**Neonatal Head Injuries - a prospective PREDICT cohort study**

Nitaa Eapen, Meredith L. Borland, Natalie Phillips, Amit Kochar, Sarah Dalton, John A. Cheek, Yuri Gilhotra, Jeremy Furyk, Mark D. Lyttle, Susan Donath, Louise Crowe, Stuart R Dalziel, Ed Oakley, Stephen Hearps, Silvia Bressan, Franz E Babl

**AUTHORS:**

Nitaa Eapen Bsc1, 2; [nitaa.eapen@mcri.edu.au](mailto:nitaa.eapen@mcri.edu.au)

Stephen Hearps PGDipPsych2; [stephen.hearps@mcri.edu.au](mailto:stephen.hearps@mcri.edu.au)

Silvia Bressan MD, PhD 2,14; [silviabress@gmail.com](mailto:silviabress@gmail.com)

Meredith L. Borland MBBS 4, 5[; meredith.borland@health.wa.gov.au](mailto:;%20meredith.borland@health.wa.gov.au)

Natalie Phillips MBBS 6 ; n[atalie.phillips@merton-oxford.com](mailto:atalie.phillips@merton-oxford.com)

Amit Kochar MD 7; [amit.kochar@health.sa.gov.au](mailto:amit.kochar@health.sa.gov.au)

Sarah Dalton BMed 8 [; sarah.dalton@health.nsw.gov.au](mailto:;%20sarah.dalton@health.nsw.gov.au)

John A. Cheek MBBS 1,2,9; john.cheek@rch.org.au

Yuri Gilhotra MBBS 6 ; yurigilhotra@me.com

Jeremy Furyk MBBS 10; [jeremy.furyk@health.qld.gov.au](mailto:jeremy.furyk@health.qld.gov.au)

Jocelyn Neutze MBChB 11; [jocelyn.neutze@middlemore.co.nz](mailto:jocelyn.neutze@middlemore.co.nz)

Mark D. Lyttle MBChB 2,12,13; [mdlyttle77@gmail.com](mailto:mdlyttle77@gmail.com)

Susan Donath MA 2,3; [susan.donath@mcri.edu.au](mailto:susan.donath@mcri.edu.au)

Louise Crowe PhD 2; louise.crowe@mcri.edu.au

Stuart R Dalziel PhD 15, 16; [sdalziel@adhb.govt.nz](mailto:sdalziel@adhb.govt.nz)

Vicki Anderson1-3; Vicki.anderson@rch.org.au

Gavin Davis 2; Gavin.davis@me.com

Ed Oakley MBBS 1-3; [ed.oakley@rch.org.au](mailto:ed.oakley@rch.org.au)

Franz E Babl MD 1-3; franz.babl@rch.org.au

1 Royal Children’s Hospital, Melbourne.

Address: Emergency Department, Royal Children’s Hospital, 50 Flemington Rd, Parkville, VIC, 3052, Australia.

2 Murdoch Childrens Research Institute, Melbourne.

Address: 50 Flemington Rd, Parkville, VIC, 3052, Australia.

3 Department of Paediatrics, Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Melbourne.

Address: Grattan St, Parkville, VIC, 3010, Australia.

4 Princess Margaret Hospital for Children, Perth.

Address: Emergency Department, Princess Margaret Hospital for Children, Roberts Rd, Subiaco, Perth, WA, 6008, Australia.

5 Schools of Paediatrics and Child Health and Primary, Aboriginal and Rural Healthcare, University of Western Australia.

Address: 35 Stirling Hwy, Crawley, WA, 6009, Australia.

6 Lady Cilento Children’s Hospital, Brisbane and Child Health Research Centre, School of Medicine, The University of Queensland.

Address: Emergency Department, Lady Cilento Children’s Hospital, 501 Stanley St, South Brisbane, QLD, 4101, Australia.

7 Women’s & Children’s Hospital, Adelaide.

Address: Emergency Department, Women’s & Children’s Hospital, 72 King William St, North Adelaide, SA, 5006, Australia.

8 The Children’s Hospital at Westmead, Sydney.

Address: Emergency Department, The Children’s Hospital at Westmead, 212 Hawkesbury Rd, Westmead, NSW, 2145, Australia.

9 Monash Medical Centre, Melbourne.

Address: Emergency Department, Monash Medical Centre, 246 Clayton Rd, Clayton, VIC, 3186, Australia.

10 The Townsville Hospital, Townsville.

Address: Emergency Department, The Townsville Hospital, 100 Angus Smith Dr, Douglas, QLD, 4814, Australia.

11 Kidzfirst Middlemore Hospital, Auckland.

Address: Emergency Department, Kidzfirst Middlemore Hospital, 100 Hospital Rd, Auckland, 2025, New Zealand.

12 Bristol Royal Hospital for Children, Bristol.

Address: Emergency Department, Bristol Children’s Hospital, Paul O’Gorman Building, Upper Maudlin St, Bristol, BS2 8BJ, United Kingdom.

13 Academic Department of Emergency Care, University of the West of England, Bristol.

Address: Blackberry Hill, Bristol, BS16 1XS, United Kingdom.

14 Department of Women’s and Child Heath, University of Padova, Padova.

Address: Via Giustiniani3, 2 35128, Padova, PD, Italy.

15 Starship Children’s Health, Auckland.

Address: Emergency Department, Starship Children’s Health, 2 Park Rd, Grafton, Auckland, 1023, New Zealand.

16 Liggins Institute, University of Auckland, Auckland.

Address: 85 Park Ave, Grafton, Auckland, 1023, New Zealand.

**CORRESPONDING AUTHOR:**

Franz E Babl

Emergency Research

Murdoch Childrens Research Institute  
Flemington Rd  
Parkville  
Victoria 3052

Australia

Phone 61 3 9345 6153

Fax 61 3 9345 600

Email [franz.babl@rch.org.au](mailto:franz.babl@rch.org.au)

**ABSTRACT**

**Aim:** To characterise the causes, clinical characteristics and outcomes of head injuries in neonates who presented to paediatric emergency departments.

**Methods:** Secondary analysis of a large prospective dataset of paediatric head injuries at 10 emergency departments in Australia and New Zealand. Patients without neuroimaging were followed up by telephone call. We extracted epidemiological information, clinical findings and short term outcomes in infants <28 days.

**Results:** Of 20,137 children with head injuries, 93 (0.5%) occurred in neonates. They were mostly fall-related (74.2%), commonly from caregivers arm, or due to being accidentally struck by a person/object (19.4%). There were 6 suspected non-accidental head injuries (6.5%). Most neonates were asymptomatic (67.74%) with a GCS of 15 and many also had no findings on examination (47.31%). Most neonates had a GCS 15 (89.2%) or 14 (7.5%). 15.1% of neonates presented with vomiting, 5.4% were abnormally drowsy/difficult to wake but none experienced a loss of consciousness. The most common findings on examination were scalp haematoma (28.0%) followed by possible palpable skull fracture (6.5%). 8.6% of neonates underwent CT scan and 4.3% an ultrasound. Overall, 5 of 8 CTs (5.4% of neonates overall) had traumatic brain injury (TBI) on CT scan and 2 of 4 (2.2% overall) had a TBI on ultrasound. 37% were admitted, 1 patient was intubated, none had neurosurgery or died.

**Conclusions:** Neonatal head injuries are rare with a mostly benign short term outcome and are appropriate for management at home. However, non-accidental injuries need to be considered.

**INTRODUCTION**

Children of all ages present to emergency departments (EDs) and acute care clinics with head injuries (HIs), one of the most concerning age groups are neonates. Their skulls are thin and pliable to facilitate passage through the birth canal (1,2) and their brains less protected in head trauma. (3,4) While minor trauma can result in intracranial injuries or skull fractures, it may be difficult for clinicians to assess deteriorating Glasgow Coma Scale (GCS) in preverbal infants; intracranial injuries in children aged under 2 years can be asymptomatic (5,6) and familiar signs of more severe head injury in older children and adults, like vomiting, (7–9) may not be reliable. At the same time, clinicians will be particularly reluctant to use computed tomography (CT) scans in young children due to the increased risk of radiation-induced cancer. (10–13) CT scans remains the preferred imaging modality for suspected intracranial injury (14) requiring immediate intervention, as some areas of the brain are difficult to visualise with cranial ultrasound. (15) However, in mild neonatal HI, the significant risks of ionising radiation should be considered carefully. Magnetic resonance imaging avoids ionising radiation but may be difficult to obtain in the acute setting and may require sedation. (15) While cranial ultrasound is a useful tool to evaluate brain abnormalities in neonates, it has limitations; cranial ultrasound is insensitive to detect parenchymal injuries and small acute subdural hematomas (16) as well as other intracranial injuries. (15)

While a number of studies explore how head injuries in children less than 2 years of age differ from older children, particularly around the importance of scalp haematomas and vomiting, (6,9,17,18) the literature on injuries in very young infants is limited. The mechanism of injury in young infants differs from older infants and often includes falls from care giver’s arms and change tables. (19,20) Non-accidental injuries also occur at higher rates in the early months of life. (21,22) Neonatal specific papers often focus on injuries sustained in hospital through falls in admitted infants. (23,24)

We therefore set out to analyse the neonatal cohort from a large multicentre prospective study of head injuries in all childhood age groups. We extracted information on injury mechanism, severity and short term outcomes.

**METHODS**

**Study design, setting and patients**

We performed a secondary analysis for neonatal head injuries in a prospective multicentre observational study which enrolled children presenting with head injuries of any severity to 10 paediatric EDs in Australia and New Zealand between April 2011 and November 2014. All EDs are members of the Paediatric Research in Emergency Departments International Collaborative research network. (25) The study was approved by the ethics offices at all participating sites.

For the primary study, we collected and analysed predictor and outcome variables for three head injury clinical decision rules (CDRs) for neuroimaging in head-injured children. (19,26,27) The following patients were excluded in the original study: trivial facial injury only, patient/family refusal to participate, referral from ED triage to an external provider (i.e. not seen in the ED), did not wait to be seen or neuroimaging done prior to the transfer to a study site.

The present study defined neonates as 28 days old or younger. Activity, place and mechanism of injury were identified by epidemiology codes assigned by research assistants at each site from ED clinician documentation, medical records and the follow-up call. These epidemiology codes are based on Victorian government codes which are routinely collected in EDs in Victoria. We had collected these codes for patients across all sites; for the purposes of this study, we added additional activity codes to more accurately reflect the synopsis of the injury for the neonatal cohort if the existing Victorian government codes were not sufficiently detailed.

**Study Procedures**

Details of the study protocol are described in detail elsewhere. (28,29) Patients were enrolled by the treating ED clinician who collected clinical data. Research assistants recorded ED and hospital management data after the visit and conducted telephone follow-up for patients who had not undergone neuroimaging. Data included CDR predictor variables, demographic and epidemiological information, and neuroimaging, admission and neurosurgery details.

To identify neonates in our population, we searched the database by age. We then manually reviewed all eligible case report forms to descriptively record the synopsis of the injury. Where available and necessary, we used medical records to augment the information from the case report forms.

**Definitions**

***Glasgow Coma Scale***

We used the Glasgow Coma Scale (GCS) as assigned by the ED clinician on their assessment, or if not available, GCS at triage. (Babl F 2017)

***Results of neuroimaging and neurosurgery***

We used senior radiologist reports to determine the results of CT and ultrasound scans and operative reports for patients who underwent neurosurgery.

Traumatic brain injury (TBI) on CT or ultrasound was defined as intracranial haemorrhage or contusion, cerebral oedema, traumatic infarction, diffuse axonal injury, shearing injury, sigmoid sinus thrombosis, midline shift of intracranial contents or signs of brain herniation, diastasis of the skull, pneumocephalus or depressed skull fracture. In addition we collected any type of skull fracture (depressed, non-depressed, basal, unknown type).

Neurosurgical intervention was defined as intracranial pressure monitoring, elevation of depressed skull fracture, ventriculostomy, haematoma evacuation, lobectomy, tissue debridement or dura repair.

***Clinically important traumatic brain injury***

Clinically-important traumatic brain injury (ciTBI) was defined as per PECARN (Kuppermann 2009) death from TBI, neurosurgical intervention from TBI, intubation of more than 24 h for TBI or hospital admission of 2 nights or more for TBI in association with TBI on CT.

**Statistical analysis**

Data were entered into Epidata (The Epidata Association, Odense, Denmark), and later REDCap, (Harris 2009) and analysed using Stata 13 (Statacorp, College Station, Texas, USA). Descriptive statistics were calculated for key variables with 95% confidence intervals (CI) where relevant.

**RESULTS**

We identified 93 neonates who presented with head injury (0.5% of the original cohort of 20 137 children). The mean age was 16.3 days; 59.1% were male. Most had a GCS of 15 (89.2%, 95% CI: 81.1–94.7) or 14 (7.5%, 95% CI: 3.1–14.9). Only 3.2% had a GCS of ≤13, and none had a GCS of ≤8. The most frequent signs and symptoms were vomiting (15.1%, 95% CI: 8.5–24.0) and abnormal drowsiness (5.4%, 95% CI: 1.8–12.1). None had loss of consciousness. The most common abnormalities on examination were scalp haematomas (28.0%, 95% CI: 19.1–38.2) and possible palpable skull fracture (6.5%, 95% CI: 2.4–13.5) (Table 1). Most were asymptomatic (67.7%); 47.3% were asymptomatic and had no findings on examination.

Most of the neonatal head injuries were fall related (75.2%) with a smaller percentage attributable to being struck by a person/object (20.4%). The most common mechanism was a fall from a care giver’s arms (28.0%) followed by struck by inanimate stationary object (12.9%) and fall from couch (9.7%). Most injuries (75%) occurred at home in a bedroom or a living area (Table 2). Half presented between 2 pm and 9 pm; only 8.6% presented between midnight and 6 am (Fig. 1). There were three non-accidental head injuries confirmed by local multidisciplinary committees (3.2%).

Eleven of 93 neonates (11.8%) underwent imaging of the head which comprised of CT scan in 8 (8.6%), transfontanelle ultrasound in 4 (4.3%), magnetic resonance imaging in 2 (2.2%) and X-ray in one skull (1.1%). Two of the 11 neonates who had imaging of the head were asymptomatic and had no findings on examination. The presence of vomiting, abnormal drowsiness and irritability in the initial presentation was not correlated with neuroimaging. However, all 6 neonates who sustained palpable skull fractures underwent neuroimaging and 8 of the 11 neonates who underwent imaging of the head had a scalp haematoma. In the four neonates that underwent ultrasound, two showed TBI, which was confirmed by CT. In total, TBI on CT was observed in 5 of 11. Overall, one third (36.6%, 95% CI: 26.8–47.2) of neonates, including 13 asymptomatic infants with no examination findings, were admitted with a median length of stay of 1 day.

Only one patient was intubated >1 day. Four patients had ciTBI (4.3%, 95% CI: 1.2–10.6), as defined by admission ≥2 days. This included the one intubated patient. No neonates had neurosurgery and there were no deaths (Tables 1,3). Of the five patients with TBI on CT, four had intracranial haemorrhage/contusion and skull fractures (of which two were depressed skull fractures). One had midline shift of intracranial contents or signs of brain herniation, diastasis of the skull and sigmoid sinus thrombosis. Of the three non-accidental head injuries, one neonate had no intracranial findings on neuroimaging, and two neonates had skull fractures and intracranial haemorrhages; one neonate had a ciTBI (Table 3).

**DISCUSSION**

In this multicentre, prospective study we characterised the causes, clinical characteristics and outcomes of 93 neonates with head injuries presenting to EDs. The majority of neonatal head injuries presenting to Australasian EDs were surprisingly benign with two thirds discharged home, with two thirds asymptomatic and half having normal physical examinations. Only 11.8% had imaging of the head of any kind and in these children the incidence of TBI was high. Overall 4.3% had ciTBI which is three times higher than the percentage of ciTBI in the cohort of head injured children of all ages (1.4% ciTBI). (29) None of the neonates underwent neurosurgery or died. The risk of intracranial injury in young children is influenced by mechanism of injury (e.g. height of fall), size and location of scalp swelling and change in behaviour, among other factors. (6)

In line with previous research on head injuries in infants, most neonatal head injuries were caused by falls at home (32) with the predominant mechanism being falls from care giver’s arms. (20) Mulligan

et al.(33) found that infants <1 year dropped by care givers were three times more likely to be admitted than infants from other fall types. A national Australian report34 found that infants were most likely to be admitted when they were dropped by a care giver, consistent with our results. A smaller but significant proportion of head injuries were caused by neonates being struck by objects. Most neonates presented during the afternoon and early evening.

Of the four neonates with ciTBI, three had injuries from falls, including one who fell unrestrained from a pram. One neonate was accidentally struck by a person at home. All neonates with ciTBI had skull fractures, three of the four neonates had haematomas on head examination and two had intracranial haemorrhages. In contrast to our cohort of out of hospital head injuries, Khan et al. (24) investigated in-hospital newborn head injuries, all due to falls.

Seven of 24 received a skull radiograph followed by CT in 6; 2 had a non-depressed linear parietal skull fracture and 2 had TBI with small subdural haemorrhages. Three neonates had non-accidental trauma; one had no findings on neuroimaging, two of the three neonates had intracranial haemorrhages and skull fractures of whom one had ciTBI. Non-accidental injuries must be considered in all neonates based on their anatomical vulnerability (1,35,36) and susceptibility to serious head injuries caused by blunt impact and rotational movement of the brain within the cranial cavity. (3,37) Non-accidental injuries or suspected non-accidental injuries are associated with a higher injury severity score and higher mortality compared to injuries sustained accidentally. (38–40) In addition, TBI secondary to non-accidental trauma can require longer intensive care unit admission and higher mortality than TBI sustained by other mechanisms. (40)

In our study, head-injured neonates requiring neuroimaging most frequently underwent a CT or ultrasound. All neonates who had a palpable skull fracture underwent imaging of the head. The presence of vomiting, abnormal drowsiness and irritability did not appear to be correlated with imaging of the head. Two neonates who received neuroimaging were entirely asymptomatic and had no findings on examination. In this very young cohort, it is possible that clinician concern for ciTBI, variation in clinician practice and variation in the extent of paediatric emergency training may explain imaging of the head in the two asymptomatic neonates (41) in the absence of supporting CDRs. At the same time, clinical assessment of neonates presenting with HI can be indeterminate and neuroimaging in these cases may be warranted. (14) Although the ciTBI rate in our cohort was high (4.3%), this was largely driven by the admission of neonates with TBI for two nights or more and may therefore represent increased concern by treating clinicians for potential sequelae in this young age group rather than more severe head injuries.

The gold standard imaging for paediatric TBI is CT but it carries risks of ionising radiation. (10–13) Many CDRs have been devised to help clinicians decide if a CT scan is required. (9,26–29,42,43) In addition to being able to identify skull fractures, in neonates the open fontanelle may allow the use of ultrasound to investigate if there is an intracranial injury. In our study, four neonates underwent transfontanelle ultrasound with two showing TBI on ultrasound, which was confirmed by CT scan. The role of ultrasound as a safe (lack of radiation), cost-effective tool in the diagnosis and management of TBI (44) and skull fractures (45,46) remains to be determined.

This study had some limitations. The coding of the injury mechanism depended on local research staff being able to extract relevant information from the medical records at the time of data collection. If not recorded these data could not be extracted. Our study was not designed to capture neonates who are admitted with medical issues unrelated to head injuries but are later found to have non-accidental head injuries. This may underestimate the prevalence of non-accidental trauma. We did not collect information on why clinicians chose one imaging modality over another.

Our data were focused on short term outcomes and we do not know the longer-term outcome of neonatal head injuries.

**CONCLUSIONS**

Neonatal head injuries predominantly occurred after falls from care giver’s arms and have a mostly benign short term outcome that is appropriate for observation. However, non-accidental injuries remain an important cause of serious head injury in infants but were rare in our cohort.

**REFERENCES**

1. Standring S. Gray’s Anatomy, 40th edn, 416–8. New York, NY: Churchchill Livingstone; 2008.
2. Pinto PS, Poretti A, Moeded A, Tekes A, Huisman TA. The unique features of traumatic brain injury in children. Review of the characteristics of the pediatric skull and brain, mechanisms of trauma, patterns of injury, complications and their imaging findings – Part 1. J. Neuroimaging 2012; 22: e1–e17.
3. Case ME. Abusive head injuries in infants and young children. Leg. Med. 2007; 9: 83–7.
4. Figaji AA. Anatomical and physiological differences between children and adults relevant to traumatic brain injury and the implications for clinical assessment and care. Front. Neurol. 2017; 8: 685.
5. Greenes DS, Schultzman SA. Occult intracranial injury in infants. Ann. Emerg. Med. 1998; 32: 680–6.
6. Schutzman SA, Barnes P, Duhaime AC et al. Evaluation and management of children younger than two years old with apparently minor head trauma: Proposed guidelines. Pediatrics 2001; 107: 983–93.
7. Schnadower D, Vazquez H, Lee J, Dayan P, Roskind CG. Controversies in the evaluation and management of minor blunt head trauma in children. Curr. Opin. Pediatr. 2007; 19: 258–64.
8. Willis AP, Latif SA, Chandratre S, Stanhope B, Johnson K. Not a NICE CT protocol for the acutely head injured child. Clin. Radiol. 2008; 63: 165–9.
9. Kuppermann N, Holmes JF, Dayan PS et al. Identification of children at very low risk of clinically-important traumatic brain injuries after head trauma: a prospective cohort study. Lancet 2009; 374: 1160–70.
10. Brenner DJ, Hall EJ. Computed tomography—An increasing source of radiation exposure. N. Engl. J. Med. 2007; 22: 2277–84.
11. Pearce MS, Salotti JA, Little MP et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: A retrospective. Lancet 2012; 380: 499–505.
12. Miglioretti DL, Johnson E, Williams A et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. JAMA Pediatr. 2013; 167: 700–7.
13. Mathews JD, Forsythe AV, Brady Z 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: 2360.
14. Ryan ME, Palasis S, Saigal G et al. ACR appropriateness criteria head trauma – Child. J. Am. Coll. Radiol. 2014; 11: 939–47.
15. van Wezel-Meijler G, Steggerda SJ, Leijser LM. Cranial ultrasonography in neonates: Roles and limitations. Semin. Periantol. 2010; 34: 28–38.
16. Kemp AM, Jaspan T, Griffiths J et al. Neuroimaging: What neuroradiological features distinguish abusive from non-abusive head trauma? A systematic review. Arch. Dis. Child. 2011; 96: 1103–12.
17. Greenes DS, Schultzman SA. Clinical significance of scalp abnormalities in asymptomatic head-injured infants. Pediatr. Emerg. Care 2001; 17: 88–92.
18. 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; 64: 153–62.
19. Crowe L, Babl F, Anderson V, Catroppa C. The epidemiology of paediatric head injuries: Data from a referral centre in Victoria, Australia. J. Paediatr. Child Health 2009; 45: 346–50.
20. Agran PF, Anderson C, Winn D, Trent R, Walton-Haynes L, Thayer S. Rates of pediatric injuries by 3-month intervals for children 0 to 3 years of age. Pediatrics 2003; 111: e683–92.
21. Overpeck MD, Brenner RA, Trumble AC, Trifletti LB, Berendes HW. Risk factors for infant homicide in the United States. N. Engl. J. Med. 1998; 339: 1211–6.
22. Eisele JA, Kegler SR, Trent RB, Coronado VG. Nonfatal traumatic brain injury-related hospitalization in very young children-15 states, 1999. J. Head Trauma Rehabil. 2006; 21: 537–43.
23. Graham CA, O’Toole SJ, Haddock G. Neonatal head injuries. J. Accid. Emerg. Med. 2000; 17: 334–6.
24. Khan DJ, Fisher PD, Hertzler DA. Variation in management of inhospital newborn falls: A single-center experience. J. Neurosurg. Pediatr. 2017; 20: 176–82.
25. Babl F, Borland M, Ngo P et al. Paediatric research in emergency departments international collaborative (PREDICT): First steps towards the development of an Australian and New Zealand research network. Emerg. Med. Australas. 2006; 18: 143–7.
26. Osmond MH, Klassen TP, Wells GA et al. CATCH: A clinical decision rule for the use of computed tomography in children with minor head injury. CMAJ 2010; 182: 341–8.
27. Dunning J, Daly JP, Lomas JP et al. 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: 885–91.
28. Babl FE, Lyttle MD, Bressan S et al. A prospective observational study to assess the diagnostic accuracy of clinical decision rules for children presenting to emergency departments after head injuries (protocol): The Australasian Paediatric Head Injury Rules Study (APHIRST). BMC Pediatr. 2014; 14: 148.
29. Babl FE, Borland ML, Phillips N et al. Accuracy of PECARN, CATCH and CHALICE head injury decision rules in children: A prospective cohort study. Lancet 2017; 389: 2393–402.
30. Reilly P, Simpson O, Sprod R, Thomas L. Assessing the conscious level in infants and young children: A pediatric version of Glasgow Coma Scale. Childs Nerv. Syst. 1998; 4: 30–3.
31. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. J. Biomed. Inform. 2009; 42: 377–81.
32. Warrington SA, Wright CM; ALSPAC Study Team. Accidents and resulting injuries in premobile infants: Data from the ALSPAC study. Arch. Dis. Child. 2001; 85: 104–7.
33. Mulligan CS, Adams S, Tzioumi D, Brown J. Injury from falls in infants under one year. J. Paedriatr. Child Health 2017; 53: 754–60.
34. Pointer S. Hospitalised Injury in Children and Young People 2011–12. Canberra: Australian Institute of Health and Welfare; 2014.
35. Greenley CS. Abusive head trauma: A review of the evidence base. AJR Am. J. Roentgenol. 2015; 5: 967–73.
36. Coats B, Margulies SS. Material properties of human infant skull and suture rates. J. Neurotrauma 2006; 23: 1222–32.
37. Nadarasa J, Deck C, Meyer F, Willinger R, Raul JS. Update on injury mechanisms in abusive head trauma—Shaken baby syndrome. Pediatr. Radiol. 2014; 44: S565–70.
38. Davies FC, Coats TJ, Fisher R, Lawrence T, Lecky FE. A profile of suspected child abuse as a subgroup of major trauma patients. Emerg. Med. J. 2015; 32: 921–5.
39. Davies FC, Lecky FE, Fisher R, Fragoso-Iiguez M, Coats TJ. Major trauma from suspected child abuse: A profile of the patient pathway. Emerg. Med. J. 2017; 34: 562–7.
40. Deans KJ, Minneci PC, Lowell W, Groner JL. Increased morbidity and mortality of TBI in victim of nonaccidental trauma. J. Trauma Acute Care Surg. 2013; 75: 157–60.
41. Stanley RM, Hoyle JD Jr, Dayan PS et al. Emergency department practice variation in computed tomography use for children with minor blunt head trauma. J. Pediatr. 2014; 165: 1201–6.
42. 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: 785–94.
43. 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: 414–21.
44. Shin SS, Huisman TAGM, Hwang M. Ultrasound imaging for traumatic brain injury. J. Ultrasound Med. 2018; 37: 1857–67.
45. 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. <https://doi.org/10.1097/PEC>. 0000000000001485.
46. 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: 1757–64.

**Table 1: Demographics, signs and symptoms and outcomes of neonatal head injuries**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Total** | | | | | |
|  | **n** | | **%** | | **(95% CI)** | |
| N | 93 | |  | |  | |
| Mean age [days], SD | 16.3 | | 8.1 | | (14.6-17.9) | |
| Median age [days] (IQR) | 17 | |  | | (8.0-23.0) | |
| Female | 38 | | 40.9 | | (30.9-50.9) | |
| **Signs:** |  | |  | |  | |
| Vomiting | | 14 | | 15.1 | | (7.8-22.3) | |
| Abnormally drowsy/difficult to wake | | 5 | | 5.4 | | (0.8-10.0) | |
| Irritable/agitated | | 3 | | 3.2 | | (0.0-6.8) | |
| Known of suspected LOC | | 0 | | 0.0 | |  | |
| GCS: | |  | |  | |  | |
| * 15 | | 83 | | 89.2 | | (83.0-95.5) | |
| * 14 | | 7 | | 7.5 | | (2.2-12.9) | |
| * 13 | | 1 | | 1.1 | | (0.0-3.2) | |
| * 9-12 | | 2 | | 2.2 | | (0.0-5.1) | |
| * 3-8 | | 0 | | 0.0 | |  | |
| **Head Examination:** | | | | | | | |
| Laceration | | 3 | | 3.2 | | (0.0-6.8) | |
| Haematoma | | 26 | | 28.0 | | (18.8-37.1) | |
| Possible palpable skull fracture | | 6 | | 6.5 | | (1.5-11.4) | |
| Tense fontanelle | | 2 | | 2.2 | | (0.0-5.1) | |
| **Management and Outcome:** | | | | | | | |
| Any neuroimaging | | 11 | | 11.8 | | (5.3-18.4) | |
| TBI on neuroimaging | | 5 | | 5.4 | | (0.8-10.0) | |
| CT scan | | 8 | | 8.6 | | (2.9-14.3) | |
| TBI on CT scan | | 5 | | 5.4 | | (0.8-10.0) | |
| Ultrasound | | 4 | | 4.3 | | (0.2-8.4) | |
| TBI on ultrasound | | 2 | | 2.2 | | (0.0-5.1) | |
| MRI | | 2 | | 2.2 | | (0.0-5.1) | |
| X-ray | | 1 | | 1.1 | | (0.0-3.2) | |
| ETT >1d | | 1 | | 1.1 | | (0.0-3.2) | |
| PICU admission | | 1 | | 1.1 | | (0.0-3.2) | |
| Admission | | 34 | | 36.6 | | (26.8-46.3) | |
| Median length of stay [days] (IQR) | | 1 | |  | | (1.0-2.0) | |
| Neurosurgery | | 0 | | 0.0 | |  | |
| ciTBI | | 4 | | 4.3 | | (0.2-8.4) | |
| Mortality | | 0 | | 0.0 | | (0.0-0.0) | |

*LOC – loss of consciousness*

*GCS – Glasgow Coma Scale*

*CT – computed topography*

*TBI – traumatic brain injury*

*ETT – endotracheal tube*

*PICU –paediatric intensive care unit*

*IQR – interquartile range*

*ciTBI – clinically important traumatic brain injury*

**Table 2: Mechanism of neonatal head injuries**

|  |  |  |  |
| --- | --- | --- | --- |
| **Activity Code** | **n** | **%** | **%\*** |
| **Fall related** | **69** | **74.2** | **100.0** |
| Fall from caregiver's arms | 26 | 28.0 | 37.7 |
| Fall from couch | 9 | 9.7 | 13.0 |
| Fall from pram | 5 | 5.4 | 7.2 |
| Car seat falling off table/stationary car | 5 | 5.4 | 7.2 |
| Fall from bed | 4 | 4.3 | 5.8 |
| Fall from bouncer | 4 | 4.3 | 5.8 |
| Fall from bassinet | 3 | 3.2 | 4.3 |
| Fall from chair | 3 | 3.2 | 4.3 |
| Fall from change table | 2 | 2.2 | 2.9 |
| Fall from parent's lap | 2 | 2.2 | 2.9 |
| Fall from table | 2 | 2.2 | 2.9 |
| Unknown fall related | 4 | 4.3 | 5.8 |
|  |  |  |  |
| **Struck by** | **18** | **19.4** | **100.0** |
| Struck by object | 12 | 12.9 | 66.7 |
| Struck by limb/body | 3 | 3.2 | 16.7 |
| Head strike with another child | 3 | 3.2 | 16.7 |
|  |  |  |  |
| **Suspected NAHI\* (n=6)** | **6** | **6.5** | **100.0** |
| **Total neonatal head injuries** | **93** | **100** |  |

*\*NAHI – nonaccidental head injury*

*%\* proportion of specific head injury mechanism within each activity code*

**Table 3: Traumatic brain injuries seen on neuroimaging**

|  |  |
| --- | --- |
|  | **Total** |
|  | **n** |
| **Any traumatic brain injury** | 5 |
| Intracranial haemorrhage or contusion | 4 |
| Any skull fracture | 4 |
| Depressed skull fracture | 2 |
| Midline shift of intracranial contents or signs of brain herniation | 1 |
| Diastasis of the skull | 1 |
| Sigmoid sinus thrombosis | 1 |

**Figure 1: Distribution of neonatal head injuries by time of injury**

**Figure 2: Distribution of neonatal head injuries by place of injury**