. Fabbri A, Vandelli A, Servadei F, Marchesini G. Coagulopathy and NICE Recommendations for Patients with Mild Head Injury. J Neurol Neurosurg Psychiatry. 2004;75(12):1787–8.
64. Lee LK, Dayan PS, Gerardi MJ, Borgialli DA, Badawy MK, Callahan JM, et al. Intracranial Hemorrhage after Blunt Head Trauma in Children with Bleeding Disorders. J Pediatr. 2011;158(6):1003–8 e1–2.
65. Hamilton M, Mrazik M, Johnson DW. Incidence of Delayed Intracranial Hemorrhage in Children after Uncomplicated Minor Head Injuries. Pediatrics. 2010;126(1):e33–9.
66. Schonfeld D, Fitz BM, Nigrovic LE. Effect of the Duration of Emergency Department Observation on Computed Tomography Use in Children with Minor Blunt Head Trauma. Ann Emerg Med. 2013;62(6):597–603.
67. Holmes JF, Borgialli DA, Nadel FM, Quayle KS, Schambam N, Cooper A, et al. Do Children with Blunt Head Trauma and Normal Cranial Computed Tomography Scan Results Require Hospitalization for Neurologic Observation? Ann Emerg Med. 2011;58(4):315–22.
68. Badawy MK, Dayan PS, Tunik MG, Nadel FM, Lillis KA, Miskin M, et al. Prevalence of Brain Injuries and Recurrence of Seizures in Children with Posttraumatic Seizures. Acad Emerg Med. 2017;24(5):595–605.
69. Powell EC, Atabaki SM, Wootton-Gorges S, Wisner D, Mahajan P, Glass T, et al. Isolated Linear Skull Fractures in Children with Blunt Head Trauma. Pediatrics. 2015;135(4):e851–7.
70. Culotta PA, Crowe JE, Tran QA, Jones JY, Mehollin-Ray AR, Tran HB, et al. Performance of Computed Tomography of the Head to Evaluate for Skull Fractures in Infants with Suspected Non-Accidental Trauma. Pediatr Radiol. 2017;47(1):74–81.
71. Expert Panel on Pediatric Imaging, Wootton-Gorges SL, Soares BP, Alazraki AL, Anupindi SA, Blount JP, et al. ACR Appropriateness Criteria Suspected Physical Abuse-Child. J Am Coll Radiol. 2017;14(5S):S338–S49.
72. Berger RP, Fromkin J, Herman B, Pierce MC, Saladino RA, Flom L, et al. Validation of the Pittsburgh Infant Brain Injury Score for Abusive Head Trauma. Pediatrics. 2016;138(1):7.
73. Cowley LE, Morris CB, Maguire SA, Farewell DM, Kemp AM. Validation of a Prediction Tool for Abusive Head Trauma. Pediatrics. 2015;136(2):291–8.
74. Escobar MA, Flynn-O'Brien KT, Auerbach M, Tiyyagura G, Borgman MA, Duffy SJ, et al. The Association of Nonaccidental Trauma with Historical Factors, Examination Findings, and Diagnostic Testing During the Initial Trauma Evaluation. J Trauma Acute Care Surg. 2017;82(6):1147–57.
75. Hymel KP, Wang M, Chinchilli VM, Karst WA, Willson DF, Dias MS, et al. Estimating the Probability of Abusive Head Trauma after Abuse Evaluation. Child Abuse Negl. 2019;88:266–74.
76. Pfeiffer H, Smith A, Kemp AM, Cowley LE, Cheek JA, Dalziel SR, et al. External Validation of the PediBIRN Clinical Prediction Rule for Abusive Head Trauma. Pediatrics. 2018;141(5), [e20173674].
77. Gravel J, Gouin S, Chalut D, Crevier L, Decarie JC, Elazhary N, et al. Derivation and Validation of a Clinical Decision Rule to Identify Young Children with Skull Fracture Following Isolated Head Trauma. CMAJ. 2015;187(16):1202–8.
78. Choi JY, Lim YS, Jang JH, Park WB, Hyun SY, Cho JS. Accuracy of Bedside Ultrasound for the Diagnosis of Skull Fractures in Children Aged 0 to 4 Years. Pediatr Emerg Care. 2018;24:24.
79. Parri N, Crosby BJ, Mills L, Soucy Z, Musolino AM, Da Dalt L, et al. Point-of-Care Ultrasound for the Diagnosis of Skull Fractures in Children Younger Than Two Years of Age. J Pediatr. 2018;196:230–6.e2.
80. Trenchs V, Curcoy AI, Castillo M, Badosa J, Luaces C, Pou J, et al. Minor Head Trauma and Linear Skull Fracture in Infants: Cranial Ultrasound or Computed Tomography? Eur J Emerg Med. 2009;16(3):150–2.
81. Elkhunovich M, Sirody J, McCormick T, Goodarzian F, Claudius I. The Utility of Cranial Ultrasound for Detection of Intracranial Hemorrhage in Infants. Pediatr Emerg Care. 2018;34(2):96–101.

82. Buttram SD, Garcia-Filion P, Miller J, Youssfi M, Brown SD, Dalton HJ, et al. Computed Tomography Vs Magnetic Resonance Imaging for Identifying Acute Lesions in Pediatric Traumatic Brain Injury. Hosp Pediatr. 2015;5(2):79–84.
83. Cohen AR, Caruso P, Duhaime AC, Klig JE. Feasibility of "Rapid" Magnetic Resonance Imaging in Pediatric Acute Head Injury. Am J Emerg Med. 2015;33(7):887–90.
84. Mehta H, Acharya J, Mohan AL, Tobias ME, LeCompte L, Jeevan D. Minimizing Radiation Exposure in Evaluation of Pediatric Head Trauma: Use of Rapid MR Imaging. AJNR Am J Neuroradiol. 2016;37(1):43688.
85. Roguski M, Morel B, Sweeney M, Talan J, Rideout L, Riesenburger RI, et al. Magnetic Resonance Imaging as an Alternative to Computed Tomography in Select Patients with Traumatic Brain Injury: A Retrospective Comparison. J Neurosurg Pediatr. 2015;15(5):529–34.
86. Dundamadappa SK, Thangasamy S, Resteghini N, Vedantham S, Chen A, Takhtani D. Skull Fractures in Pediatric Patients on Computerized Tomogram: Comparison between Routine Bone Window Images and 3d Volume-Rendered Images. Emerg Radiol. 2015;22(4):367–72.
87. Maetani K, Namiki J, Matsumoto S, Matsunami K, Narumi A, Tsuneyoshi T, et al. Routine Head Computed Tomography for Patients in the Emergency Room with Trauma Requires Both Thick- and Thin-Slice Images. Emerg Med Int. 2016;2016: 5781790.
88. Orman G, Wagner MW, Seeburg D, Zamora CA, Oshmyansky A, Tekes A, et al. Pediatric Skull Fracture Diagnosis: Should 3d CT Reconstructions Be Added as Routine Imaging? J Neurosurg Pediatr. 2015;16(4):426–31.
89. Niiniviita H, Kiljunen T, Huuskonen M, Teperi S, Kulmala J. Dose Monitoring in Pediatric and Young Adult Head and Cervical Spine CT Studies at Two Emergency Duty Departments. Emerg Radiol. 2018;25(2):153–9.
90. Nabaweesi R, Ramakrishnaiah RH, Aitken ME, Rettiganti MR, Luo C, Maxson RT, et al. Injured Children Receive Twice the Radiation Dose at Nonpediatric Trauma Centers Compared with Pediatric Trauma Centers. J Am Coll Radiol. 2018;15(1 Pt A):58–64.
91. Kaul D, Kahn J, Huizing L, Wiener E, Boning G, Renz DM, et al. Dose Reduction in Paediatric Cranial CT Via Iterative Reconstruction: A Clinical Study in 78 Patients. Clini Radiol. 2016;71(11):1168–77.
92. Meltzer JA, Stone ME, Jr., Reddy SH, Silver EJ. Association of Whole-Body Computed Tomography with Mortality Risk in Children with Blunt Trauma. JAMA Pediatr. 2018;172(6):542–9.
93. Southard RN, Bardo DME, Temkit MH, Thorkelson MA, Augustyn RA, Martinot CA. Comparison of Iterative Model Reconstruction Versus Filtered Back-Projection in Pediatric Emergency Head CT: Dose, Image Quality, and Image-Reconstruction Times. AJNR Am J Neuroradiol. 2019;40(5):866–71.
94. Suffoletto B, Callaway CW, Kristan J, Monti P, Clark DB. Mobile Phone Text Message Intervention to Reduce Binge Drinking among Young Adults: Study Protocol for a Randomized Controlled Trial. Trials. 2013;14:93.
95. Zemek R, Barrowman N, Freedman SB, Gravel J, Gagnon I, McGahern C, et al. Clinical Risk Score for Persistent Postconcussion Symptoms among Children with Acute Concussion in the ED. JAMA. 2016;315(10):1014–25.
96. Babcock L, Byczkowski T, Wade SL, Ho M, Mookerjee S, Bazarian JJ. Predicting Postconcussion Syndrome after Mild Traumatic Brain Injury in Children and Adolescents Who Present to the Emergency Department. JAMA Pediatr. 2013;167(2):156–61.
97. Barlow KM, Crawford S, Stevenson A, Sandhu SS, Belanger F, Dewey D. Epidemiology of Postconcussion Syndrome in Pediatric Mild Traumatic Brain Injury. Pediatrics. 2010;126(2):e374–e81.
98. Barlow M, Schlabach D, Peiffer J, Cook C. Differences in Change Scores and the Predictive Validity of Three Commonly Used Measures Following Concussion in the Middle School and High School Aged Population. Int J Sports Phys Ther. 2011;6(3):150–7.
99. Barr WB, Prichep LS, Chabot R, Powell MR, McCrea M. Measuring Brain Electrical Activity to Track Recovery from Sport-Related Concussion. Brain Inj. 2012;26(1):58–66.
100. Grubenhoff JA, Deakyne SJ, Brou L, Bajaj L, Comstock RD, Kirkwood MW. Acute Concussion Symptom Severity and Delayed Symptom Resolution. Pediatrics. 2014;134(1):54–62.
101. Korinthenberg R, Schreck J, Weser J, Lehmkuhl G. Post-Traumatic Syndrome after Minor Head Injury Cannot Be Predicted by Neurological Investigations. Brain Dev. 2004;26(2):113–7.

102. Lau BC, Collins MW, Lovell MR. Sensitivity and Specificity of Subacute Computerized Neurocognitive Testing and Symptom Evaluation in Predicting Outcomes after Sports-Related Concussion. Am J Sports Med. 2011;39(6):1209–16.
103. Lee MA, Fine B. Adolescent Concussions. Conn Med. 2010;74(3):149–56.
104. Lee YM, Odom MJ, Zuckerman SL, Solomon GS, Sills AK. Does Age Affect Symptom Recovery after Sports-Related Concussion? A Study of High School and College Athletes. J Neurosurg Pediatr. 2013;12(6):537–44.
105. Meehan WP, Mannix RC, Stracciolini A, Elbin RJ, Collins MW. Symptom Severity Predicts Prolonged Recovery after Sport-Related Concussion, but Age and Amnesia Do Not. J Pediatr. 2013;163(3):721–5.
106. Merritt VC, Arnett PA. Premorbid Predictors of Postconcussion Symptoms in Collegiate Athletes. J Clin Exp Neuropsychol. 2014;36(10):1098–111.
107. Morgan CD, Zuckerman SL, Lee YM, King L, Beaird S, Sills AK, et al. Predictors of Postconcussion Syndrome after Sports-Related Concussion in Young Athletes: A Matched Case-Control Study. J Neurosurg Pediatr. 2015;15(6):589–98.
108. Ponsford J, Willmott C, Rothwell A, Cameron P, Ayton G, Nelms R, et al. Cognitive and Behavioral Outcome Following Mild Traumatic Head Injury in Children. J Head Trauma Rehabil. 1999;14(4):360–72.
109. Thomas DG, Collins MW, Saladino RA, Frank V, Raab J, Zuckerbraun NS. Identifying Neurocognitive Deficits in Adolescents Following Concussion. Acad Emerg Med. 2011;18(3):246–54.
110. Yeates KO, Luria J, Bartkowski H, Rusin J, Martin L, Bigler ED. Postconcussive Symptoms in Children with Mild Closed Head Injuries. J Head Trauma Rehabil. 1999;14(4):337–50.
111. Yeates KO, Taylor HG, Rusin J, Bangert B, Dietrich A, Nuss K, et al. Longitudinal Trajectories of Postconcussive Symptoms in Children with Mild Traumatic Brain Injuries and Their Relationship to Acute Clinical Status. Pediatrics. 2009;123(3):735–43.
112. Zemek R, Clarkin C, Farion KJ, Vassilyadi M, Anderson P, Irish B, et al. Parental Anxiety at Initial Acute Presentation Is Not Associated with Prolonged Symptoms Following Pediatric Concussion. Acad Emerg Med. 2013;20(10):1041–9.
113. Nowacki R, van Eldik N, Eikens M, Roijen R, Haga N, Schott D, et al. Evaluation of a Follow-up Program for Mild Traumatic Brain Injury in Schoolchildren. Eur J Paediatr Neurol. 2017;21(2):382–7.
114. Mortenson P, Singhal A, Hengel AR, Purtzki J. Impact of Early Follow-up Intervention on Parent-Reported Postconcussion Pediatric Symptoms: A Feasibility Study. J Head Trauma Rehabil. 2016;31(6):E23–E32.
115. Iverson GL, Gioia GA. Returning to School Following Sport-Related Concussion. Phys Med Rehabil Clin N Am. 2016;27(2):429–36.
116. Babcock L, Kurowski BG, Zhang N, Dexheimer JW, Dyas J, Wade SL. Adolescents with Mild Traumatic Brain Injury Get Smart: An Analysis of a Novel Web-Based Intervention. Telemed J E Health. 2017;23(7):600–7.
117. Kerr ZY, Zuckerman SL, Wasserman EB, Covassin T, Djoko A, Dompier TP. Concussion Symptoms and Return to Play Time in Youth, High School, and College American Football Athletes. JAMA Pediatr. 2016;170(7):647–53.
118. McClincy MP, Lovell MR, Pardini J, Collins MW, Spore MK. Recovery from Sports Concussion in High School and Collegiate Athletes. Brain Inj. 2006;20(1):33–9.
119. McKeon JM, Livingston SC, Reed A, Hosey RG, Black WS, Bush HM. Trends in Concussion Return-to-Play Timelines among High School Athletes from 2007 through 2009. J Athl Train. 2013;48(6):836–43.
120. Purcell L, Harvey J, Seabrook JA. Patterns of Recovery Following Sport-Related Concussion in Children and Adolescents. Clin Pediatr. 2016;55(5):452–8.
121. Carson JD, Lawrence DW, Kraft SA, Garel A, Snow CL, Chatterjee A, et al. Premature Return to Play and Return to Learn after a Sport-Related Concussion: Physician's Chart Review. Can Fam Physician. 2014;60(6):e310, e2–5.
122. McLendon LA, Kralik SF, Grayson PA, Golomb MR. The Controversial Second Impact Syndrome: A Review of the Literature. Pediatr Neurol. 2016;62:42979.
123. Brooks BL, Low TA, Daya H, Khan S, Mikrogianakis A, Barlow KM. Test or Rest? Computerized Cognitive Testing in the Emergency Department after Pediatric Mild Traumatic Brain Injury Does Not Delay Symptom Recovery. J Neurotrauma. 2016.

124. Howell DR, Mannix RC, Quinn B, Taylor JA, Tan CO, Meehan WP, 3rd. Physical Activity Level and Symptom Duration Are Not Associated after Concussion. Am J Sports Med. 2016;44(4):1040–6.
125. Moor HM, Eisenhauer RC, Killian KD, Proudfoot N, Henriques AA, Congeni JA, et al. The Relationship between Adherence Behaviors and Recovery Time in Adolescents after a Sports-Related Concussion: An Observational Study. Int J Sports Phys Ther. 2015;10(2):225–33.
126. Thomas DG, Apps JN, Hoffmann RG, McCrea M, Hammeke T. Benefits of Strict Rest after Acute Concussion: A Randomized Controlled Trial. Pediatrics. 2015;135(2):213–23.
127. Moser RS, Schatz P, Glenn M, Kollias KE, Iverson GL. Examining Prescribed Rest as Treatment for Adolescents Who Are Slow to Recover from Concussion. Brain Inj. 2015;29(1):58–63.
128. Brown NJ, Mannix RC, O'Brien MJ, Gostine D, Collins MW, Meehan WP, 3rd. Effect of Cognitive Activity Level on Duration of Post-Concussion Symptoms. Pediatrics. 2014;133(2):e299–304.
129. Gibson S, Nigrovic LE, O'Brien M, Meehan WP, 3rd. The Effect of Recommending Cognitive Rest on Recovery from Sport-Related Concussion. Brain Inj. 2013;27(7-8):839–42.
130. Moser RS, Glatts C, Schatz P. Efficacy of Immediate and Delayed Cognitive and Physical Rest for Treatment of Sports-Related Concussion. J Pediatr. 2012;161(5):922–6.
131. Renjilian C, Basta L, Wiebe D, Master C, Houseknecht E, Nance M. Physical Activity in Pediatric Concussion: Using Accelerometers to Evaluate How Total Daily Activity or Physical Exertion Relate to Symptoms. Clin J Sport Med. 2015;25(2):211.
132. Grool AM, Aglipay M, Momoli F, Meehan WP, Freedman SB, Yeates KO, et al. Association between Early Participation in Physical Activity Following Acute Concussion and Persistent Postconcussive Symptoms in Children and Adolescents. JAMA. 2016;316(23):2504–14.
133. Leddy JJ, Haider MN, Hinds AL, Darling S, Willer BS. A Preliminary Study of the Effect of Early Aerobic Exercise Treatment for Sport-Related Concussion in Males. Clin J Sport Med. 2018;19:19.
134. Baker JG, Leddy JJ, Darling SR, Rieger BP, Mashtare TL, Sharma T, et al. Factors Associated with Problems for Adolescents Returning to the Classroom after Sport-Related Concussion. Clin Pediatr. 2015;54(10):961–8.
135. Corwin DJ, Zonfrillo MR, Master CL, Arbogast KB, Grady MF, Robinson RL, et al. Characteristics of Prolonged Concussion Recovery in a Pediatric Subspecialty Referral Population. J Pediatr. 2014;165(6):1207–15.
136. Corwin DJ, Wiebe DJ, Zonfrillo MR, Grady MF, Robinson RL, Goodman AM, et al. Vestibular Deficits Following Youth Concussion. J Pediatr. 2015;166(5):1221–5.
137. Darling SR, Leddy JJ, Baker JG, Williams AJ, Surace A, Miecznikowski JC, et al. Evaluation of the Zurich Guidelines and Exercise Testing for Return to Play in Adolescents Following Concussion. Clin J Sport Med. 2014;24(2):128–33.
138. Glang AE, Koester MC, Chesnutt JC, Gioia GA, McAvoy K, Marshall S, et al. The Effectiveness of a Web-Based Resource in Improving Postconcussion Management in High Schools. J Adolesc Health. 2015;56(1):91–7.
139. Grubenhoff JA, Deakyne SJ, Comstock RD, Kirkwood MW, Bajaj L. Outpatient Follow-up and Return to School after Emergency Department Evaluation among Children with Persistent Post-Concussion Symptoms. Brain Inj. 2015;29(10):1186–91.
140. Lovell MR, Collins MW, Iverson GL, Field M, Maroon JC, Cantu R, et al. Recovery from Mild Concussion in High School Athletes. J Neurosurg. 2003;98(2):296–301.
141. Ransom DM, Vaughan CG, Pratson L, Sady MD, McGill CA, Gioia GA. Academic Effects of Concussion in Children and Adolescents. Pediatrics. 2015;135(6):1043–50.
142. Andersson K, Bellon M, Walker R. Parents' Experiences of Their Child's Return to School Following Acquired Brain Injury (ABI): A Systematic Review of Qualitative Studies. Brain Inj. 2016;30(7):829–38.