Neonatal Head Injuries - a prospective PREDICT cohort study

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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.

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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

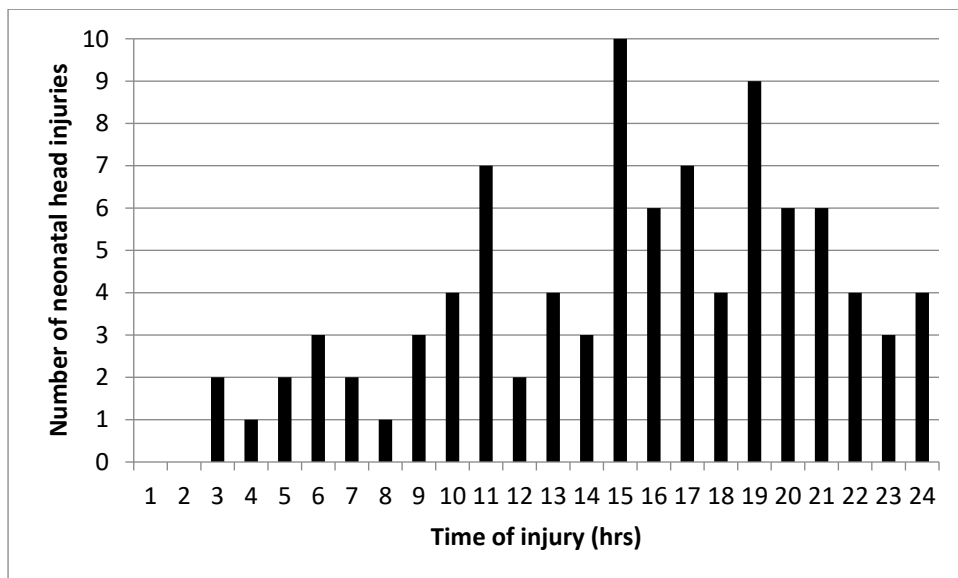**Figure 1: Distribution of neonatal head injuries by time of injury**

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