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The Royal Australian and New Zealand College of Radiologists®

Education Modules for Appropriate Imaging Referrals

PAEDIATRIC HEAD TRAUMA

This document is part of a set of ten education modules which are aimed at improving the appropriateness of referrals for medical imaging by educating health professionals about the place of imaging in patient care.

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TABLE OF CONTENTS

Authors....3

Introduction....3

What is Paediatric Head Injury?.... 3

When should you have increased suspicion of non-accidental injury (NAI) in a child who presents with blunt head trauma?.... 4

How can clinical decision rules help to standardise pre-test risk evaluation of children and younger adolescents with blunt head trauma?.... 6

What else do you need to think about when you consider imaging a patient with Blunt Head Trauma apart from pre-test risk?.... 8

Clinical Decision Rules....9

How can CDRs help determine the pre-test risk of clinically important intracranial injury in Paediatric patients with head trauma?.... 9

PECARN....10

Children's Head Injury Algorithm for the prediction of Important Clinical Events (CHALICE)....16

Canadian Assessment of Tomography for Childhood Head injury: the CATCH rule....18

What else do you need to think about, when you are considering performing diagnostic imaging in a paediatric patient with blunt head trauma?....19

Urgency....19

Test performance....19

Modality Table....19

References:....26

Appendix One: Evidence Summary Table....27

Appendix Two: PECARN....29

Appendix Three: CHALICE....30

Appendix Four: CATCH....31

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INTRODUCTION

WHAT IS PAEDIATRIC HEAD INJURY?

In Australia and other developed countries head injury is a common cause of death and neurological disability in children. It is a very common reason for presentation to emergency departments but the majority (80% to 90%) of head injuries are mild. However, even seemingly mild trauma can cause intracranial injuries. Few head injuries are life threatening or require neurosurgical intervention.

The **causes** of head injuries in children are age dependent. Infants typically are accidentally dropped or fall from a change table. Toddlers often fall as they learn to walk and later when they explore their environment and fall down stairs or off play equipment. Older children often fall off bikes and scooters or from climbing equipment. Adolescents sustain head injuries during contact sports or activities involving non-motorised or motorised vehicles.

Head injuries can lead to concussion, sometimes defined as mild head injury with alteration in mental status, mild or no depression in consciousness (Glasgow Coma Scale) and no focal neurological deficits. If brain imaging (head CT) is done, it is normal. Skull fractures can involve any bone of the skull but most frequently involve the parietal bones. Brain injuries can be parenchymal contusions, bleeding (parenchymal, epidural, subarachnoid, subdural or ventricular), diffuse axonal injury or diffuse brain swelling.

The gold standard for the diagnosis of acute intracranial injury is a head CT scan. This permits highly accurate diagnosis of clinically important intracranial injuries and skull fractures.

Treatment depends on history, mechanism of the injury, the clinical findings and results of a CT scan if undertaken. This may range from discharge home with head injury instructions, observation in the emergency department or an inpatient ward to neurosurgery such as the insertion of an intracranial pressure monitor, evacuation of an intracranial haematoma (e.g. subdural or epidural haematomas) or the elevation of a depressed skull fracture.

While CT scans are widely available, completed quickly and provide a definitive answer to rule in or exclude an intracranial injury in a head injured child, they are associated with a number of potential adverse consequences. Chief among them is the radiation associated cell damage which may cause lethal malignancies[1-3]. The younger the child, the greater the risk of carcinogenesis as a result of exposure to ionising radiation[4]. There is also the risk of complications in children who require sedation or anaesthesia to enable a CT to be performed. In addition, CT scanning is a resource intensive diagnostic test requiring specialised equipment and staff.

WHEN SHOULD YOU HAVE INCREASED SUSPICION OF NON-ACCIDENTAL INJURY (NAI) IN A CHILD WHO PRESENTS WITH BLUNT HEAD TRAUMA?

NAI needs to be considered in all children with head trauma. Head injuries are the main cause of death in child abuse. These injuries typically present as shaking injuries or are due to direct trauma (e.g. striking or throwing the child). There are a number of red flags for NAI:[5]

- History:
  - Absence of history.
  - Delay in seeking care.
  - Inconsistencies in the history of "what happened".
  - Repeat hospitalisations.
  - History of prematurity, failure to thrive.
  - Parental factors (e.g. stress, crowding, depression, drug abuse).
- Physical:
  - Mismatch of history and examination.
  - Multiple injuries.
  - Injuries of various ages.
  - Injuries in unusual locations.
  - Pathognomonic injuries (e.g. cigarette burns).
  - In shaken babies general lethargy, seizures and coma ("septic" appearance).
  - Retinal haemorrhages.
- Diagnostic imaging:
  - Occipital and frontal contusions.
  - Skull fractures.
  - Subarachnoid haemorrhages.
  - Co-existence of old and recent intracranial injuries.

QUESTION 1.

Which of the following features of the clinical history and examination increase the risk of blunt head trauma in a child being the result of non-accidental injury? Select all possible answers.

1A. Delay in seeking medical care for the child by the parents.

1B. Inconsistent history.

1C. Low socioeconomic status of parents.

1D. Intracranial injuries of various ages.

1E. Retinal haemorrhages.

CORRECT ANSWERS:

The following increase risk of non-accidental injury:

1A. Delay in seeking medical care for the child by the parents.

1B. Inconsistent history.

1D. Intracranial injuries of various ages.

1E. Retinal haemorrhages.

Examples of images showing injuries that may be due to NAI:

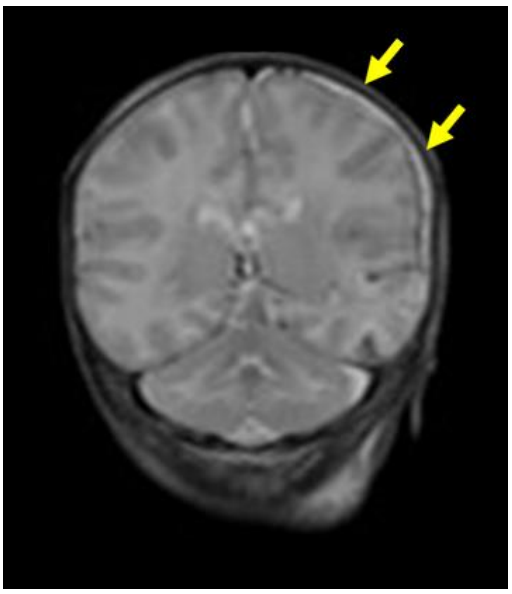


FIGURE 1: CORONAL T2 WEIGHTED IMAGE SHOWS LEFT FRONTOPARIETAL SUBDURAL HYGROMA (YELLOW ARROWS) CONSISTENT WITH DURAL TEARING AND LEAKAGE OF CSF INTO THE SUBDURAL SPACE.

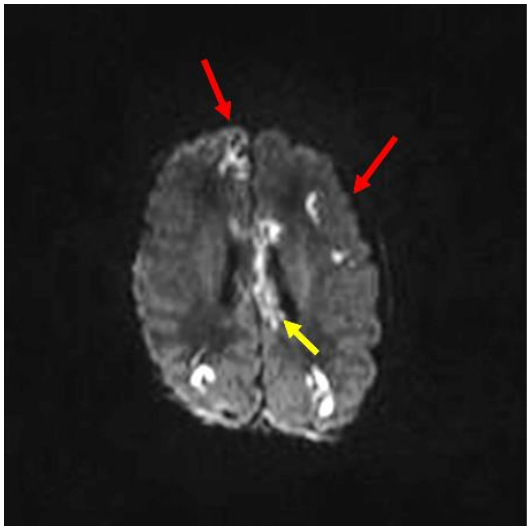


FIGURE 2: DIFFUSION WEIGHTED IMAGE SHOWING SUBCORTICAL (RED ARROWS) AND CORPUS CALLOSUM (YELLOW ARROWS) BRAIN LESIONS CONSISTENT WITH DIFFUSE AXONAL INJURY CHARACTERISTIC OF A SHAKING, ROTATIONAL, OR TRANSLATIONAL FORCE TO THE HEAD.

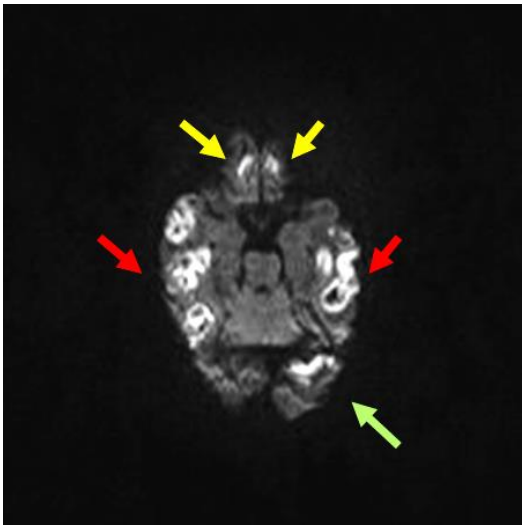


FIGURE 3: DIFFUSION WEIGHTED IMAGE SHOWING RESTRICTED DIFFUSION IN THE BILATERAL TEMPORAL (RED ARROWS), BILATERAL FRONTAL (YELLOW ARROWS) AND LEFT OCCIPITAL (GREEN ARROW) LOBES, CONSISTENT WITH BRAIN CONTUSION. THE INFERIOR FRONTAL AND INFERIOR AND ANTERIOR TEMPORAL LOBES ARE ESPECIALLY PRONE TO TRAUMATIC INJURY DUE TO THEIR PROXIMITY TO THE ANTERIOR AND MIDDLE CRANIAL FOSSA FLOORS.

HOW CAN CLINICAL DECISION RULES HELP TO STANDARDISE PRE-TEST RISK EVALUATION OF CHILDREN AND YOUNGER ADOLESCENTS WITH BLUNT HEAD TRAUMA?

When evaluating paediatric patients with suspected intracranial injury, one of the key issues to be addressed is whether or not the patient should be investigated using imaging to confirm or refute the presence of clinically important injury(ies) that would change the subsequent medical treatment or investigation of the patient.

When attempting to make the decision about whether or not to use diagnostic imaging, it is important to focus on **features of the history and physical exam** that have been found to be associated with the presence of **clinically important intracranial injury**.

At first, it might seem simpler, quicker, and safer simply to perform an imaging test on everyone presenting with head trauma. When the pre-test probability of a condition is not very low, the costs and risks of diagnostic imaging are more than outweighed by the considerable benefits of earlier diagnosis of a potentially serious disorder. These benefits can include simpler, less invasive treatment or guidance for surgical or medical therapy that prevent severe disability or death.

However, there are a number of disadvantages to the practice of referral of patients for imaging without first considering what the pre-test probability of a condition is likely to be. They include:

- **Unnecessary exposure to ionising radiation**. This is particularly important in babies, children, and adolescents who are more sensitive to the carcinogenic effects of exposure to ionising radiation. CT scanning is associated with around 100 times the dose of radiation delivered by a plain radiograph (or x-ray)
- **Financial cost to the patient and health system of unnecessary testing**. These costs are both direct and indirect (the latter due to waiting time in emergency departments, prolonged length of stay in a hospital, time away from work, school, and other responsibilities for patients and caregivers waiting for imaging to be performed, having it performed, and then waiting for the result).
- **Incidental findings on imaging frequently have no clinical significance for the patient but trigger further imaging follow up to exclude the very small possibility of something significant.** An example of this includes dilated perivascular spaces and intracranial cysts which are relatively common, and generally clinically insignificant, findings on CT scans of the brain performed in children. These can trigger follow up imaging to further characterise the abnormality and exclude something that is very unlikely but potentially serious, such as a brain neoplasm. Follow up imaging may necessitate more exposure to CT scanning.

Continued increases in healthcare costs are a global problem. More than ever before, medical practitioners are being asked to be accountable for utilisation of finite health care resources and to add value and reduce waste in the care they deliver to patients. Reducing inappropriate use of diagnostic imaging in situations where it is highly unlikely to result in a net benefit to the patient is an important way to reduce waste and improve quality of care.

Clinical decision rules (CDRs)[6] can help you to focus on the aspects of the history and examination that best discriminate between:

- **Patients with low-to-no risk of significant pathology** who are, therefore, unlikely to benefit from diagnostic imaging; and
- **Patients who do not have negligible risk** who need imaging to guide further specific treatment including in some cases in-hospital monitoring, medical therapy, or even surgery.

CDRs have been developed by gathering detailed clinical datasets from large numbers patients with a particular condition, such as children presenting to an emergency department following head trauma. They are comprised of a series of key examination findings (such as altered conscious state) and aspects of the history (such as number of episodes of vomiting) that have been found, when absent, to be associated with such a low risk (or pre-test probability) of clinically important injury that imaging is not required to further reduce this risk.

The emphasis of the current educational modules is on CDRs that involve risk assessment of patients with regard to their requirement for diagnostic imaging, but CDRs for other outcomes (such as prognosis) have also been developed.

The usefulness of CDRs is that they **help to reduce the subjectivity and inter-observer variation** involved in the clinical assessment of patients with specific conditions that sometimes, but not always, require imaging. Imaging is sometimes performed in these conditions to allow diagnosis of serious pathology.

- CDRs help to standardise the otherwise subjective process of pre-test risk assessment.
- Using CDRs can help to increase your confidence about the safety of managing your patient without imaging when recognised clinical risk factors for serious pathology are entirely absent. Alternatively, they can help you correctly identify patients at higher risk who do require further investigation.
- Documentation in the medical record that you have used a high quality CDR to evaluate your patient and make management decisions based on this is not only good practice but increases the likelihood that another medical practitioner evaluating your patient would come to the same conclusions as you did about management.

Please see the Clinical Decision Rules Module for more information about:

- **what CDRs are;**
- **how they are developed; and**
- **what the characteristics of a high quality CDR are.**

Resources: Something that will become apparent as you work through these modules is the difficulty involved in trying to commit the elements of CDR to memory. It is a good idea to refer to an electronic or hard copy of the CDR each time you use it to ensure that you are applying it correctly. To support this, the following resources are provided:

- Printable PDFs of all of the CDRs including inclusion and exclusion criteria.
- "Pocket-sized" PDFs suitable for printing, lamination, and attachment to a lanyard.
- Links to the website MDCalc where you will find a calculator that allows you to enter clinical data for your patient into a clinical decision rule. This website does not feature all published CDRs for paediatric patients with suspected intracranial injury and does not discuss the reasons for featuring some and not others. However, this module will help you develop an understanding of the advantages and disadvantages as well as relative performance of the various CDRs. Go to the website now and try out the calculator for the PECARN CDR for use in children with blunt head trauma:
  - *www.mdcalc.com/pecarn-pediatric-head-injury-trauma-algorithm/*
- For more information about specific imaging tests and procedures please see – *www.insideradiology.com.au*

WHAT ELSE DO YOU NEED TO THINK ABOUT WHEN YOU CONSIDER IMAGING A PATIENT WITH BLUNT HEAD TRAUMA APART FROM PRE-TEST RISK?

- **Test performance** (sensitivity, specificity, LR+ and LR-) in relation to the pathological process(es) you are trying to diagnose or exclude.
- **What is available locally**, especially in an emergency?
- **Radiation dose** (of particular importance in young and pregnant patients).
- **Need for sedation or general anaesthesia** in young or uncooperative children, which can be associated with adverse events.
- **Financial and other costs** to the patient and health system of one diagnostic strategy compared with another.
- **Renal function** in the case of imaging tests that involve the use of iodinated contrast media or gadolinium chelates.
- **Patient preferences** – if two diagnostic tests perform equally well at confirming or excluding the presence of a particular condition, patients may have a preference for one over another for reasons of cost, convenience, risk, or real/perceived discomfort associated with a particular diagnostic test or diagnostic strategy.

CLINICAL DECISION RULES

HOW CAN CDRS HELP DETERMINE THE PRE-TEST RISK OF CLINICALLY IMPORTANT INTRACRANIAL INJURY IN PAEDIATRIC PATIENTS WITH HEAD TRAUMA?

A number of CDRs exist that are applicable to paediatric patients with suspected intracranial injury[7]. We have selected three of these for the current module. They have been identified through a systematic search of the literature to be the best performing tools available for this patient group.

The following CDRs have been chosen based on the rigour of their development methodology and because they are designed specifically for use in children.

You should be aware that the Canadian CT Head Rule (CCHR) can be used in adolescents 16 years of age and older. Please refer to the module on Adult Head Trauma for more information on the CCHR. The New Orleans Criteria (NOC) were developed from data collected from a series of patients, including children, with blunt head trauma. However, the subset of patients who were children was so small that uncertainty about how the NOC perform in this group prevents their routine use in paediatric practice.

The three CDRs for use in paediatric patients with head trauma that we will be discussing in more detail are:

1. **PECARN**[8]
2. **CHALICE**[9]
3. **CATCH**[10]

For each CDR, you will find a summary statement that provides:

- an overview of the performance of the rule;
- general inclusion and exclusion criteria;
- precautions about routine clinical use of the CDR;
- more detailed information about these aspects of the three CDRs can be found in the evidence table (Appendix One) at the end of the module. It allows rapid comparison of the performance, inclusion and exclusion criteria for each CDR.

Throughout this module, you will be presented with questions that will evaluate module content and also your ability to apply this to real clinical situations.

PECARN[8]

Summary Statement:

The PECARN[8] clinical decision rule aims to determine which children are at very low risk of important brain injury and who therefore do not require a CT scan of the head. It has been developed from the largest paediatric data set of the three CDRs featured in this module. The PECARN clinical decision rule has been shown in a single, multicentre validation study to be high performing in identifying children who present within 24 hours of blunt head trauma with GCS of 14 or 15 who are at very low risk of a clinically important traumatic brain injury (defined as death, neurosurgical intervention, intubation for more than 24 hours or admission of 2 nights or more due to traumatic brain injury). The PECARN clinical decision rule consists of 2 age specific rules: one for children less than 2 years of age, one for children 2 years and older. The elements for both age groups overlap but are not identical.

Inclusion criteria (ALL must be satisfied if PECARN algorithm to be applied):

- Age < 18 years old.
- GCS 14 or 15.
- Presented to ED within 24 hours of head trauma.

Exclusion criteria (if ANY are present the algorithm cannot be applied):

- Trivial injury mechanisms: ground level falls, walking or running into stationary objects, no signs or symptoms of head trauma other than scalp abrasions and lacerations.
- Penetrating trauma.
- Known brain tumours.
- Pre-existing neurological disorders.
- Neuroimaging at an outside hospital before transfer.
- Patients with ventricular shunts.
- Bleeding disorders.

Algorithm:

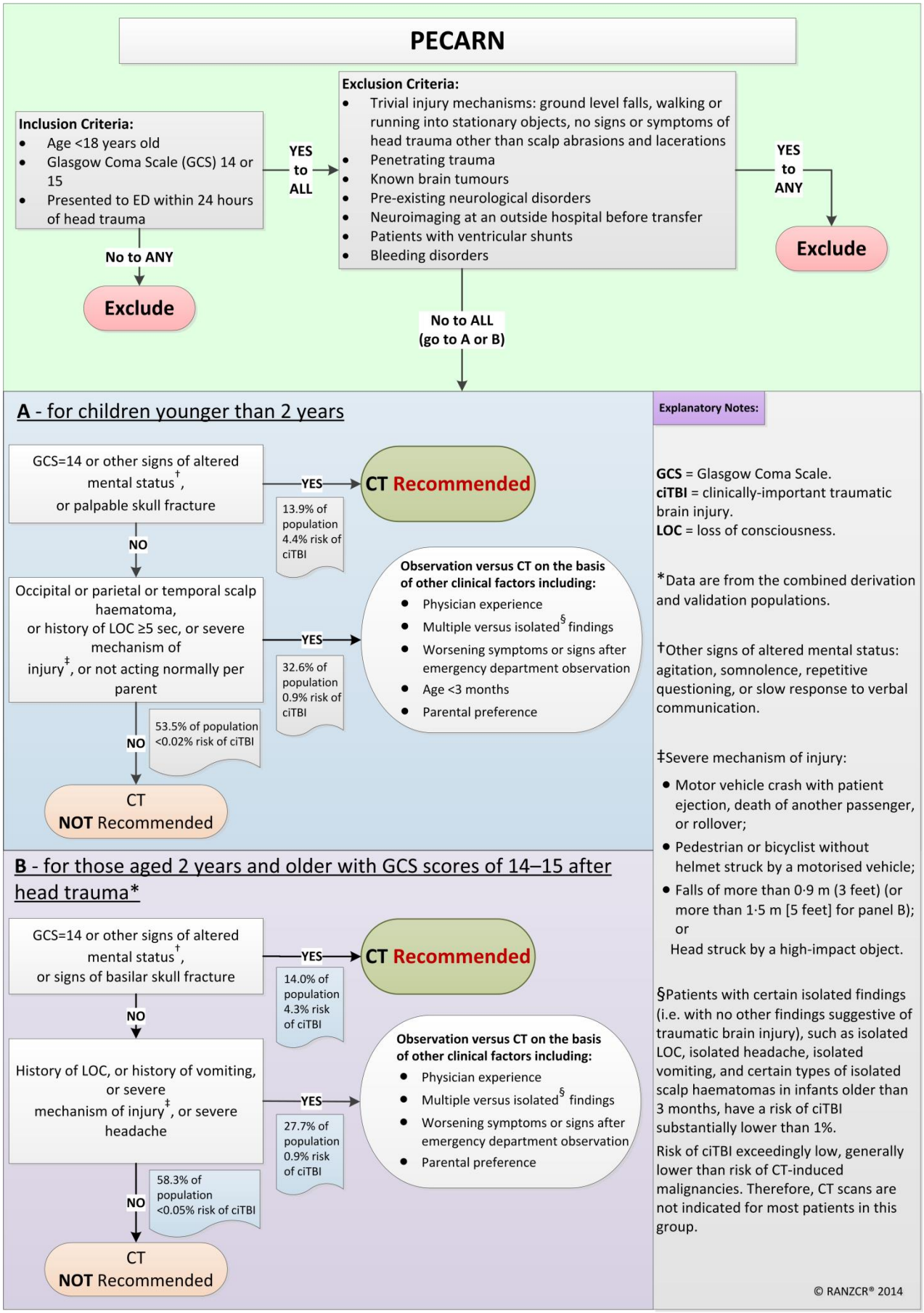


FIGURE 4: FLOWCHART TO DECIDE IF A PAEDIATRIC PATIENT NEEDS IMAGING USING THE PECARN CLINICAL DECISION RULE
(A) FOR CHILDREN YOUNGER THAN 2 YEARS; AND
(B) FOR THOSE AGED 2 YEARS AND OLDER WITH GCS SCORES OF 14–15 AFTER HEAD TRAUMA

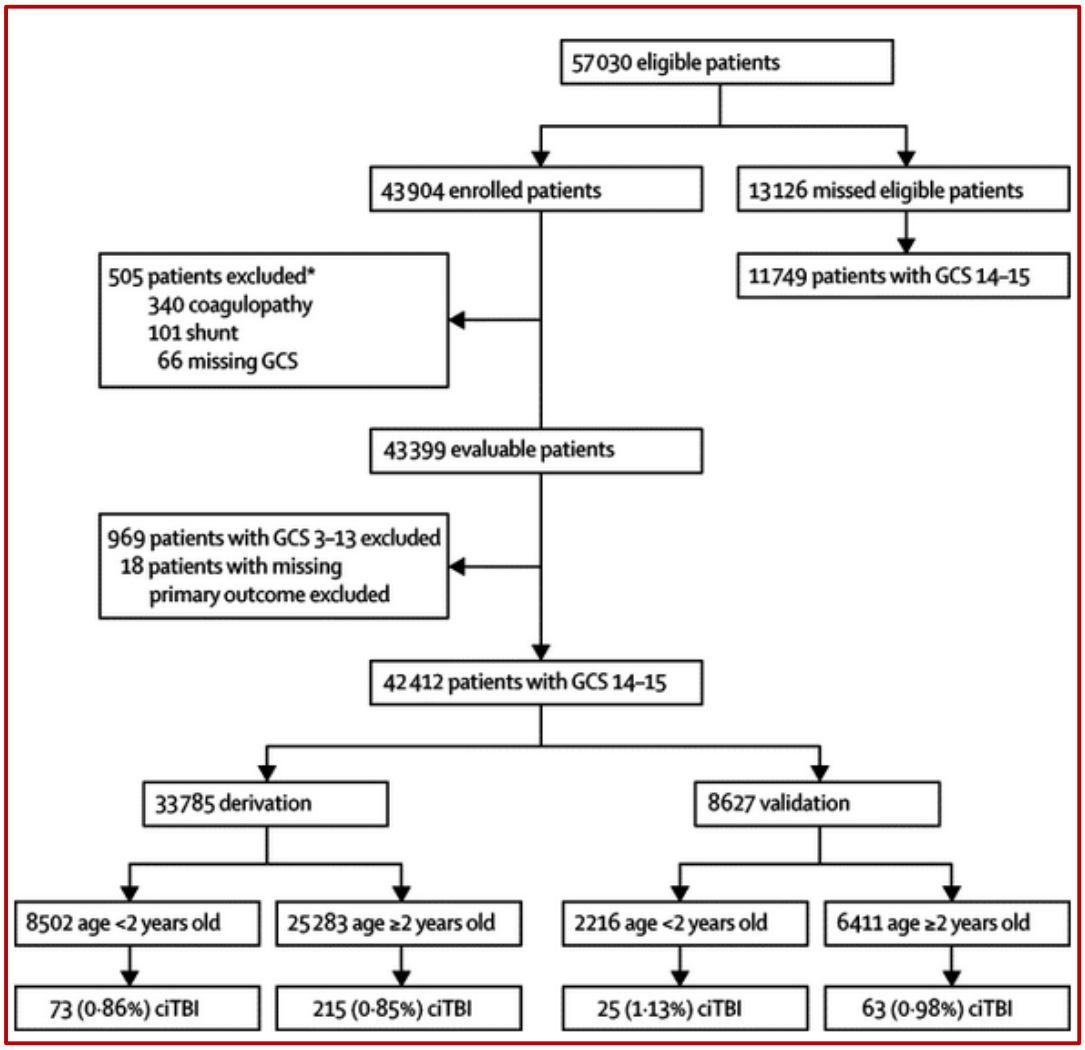
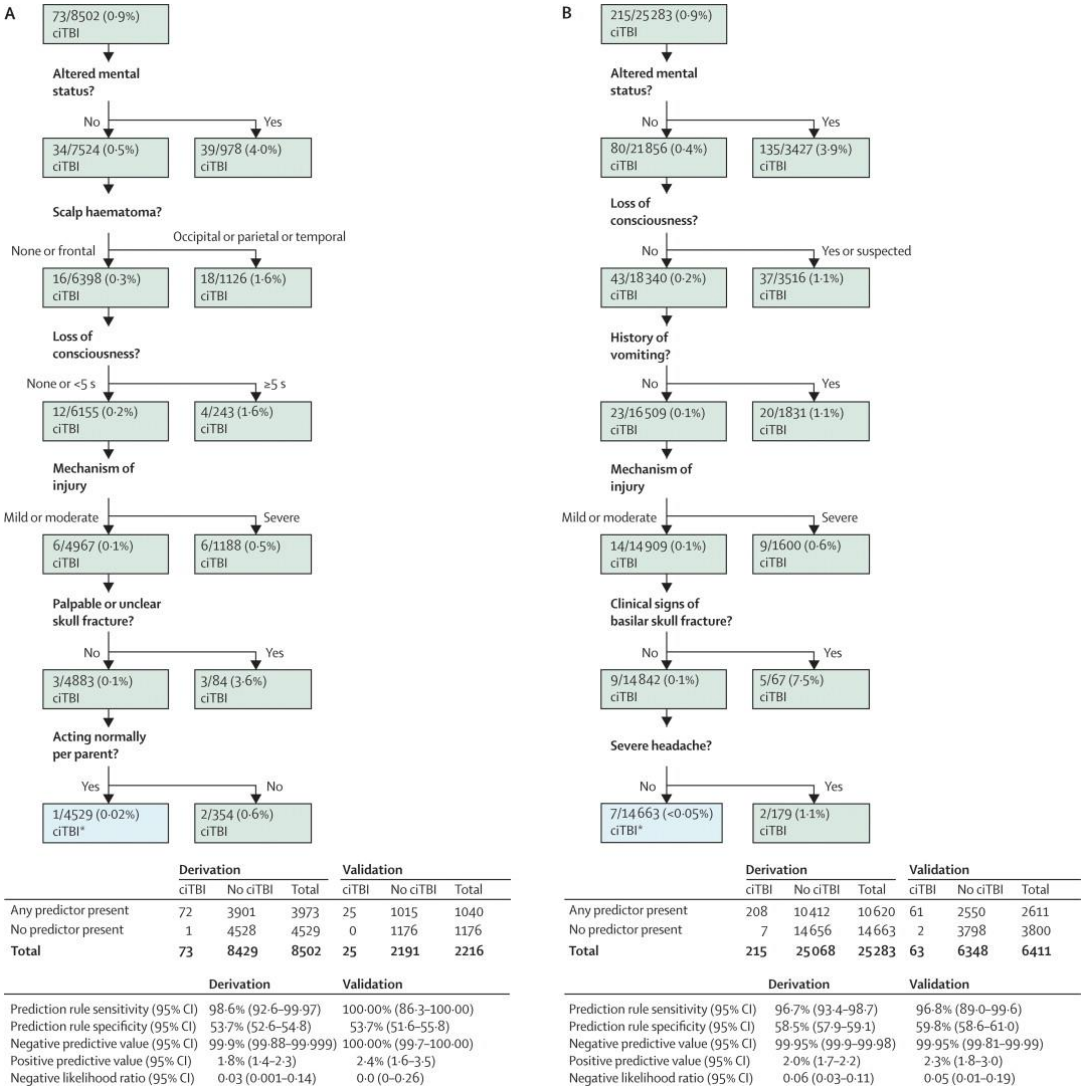


FIGURE 5 - FLOWCHART ILLUSTRATING PATIENT RECRUITMENT FOR THE PECARN STUDY

GCS = Glasgow Coma Scale, ciTB = clinically-important Traumatic Brain Injury. *Two patients had more than one exclusion.



	Derivation			Validation		
	ciTBI	No ciTBI	Total	ciTBI	No ciTBI	Total
Any predictor present	72	3901	3973	25	1015	1040
No predictor present	1	4528	4529	0	1176	1176
Total	**73**	**8429**	**8502**	**25**	**2191**	**2216**

	Derivation	Validation
Prediction rule sensitivity (95% CI)	98·6% (92·6–99·97)	100·00% (86·3–100·00)
Prediction rule specificity (95% CI)	53·7% (52·6–54·8)	53·7% (51·6–55·8)
Negative predictive value (95% CI)	99·9% (99·88–99·999)	100·00% (99·7–100·00)
Positive predictive value (95% CI)	1·8% (1·4–2·3)	2·4% (1·6–3·5)
Negative likelihood ratio (95% CI)	0·03 (0·001–0·14)	0·0 (0–0·26)

	Derivation			Validation		
	ciTBI	No ciTBI	Total	ciTBI	No ciTBI	Total
Any predictor present	208	10 412	10 620	61	2550	2611
No predictor present	7	14 656	14 663	2	3798	3800
Total	**215**	**25 068**	**25 283**	**63**	**6348**	**6411**

	Derivation	Validation
Prediction rule sensitivity (95% CI)	96·7% (93·4–98·7)	96·8% (89·0–99·6)
Prediction rule specificity (95% CI)	58·5% (57·9–59·1)	59·8% (58·6–61·0)
Negative predictive value (95% CI)	99·95% (99·9–99·98)	99·95% (99·81–99·99)
Positive predictive value (95% CI)	2·0% (1·7–2·2)	2·3% (1·8–3·0)
Negative likelihood ratio (95% CI)	0·06 (0·03–0·11)	0·05 (0·01–0·19)

FIGURE 6: PREDICTION TREE FOR ciTBI IN CHILDREN YOUNGER THAN 2 YEAR (A) AND IN THOSE AGED 2 YEARS AND OLDER (B) IN THE DERIVATION GROUP

ciTBI = clinically-important Traumatic Brain Injury.

*This box indicates children at very low risk of ciTBI in whom CT scans could be obviated.

Ultimately the PECARN rule provides risk estimates which clinicians can use in discussion with parents to decide on management strategies in children with head injuries. If patients have none of the identified risk criteria shown in the figures above (Figures 5 and 6) from the derivation study by Kuppermann et al[8] their risk of a clinically important traumatic brain injury is very low (less than 0.02% in ≥2 years olds and less than 0.05% in < 2 year olds) and therefore they do not require CT scanning.

- The criteria in children < 2 years of age are GCS 14 or other signs of mental status change, palpable skull fracture, occipital or temporal scalp haematoma, loss of consciousness, severe mechanism or not acting normally.
- The criteria in children ≥ 2 years of age are GCS 14 or other signs of mental status change, signs of basilar skull fracture, loss of consciousness, vomiting, severe mechanism or severe headache.

The authors of the rule provide an algorithm (reproduced in Figure 4 above) which helps clinicians risk stratify the management of patients into those with:

1. Very low risk - *no CT required*;
2. Higher risk based on altered mental status or signs of skull fracture - *CT required*; and
3. A middle group with any of the other 4 predictors - this middle group **may be managed by CT or observation over a period of time without CT** depending on other factors such as:
    a. multiple rather than isolated findings;
    b. worsening symptoms or signs;
    c. physician experience; and
    d. parental preference

The tool requires external validation in other countries and outside dedicated paediatric emergency settings where it may not perform as well, due to lesser expertise of clinicians in the assessment of children.

QUESTION 2.

A child under 2 years sustained a blunt head injury.

Which of the following features of the clinical history and examination need to be ABSENT to regard the injury as very low risk (CT scan not required) according to the PECARN CDR? Select all possible answers.

2A. Occipital scalp haematoma
2B. Palpably depressed fracture
2C. Vomiting
2D. Mental state alteration
2E. GCS less than 15

CORRECT ANSWER

The following features all need to be absent to regard the injury as very low risk:

2A. Occipital scalp haematoma
2B. Palpably depressed fracture
2D. Mental state alteration
2E. GCS less than 15

QUESTION 3.

A child above 2 years sustained a blunt head injury.

Which of the following features of the clinical history and examination need to be ABSENT to regard the injury as very low risk and therefore the child does not require a CT scan according to the PECARN clinical decision rule? Select all possible answers.

3A. Severe headache
3B. Loss of consciousness
3C. Vomiting
3D. Racoon's eyes sign
3E. GCS less than 15

CORRECT ANSWER

The following features need to be absent to regard the injury as very low risk and thus according to the PECARN CDR the chid does not require a CT scan:

3A. Severe headache
3B. Loss of consciousness
3C. Vomiting
3D. Racoon's eyes sign
3E. GCS less than 15

Question 4.

Use the link below to the PECARN calculator and enter the following information about an 8 year old boy who had a blunt head injury while playing football at school due to colliding with one of his classmates on the football ground during a match.

He has a GCS of 15, has vomited twice in the car on the way to the emergency department, and is complaining of a mild to moderate headache. There is nothing to find on examination.
(link - *www.mdcalc.com/pecarn-pediatric-head-injury-trauma-algorithm/)*

Based on the data presented, is CT indicated?

4A. Yes.

4B. No.

4C. It could be considered after a period of observation and is unlikely to be necessary if his signs and symptoms do not change.

CORRECT ANSWER

Based on the data presented, is CT indicated?

4C. It could be considered after a period of observation and is unlikely to be necessary if his signs and symptoms do not change.

CHILDREN'S HEAD INJURY ALGORITHM FOR THE PREDICTION OF IMPORTANT CLINICAL EVENTS (CHALICE)

Summary Statement:

The CHALICE[9] clinical decision rule aims to determine which children with head injuries of any severity require a CT scan of the head.

The CHALICE decision rule is for paediatric patients presenting acutely with head trauma. A validation study is yet to be performed. Many of the variables listed in the algorithm rely on the clinician's judgement and the accuracy of the information provided by the witness, both of which could be biased by problems with recall and inter-observer disagreement due to subjectivity of the CDR elements. This could in turn affect the decision to perform a CT scan. In future validation studies, it would be useful to test reproducibility. The rule has been shown to be sensitive at predicting patients who will either:

- die from their intracranial injuries;
- need neurosurgical intervention; or
- have an intracranial injury on CT scan but require only observation and supportive treatment.

Inclusion criteria (ALL must be satisfied for the CHALICE rule to be applied)

- Patients less than 16 years old with a history or signs of injury to head.
- Loss of consciousness or amnesia not a requirement.

Exclusion criteria – None.

The children's head injury algorithm for the prediction of important clinical events rule
A computed tomography scan is required if any of the following criteria are present. • **History** ▪ Witnessed loss of consciousness of >5 min duration. ▪ History of amnesia (either antegrade or retrograde) of >5 min duration. ▪ Abnormal drowsiness (defined as drowsiness in excess of that expected by the examining doctor). ▪ ≥3 vomits after head injury (a vomit is defined as a single discrete episode of vomiting). ▪ Suspicion of non-accidental injury (NAI, defined as any suspicion of NAI by the examining doctor). ▪ Seizure after head injury in a patient who has no history of epilepsy. • **Examination** ▪ Glasgow Coma Score (GCS) <14, or GCS<15 if <1 year old. ▪ Suspicion of penetrating or depressed skull injury or tense fontanelle. ▪ Signs of a basal skull fracture (defined as evidence of blood or cerebrospinal fluid from ear or nose, panda eyes, Battles sign, haemotympanum, facial crepitus or serious facial injury). ▪ Positive focal neurology (defined as any focal neurology, including motor, sensory, coordination or reflex abnormality). ▪ Presence of bruise, swelling or laceration >5 cm if <1 year old. • **Mechanism** ▪ High-speed road traffic accident (defined as accident with speed >40 m/h) either as pedestrian, cyclist or occupant. ▪ Fall of >3 m in height. ▪ High-speed injury from a projectile or an object. If none of the above variables are present, patient is at low risk of intracranial pathology.

TABLE 1 - CHALICE ALGORITHM [9]

QUESTION 5.

According to the CHALICE decision rule for children with blunt head trauma, which of the following features is an indication for CT scanning? Select all possible answers.

5A. GCS of 15 or less regardless of the age of the patient.

5B. Vomiting 5 times after the acute injury.

5C. Loss of consciousness for 60 seconds.

5D. Raccoon eyes OR CSF otorrhoea OR palpably depressed skull fracture.

5E. Weakness in one arm.

CORRECT ANSWER

Based on the CHALICE CDR, the following features are indicators for CT scanning:

5B. Vomiting 5 times after the acute injury.

5D. Raccoon eyes OR CSF otorrhoea OR palpably depressed skull fracture.

5E. Weakness in one arm.

CANADIAN ASSESSMENT OF TOMOGRAPHY FOR CHILDHOOD HEAD INJURY: THE CATCH RULE

Summary statement:

The CATCH[10] clinical decision rule aims to determine which children with mild head injuries require a CT scan of the head.

The CATCH rule was developed for children with mild head injuries. The application of the CATCH rule requires two steps. First, it assesses if a patient has a mild head injury defined as GCS of 13-15, witnessed loss of consciousness, definite amnesia, witnessed disorientation, more than one vomit or persistent irritability (in a child under 2 years of age). If a patient has such a head injury, the CATCH rule can be applied. **For patients who have a milder or more severe injury the CATCH rule does not apply.**

The CATCH derivation study found 4 clinical findings that are highly sensitive for the need for neurosurgical intervention (primary outcome) and an additional 3 that are sensitive for predicting brain injury on CT. When the 7 findings are combined, an algorithm is created that can predict the need for CT scanning. The CATCH rule requires external validation.

Inclusion criteria (ALL must be satisfied for the CATCH rule to be applied):

- Blunt trauma to the head resulting in witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (two or more distinct episodes 15 minutes apart), or persistent irritability in the ED (for children under two years of age).
- Initial GCS of at least 13.
- Injury within the past 24 hours.

Exclusion criteria (If ANY are present the CATCH rule cannot be applied):

- Obvious penetrating skull injury.
- Obvious depressed fracture.
- Acute focal neurological deficit.
- Chronic generalized developmental delay.
- Head injury secondary to suspected child abuse.
- Patients returning for reassessment of a previously treated head injury.
- Pregnancy.

Canadian Assessment of Tomography for Childhood Head injury: the CATCH Rule
CT of the head is required only for children with minor head injury* and any one of the following findings: **High risk (need for neurosurgical intervention)** 1. Glasgow Coma Scale score <15 at two hours after injury. 2. Suspected open or depressed skull fracture. 3. History of worsening headache. 4. Irritability on examination. **Medium risk (brain injury on CT scan)** 5. Any sign of basal skull fracture (e.g., haemotympanum, "raccoon" eyes, otorrhea or rhinorrhea of the cerebrospinal fluid, Battle's sign). 6. Large, boggy haematoma of the scalp. 7. Dangerous mechanism of injury (e.g., motor vehicle crash, fall from elevation ≥3 ft [≥91 cm] or 5 stairs, fall from bicycle with no helmet). **Note:** CT = computed tomography. *Minor head injury is defined as injury within the past 24 hours associated with witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (more than one episode) or persistent irritability (in a child under two years of age) in a patient with a Glasgow Coma Scale score of 13-15.

TABLE 2 - CATCH ALGORITHM[10]

WHAT ELSE DO YOU NEED TO THINK ABOUT, WHEN YOU ARE CONSIDERING PERFORMING DIAGNOSTIC IMAGING IN A PAEDIATRIC PATIENT WITH BLUNT HEAD TRAUMA?

URGENCY – Patients who are Intubated and those with significantly depressed or deteriorating GCS require urgent CT and neurosurgical referral.

TEST PERFORMANCE – See the table below for strengths, weaknesses, and indications for different imaging strategies for paediatric patients with blunt head trauma.

MODALITY TABLE

MODALITY	STRENGTHS	WEAKNESSES	COMMENTS
CT Link - *www.insideradiology.com.au/pages/view.php?T_id=61*	• Fast. • Available. • Sensitive and specific for surgically important haemorrhages . • Sensitive and specific for skull fractures.	• Moderate radiation dose. • Insensitive to non-haemorrhagic brain injury (e.g. diffuse axonal injury).	Examination of choice for acute severe head injury.
MRI Link - *www.insideradiology.com.au/pages/view.php?T_id=53*	• No ionising radiation. • Sensitive and specific for brain parenchymal damage and haemorrhage.	• Slow. • Relatively poor availability. • May require general anaesthesia. • Pacemakers, ferromagnetic objects (e.g. bullets, aneurysm clips, cochlear/stapes implants etc.) are a contraindication. • Relatively insensitive to skull fractures.	Examination of choice for subacute/chronic head injury where clinical findings such as focal neurological signs/symptoms, cognitive, behavioural or psychiatric abnormalities and/or the development of seizures are unexplained by CT scanning. MRI can provide prognostic information for more severely injured patients regarding the nature and extent of brain parenchymal injuries.

MODALITY	STRENGTHS	WEAKNESSES	COMMENTS
Cranial Ultrasound	• No radiation.	• Slow. • Quality of the exam is highly dependent on the skill of the operator, unlike CT and MRI that are much more operator independent. • Requires open anterior fontanelle (<1yr) as a sonographic window for the ultrasound probe so not useful in toddlers/older children. • Insensitive to brain parenchymal damage and small parenchymal haemorrhage. • Insensitive to extra axial haemorrhage. • Good for demonstrating ventricular enlargement but this is a non-specific and uncommon finding in the acutely injured infant.	Inappropriate in most instance of head trauma. There may be a role in the future for the diagnosis of skull fractures but ultrasound is not currently in routine use for this purpose.
Skull radiograph (X ray) Link – *http://www.insideradiology.com.au/pages/view.php?T_id=24*	• Fast. • Inexpensive. • Sensitive to skull fractures.	• Small - moderate radiation dose. • Insensitive to brain parenchymal damage and intracranial haemorrhages.	Inappropriate in most instances of head trauma. Has a role when there is no clinical evidence of a brain injury but clinical suspicion of skull fracture. Nevertheless, most if not all children with a fracture demonstrated by skull radiography will proceed to CT or MRI because of the markedly increased risk of coexistent intracranial injury.

TABLE 3 - IMAGING MODALITIES FOR PAEDIATRIC HEAD TRAUMA

QUESTION 6.

A 6 month old boy is brought into the emergency department after having fallen off the change table (a height of 1.2metres) when the mother was distracted by another child. He did not lose consciousness or vomit. He is awake and alert, GCS 15, seems covered in, and smells of, vomit and has a soft boggy swelling (6 cm across) over the occiput. There is bruising over the lower back and both upper arms. The adults who are with the patient are yelling at each other and the male calls the mother "stupid" in front of staff.

PART 1 - What are possible indicators of NAI in this scenario? Select all possible answers.

6.1A. Discordance of history and examination.

6.1B. Parents fighting.

6.1C. Bruising in unusual locations outside the head.

6.1D. Fall from change table.

6.1E. GCS 15.

PART 2 - Which clinical decision rule/algorithm for children with head trauma can be applied in this scenario? Select all possible answers.

6.2A. CHALICE.

6.2B. CATCH.

6.2C. PECARN.

PART 3 - Which criteria for the CHALICE rule are present in this patient that should prompt a CT scan? Select all possible answers.

6.3A. Suspicion of NAI.

6.3B. Large boggy swelling.

6.3C. Vomiting.

6.3D. Height of fall.

6.4E. Amnesia .

CORRECT ANSWERS:

PART 1 - What are possible indicators of NAI in this scenario?

6.1A. Discordance of history and examination.

6.1B. Parents fighting.

6.1C. Bruising in unusual locations outside the head.

PART 2 - Which clinical decision rule/algorithm for children with head trauma can be applied in this scenario:

6.2A. CHALICE.

6.2C. PECARN.

FEEDBACK: CATCH specifically excludes cases of suspected NAI so cannot be used in this child.

PART 3 - Which criteria for the CHALICE rule are present in this patient that should prompt a CT scan?

6.3A. Suspicion of NAI.

6.3B. Large boggy swelling.

QUESTION 7.

A 12 year old girl falls off a bicycle going down a hill at 11 AM. She was not wearing a helmet. She has a brief loss of consciousness and vomits once. The event is witnessed by a neighbour who walks her home. At home she complains of headache and is taken to the GP at 2 PM. On examination she complains of headache and the GP assesses a GCS of 14 but no focal neurological abnormality and her pupils are reactive to light. She was premature and born at 32 weeks gestation.

PART 1 - Can the CATCH rule be applied to this patient?

7.1A. Yes.

7.1B. No.

PART 2 - Does this patient require a CT scan according to the CATCH rule?

7.2A. Yes.

7.2B. No.

PART 3 - What are the CATCH criteria which indicate a head CT in this patient? (tick all that apply)

7.3A. GCS.

7.3B. Vomiting.

7.3C. Headache.

7.3D. Dangerous mechanism.

7.3E. LOC.

PART 4 - Does she satisfy criteria for CT according to PECARN?

7.4A. Yes.

7.4B. No.

CORRECT ANSWERS:

PART 1 - Can the CATCH rule be applied to this patient?

7.1A. Yes.

FEEDBACK: This patient fulfils criteria for mild head injury according to CATCH (LOC, GCS 14).

PART 2 - Does this patient require a CT scan according to the CATCH rule?

7.2A. Yes.

PART 3 - What are the CATCH criteria which indicate a head CT in this patient?

7.3A. GCS.

7.3D. Dangerous mechanism.

PART 4 - Does she satisfy criteria for CT according to PECARN?

7.4A. Yes.

QUESTION 8.

A 14 year old plays Australian rules football in a friendly game and gets knocked to the ground during a tackle, landing head first. He lost consciousness for 1 minute and was groggy for 10 minutes. He was keen to return to play but was told not to by his coach. His parents were in the stands and witnessed the episode. After the game he vomited three times and complained of frontal headache. You see him in the emergency department 2 hours after the injury. He looks very well without headache, a normal neurological examination and a GCS of 15. He has an occipital scalp haematoma. Both parents are lawyers and are anxious that their son may have a brain injury.

PART 1. Can you use the PECARN rule in this patient?

8.1A. Yes.

8.1B. No.

PART 2. As he looks well and has a normal examination now, is he at very low risk (and therefore does not require a CT scan) according to the PECARN rule?

8.2A. Yes, at low risk.

8.2B. No, not necessarily low risk.

PART 3. What higher risk criteria according to the PECARN algorithm does he have? Select all possible answers.

8.3A. History of vomiting.

8.3B. History of LOC.

8.3C. Severe mechanism.

8.3D. Headache.

8.3E. Occipital scalp haematoma.

PART 4. Based on the PECARN algorithm what factors should you consider when deciding whether this patient should receive a CT scan or be observed? Select all possible answers.

8.4A. Parental anxiety about missing an injury.

8.4B. Parental anxiety about the impact of radiation exposure during CT scanning.

8.4C. Symptoms are improving.

8.4D. Physician experience with evaluating and monitoring a person of this age.

CORRECT ANSWERS:

PART 1. Can you use the PECARN rule in this patient?

8.1A. Yes.

PART 2. As he looks well and has a normal examination now, is he at very low risk (and therefore does not require a CT scan) according to the PECARN rule?

8.2B. No, not necessarily low risk.

PART 3. What higher risk criteria according to the PECARN algorithm does he have?

8.3A. History of vomiting.

8.3B. History of LOC.

PART 4. Based on the PECARN algorithm what factors should you consider when deciding whether this patient should receive a CT scan or be observed?

8.4A. Parental anxiety about missing an injury.

8.4B. Parental anxiety about the impact of radiation exposure during CT scanning.

8.4C. Symptoms are improving.

8.4D. Physician experience with evaluating and monitoring a person of this age.

QUESTION 9.

A four week old girl presents to the ED with vomiting and drowsiness for the past 3 hours. She was at home with her dad who says he left her on his bed and she rolled off onto the floor about 6 hours ago. There is a large boggy swelling in the right parietal region. Examination reveals a baby who opens eyes to gentle stimulus (gentle touching), is lying quietly and still, is markedly upset and cries loudly with minimal handling, and moves all limbs appropriately to pain. You calculate her GCS at 11 or 12.

What would your management and assessment include? Select all possible answers.

9A. Urgent CT of the brain.

9B. Notifications of the paediatricians and neurosurgeons and admission to a tertiary paediatric hospital.

9C. Cervical spine protection and imaging.

9D. Consideration of non-accidental injury.

CORRECT ANSWER:

Your management should include:

9A. Urgent CT of the brain.

9B. Notifications of the paediatricians and neurosurgeons and admission to a tertiary paediatric hospital.

9C. Cervical spine protection and imaging.

9D. Consideration of non-accidental injury.

FEEDBACK: This child has altered conscious state, altered behaviour, and vomiting a number of times post a head injury. She is also in a vulnerable age group. Her management should include a CT scan of the brain, and notification of the senior person in the emergency department. A cervical spine injury is assumed until it can be excluded which will in this case require imaging, starting with plain radiography (x-rays).

This child has a head injury and needs neurosurgical care and possibly intervention. The neurosurgical team should be notified early. There are concerns regarding NAI in this child who has a history that does not match the injury, a delay in presentation and an age that is at risk.

QUESTION 10.

An 11 year old boy is riding his BMX bike in a paddock. He comes off going over a jump and lands on his back. The accident happened 90 minutes ago. He is brought in by ambulance. He has an undisplaced fracture of the right forearm that has been temporarily splinted, and he has had oral analgesia. He was able to walk at the scene and walked back to the family who were 100 metres away, and he reports no LOC. His helmet is cracked at the back. There is no other history of note. Examination reveals a talkative and happy child who is oriented and obeying commands. His GCS is 15. There is no visible or palpable injury to the head and his cervical spine is normal to examination.

What is your management?

10A. Immediate CT of the brain as he has a distracting injury that makes neurological assessment unreliable.

10B. Observation for 4-6 hours as he as a significant mechanism of injury.

10C. Observation with repeat assessment of his GCS and his pupillary response while management of the fracture is undertaken, and discharge once the fracture has been managed.

10D. Consultation with the neurosurgical team regarding medical imaging and admission.

10E. Advice on discharge that there has been no head injury and there is no need to have concern that symptoms might appear.

CORRECT ANSWER:

Your management and assessment includes:

10C. Observation with repeat assessment of his GCS and his pupillary response while management of the fracture is undertaken, and discharge once the fracture has been managed.

FEEDBACK: This boy requires management of his fracture and head injury observations during that time would be appropriate. No other intervention would be needed and use of any of the clinical decision rules presented in this module would not result in a decision to perform cranial CT.

This child has normal neurological examination and no concerning features for intracranial injury on examination or history. Imaging is not indicated at this point in time. His fracture should be managed; this allows for a period of observation - for the head injury - and if no worsening of his condition he could be discharged. The mechanism of injury is moderate. A period of observation is a safe and conservative approach but is not mandatory in all patients with this presentation. A shorter period of observation while managing the fracture would be appropriate. For all head injury CDRs, this child does not warrant a CT or an extended period of observation. Management of head injuries should be guided by the best available CDRs. Using any of the CDRs presented in this module, head CT scan, neurosurgical intervention or admission are not required for this boy. This child has a minor head injury. It is advisable to instruct the parents of this and provide written information about head injury.

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APPENDIX ONE: EVIDENCE SUMMARY TABLE

Author and date	Name of CDR	Derivation or validation	Inclusion	Exclusion	Sensitivity (95%ci)	Specificity (95% ci)	LR- (95%CI)	High performance* (y/n)	Hierarchy **
Kuppermann et al, 2009[8]	PECARN Identification of children at very low risk of clinically-important brain injuries after head trauma: prospective cohort study	Derivation and validation	42412 patients (derivation 33875) Age < 18 years old GCS 14 or 15 Presented to ED within 24 hours of head trauma	Trivial injury mechanisms: ground level falls, walking or running into stationary objects, no signs or symptoms of head trauma other than scalp abrasions and lacerations Penetrating trauma Known brain tumours Pre-existing neurological disorders Neuroimaging at an outside hospital before transfer Patients with ventricular shunts Bleeding disorders,	< 2 years old (validation) 100.00% (95% CI 86.3 – 100%)	< 2 years old 53.7% (95% CI 51.6 – 55.8)	0	No	III
					> 2 years old 96.8% (95% CI 89 – 99.6)	> 2 years old 59.8% (95% CI 58.6 – 61%)	0.05	No	
Dunning et al, 2006[9]	Derivation of the children's head injury algorithm for the prediction of important clinical events (CHALICE) decision rule for head injury in children.	Derivation	n=22,772 Patients Patients less than 16 years old with a history or signs of injury to head Loss of consciousness or amnesia not a requirement	Refusal to consent to entry into study	98.6% (96.4 – 99.6)	86.9% (86.5 – 87.4)	0.02	Yes	IV

Author and date	Name of CDR	Derivation or validation	Inclusion	Exclusion	Sensitivity (95%ci)	Specificity (95% ci)	LR- (95%CI)	High performance* (y/n)	Hierarchy **
Osmond et al, 2010[10]	CATCH: A clinical decision rule for the use of computed tomography in children with minor head injury	Derivation	Blunt trauma to the head resulting in witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (two or more distinct episodes 15 minutes apart), or persistent irritability in the ED (for children under two years of age) Initial GCS of at least 13 Injury within the past 24 hours	Obvious penetrating skull injury. Obvious depressed fracture. Acute focal neurological deficit. Chronic generalized developmental delay. Head injury secondary to suspected child abuse. Patients returning for reassessment of a previously treated head injury. Patients who were pregnant.	**For four high-risk factors in determining primary outcome (need for neurologic intervention):** 100.0% (95% CI 86.2 – 100.0) **For all seven combined in predicting brain injury:** 98.1% (95% CI 94.6 – 99.4)	**For four high-risk factors in determining primary outcome (need for neurologic intervention):** 70.2% (95% CI 68.8 – 71.6) **For all seven combined in predicting brain injury:** 50.1% (95% CI 48.5 – 51.7)	0.04 (for all seven combined)	No Because lower limit of 95% CI for sensitivity is not >0.95	IV (Only statistical validation)

*High performance (Y/N) for the derivation study defined as:

- Sens > 0.95 AND
- Lower limit of 95%CI for sensitivity >0.95 AND
- LR-<0.1 AND
- Upper limit of LR-95% CI < 0.1
- Likelihood ratio for negative test result $= \frac{\text{proportion of patients WITH disease who have a negative test result (1 – SENSITIVITY)}}{\text{proportion of patients WITHOUT disease who have a negative test result (SPECIFICITY)}} = \frac{(1 - \text{SENSITIVITY})}{(\text{SPECIFICITY})}$

**Hierarchy (see reference i. below)

Level I: can be used in a variety of clinical settings and includes at least one validation study (external) and at least one impact analysis showing favourable change in clinician behaviour when the CDR is used/implemented

Level II: can be used in various setting with confidence about accuracy (1 prospective validation in heterogeneous population or several smaller ones)

Level III: use with caution in narrowly defined group of patients (validated in one narrow prospective sample)

Level IV: CDRs requiring more evaluation before they are implemented (no validation or only validated with statistical techniques or retrospective databases, or split samples)

APPRAISAL TABLE REFERENCES:

i. McGinn T, Guyatt G, Wyer P, Naylor C, Stiell I, Richardson W. Users' guides to the medical literature: XXII: how to use articles about clinical decision rules. Evidence-Based Medicine Working Group. *JAMA*. 2000; 284(1): 79-84.

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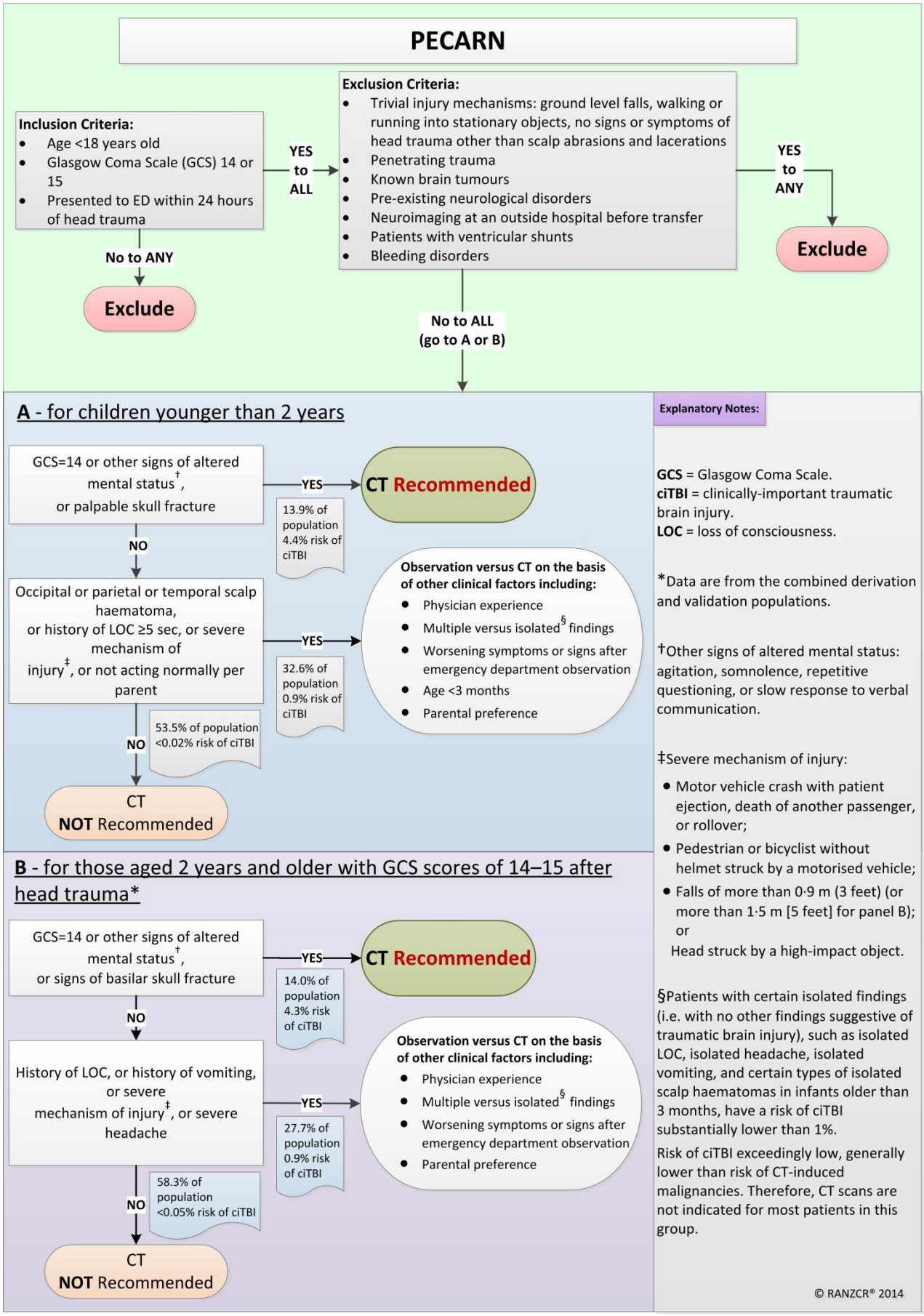
APPENDIX TWO: PECARN



Appendix Three: CHALICE

The children's head injury algorithm for the prediction of important clinical events rule

A computed tomography scan is required if any of the following criteria are present.

- **History**
  - Witnessed loss of consciousness of >5 min duration
  - History of amnesia (either antegrade or retrograde) of >5 min duration
  - Abnormal drowsiness (defined as drowsiness in excess of that expected by the examining doctor)
  - ≥3 vomits after head injury (a vomit is defined as a single discrete episode of vomiting)
  - Suspicion of non-accidental injury (NAI, defined as any suspicion of NAI by the examining doctor)
  - Seizure after head injury in a patient who has no history of epilepsy
- **Examination**
  - Glasgow Coma Score (GCS) <14, or GCS<15 if <1 year old
  - Suspicion of penetrating or depressed skull injury or tense fontanelle
  - Signs of a basal skull fracture (defined as evidence of blood or cerebrospinal fluid from ear or nose, panda eyes, Battles sign, haemotympanum, facial crepitus or serious facial injury)
  - Positive focal neurology (defined as any focal neurology, including motor, sensory, coordination or reflex abnormality)
  - Presence of bruise, swelling or laceration >5 cm if <1 year old
- **Mechanism**
  - High-speed road traffic accident (defined as accident with speed >40 m/h) either as pedestrian, cyclist or occupant
  - Fall of >3 m in height
  - High-speed injury from a projectile or an object

If none of the above variables are present, patient is at low risk of intracranial pathology

Inclusion criteria (ALL must be satisfied for the CHALICE rule to be applied)

1. Patients less than 16 years old with a history or signs of injury to head
2. Loss of consciousness or amnesia not a requirement

Exclusion criteria – None

APPENDIX FOUR: CATCH

Canadian Assessment of Tomography for Childhood Head injury: the CATCH Rule

CT of the head is required only for children with minor head injury* and any one of the following findings:

High risk (need for neurologic intervention)

- Glasgow Coma Scale score <15 at two hours after injury
- Suspected open or depressed skull fracture
- History of worsening headache
- Irritability on examination

Medium risk (brain injury on CT scan)

- Any sign of basal skull fracture (e.g., haemotympanum, "raccoon" eyes, otorrhea or rhinorrhea of the cerebrospinal fluid, Battle's sign)
- Large, boggy haematoma of the scalp
- Dangerous mechanism of injury (e.g., motor vehicle crash, fall from elevation ≥3 ft [≥91 cm] or 5 stairs, fall from bicycle with no helmet)

Note: CT = computed tomography.
*Minor head injury is defined as injury within the past 24 hours associated with witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (more than one episode) or persistent irritability (in a child under two years of age) in a patient with a Glasgow Coma Scale score of 13-15.

Inclusion criteria: (ALL must be satisfied for the CATCH rule to be applied)

- Blunt trauma to the head resulting in witnessed loss of consciousness, definite amnesia, witnessed disorientation, persistent vomiting (two or more distinct episodes 15 minutes apart), or persistent irritability in the ED (for children under two years of age)
- Initial GCS of at least 13
- Injury within the past 24 hours

Exclusion criteria: (If ANY are present the CATCH rule cannot be applied)

- Obvious penetrating skull injury
- Obvious depressed fracture
- Acute focal neurological deficit
- Chronic generalized developmental delay
- Head injury secondary to suspected child abuse
- Patients returning for reassessment of a previously treated head injury
- Pregnancy