The characteristics, pattern of injury and outcome of children admitted to a paediatric intensive care unit following an inflicted injury

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A failure to recognise inflicted injury in children presenting to hospital can increase the likelihood of repeated injury and the possibility of death.[1] These findings underscore the need for early detection and timely intervention to ensure that children, and their siblings, are protected from further harm.

However, the detection of inflicted injury is made difficult by the likelihood of an unreliable history and the often non-specific nature of a child's presentation.[1] Timely detection is dependent on health professionals' awareness of the clinical features that distinguish an inflicted from a non-inflicted injury,[2] and their willingness to give due consideration to physical abuse as a differential cause of injury.[1]

Admission to intensive care is often required for children with severe, inflicted injuries, with a traumatic brain injury the most common reason for admission.[3,4] Children, aged two years or younger, with a serious or fatal inflicted traumatic brain injury are more likely than children with a non-inflicted traumatic brain injury to have retinal haemorrhages (76.3% versus 8.3%), rib fractures (27.5% versus 5.6%), metaphyseal fractures (17.5% versus 2.8%) and subdural haemorrhages (93.8% versus 60.6%).[5] While inflicted traumatic brain injury is associated with significant mortality in children,[3,6] those who do survive are more likely than children with a non-inflicted traumatic brain injury to have poor functional outcomes at both discharge from hospital[5] and one year after injury.[7] Interestingly, population-based research has determined that the injuries in 75.7% of young children with a poor outcome following a traumatic brain injury are inflicted.[5]

To date, the characteristics, pattern of injury and outcome of children admitted to intensive care following an inflicted injury have primarily been described in relation to children from the United States of America,[3,5,8,9] with an absence of research concerning Australian children; this is despite national registry data identifying 267 children who were admitted to an intensive care unit (ICU) in Australia between 2005 and 2013 with a "non-accidental injury".[10]

The aim of this research was to describe the characteristics, pattern of injury and outcome of children admitted to the paediatric intensive care unit (PICU) at the Royal Children's Hospital, Melbourne, following an inflicted injury from 2005 to 2013.

ABSTRACT

Objective: To describe the characteristics, pattern of injury and outcome of children admitted to a paediatric intensive care unit (PICU) following an inflicted injury.

Design, setting and participants: A retrospective review of hospital records from a 30-bed PICU in a university teaching hospital, examining data for children admitted to the PICU after an inflicted injury from 1 January 2005 to 31 December 2013.

Main outcome measures: The hospital records of 46 children with an inflicted injury were reviewed. Outcome was categorised using the Pediatric Overall Performance Category score.

Results: Sixty-one percent of children admitted to the PICU after an inflicted injury were aged under 12 months. Eighty-three percent of children required admission for a head injury. Radiological findings suggestive of pre-existing inflicted injury were evident in 50% of children. Follow-up information was available for 41 children; 76% were alive at follow-up while 24% had died. Among survivors, outcome was evaluated at a median of 11.3 months after admission to the PICU; 74% had a favourable outcome, despite 61% of these children having a disability. The remaining 26% of children had an unfavourable outcome and were likely to live dependent on care.

Conclusions: The majority of children admitted to intensive care following an inflicted injury are aged under 12 months. Children most commonly require intensive care for management of a head injury. Many children have radiological findings suggestive of pre-existing inflicted injury. Despite high mortality, the majority of children survive. While most are likely to be independent, many children will have residual disabilities.

Materials and methods

A search of the intensive care patient database was conducted to identify all children who had been admitted to the PICU at the Royal Children's Hospital from 1 January 2005 to 31 December 2013 and been assigned, on discharge from the ICU, or on review one month after discharge, a "non-accidental injury" code as part of routine data collection for the Australian and New Zealand Paediatric Intensive

Care Registry.[11] The hospital records of these children were evaluated by the principal investigator (A B) with a subset of randomly selected records independently cross-checked by an intensive care physician (W B). Children were eligible to be included in the study if it was determined, by a medical professional experienced in the evaluation of child abuse and neglect, that an inflicted injury was the likely cause of a child's injuries. Children were not eligible to be included if it was determined that the most likely cause of injury was an accident or disease process.

Data was retrospectively collected from the hospital records of each child in relation to characteristics of children, pattern of injury, pre-existing injury, intensive care management and outcome.

Characteristics of children

Based on risk factors for child abuse and neglect,[12,13] likely to be documented in the hospital record, data was collected to determine each child's sex, age on admission to intensive care, and birth status (classified as singleton or child from a multiple birth). For children aged under three years at the time of admission to intensive care, gestational age was recorded, with prematurity defined as birth before 37 weeks. The presence of comorbidities in the form of a chronic illness or congenital abnormality was noted as well as pre-existing bilateral deafness or severe visual impairment (defined as cortical blindness or vision limited to light). Each child's pre-existing functional status was determined in accordance with the Pediatric Overall Performance Category (POPC) score.[14]

Pattern of injury

Each child's principal injury recorded on discharge from intensive care was classified as 1) head injury, 2) skeletal injury, 3) abdominal injury, 4) chest injury, 5) near-drowning, 6) burns or 7) other. The category of head injury was further classified as a) skull fracture only, b) intracranial injury without skull fracture or c) intracranial injury with skull fracture. The pattern of extra-axial and intra-axial injuries was recorded based on findings from computed tomography and/or magnetic resonance imaging reported by a paediatric radiologist. Only reports relating to imaging conducted within the first seven days of a child's admission to hospital were included. Data was collected to record the presence of bruising on the skin beyond the primary injury site and, in children for whom fundoscopy had been performed, the presence of retinal haemorrhages. Radiological evidence of metaphyseal fractures and rib fractures, of any age, confirmed on chest x-ray, bone scan and/or skeletal survey were also noted. Out-of-hospital cardiac arrest was recorded when external cardiac massage had been performed.

The timing of documented suspicion that a child's injuries were inflicted was classified as 1) prior to admission to intensive care, 2) during the intensive care admission or 3) after discharge from intensive care.

Pre-existing injury

Radiological findings suggestive of pre-existing fractures were recorded when there was documentation, by a paediatric radiologist, of callus formation (when diagnostic imaging had been conducted within six days of a child's admission), or documentation of fractures described as likely pre-dating the estimated time of a child's primary injury. The presence of intracranial collections of varying ages was also recorded.

Intensive care management

Intubation and ventilation hours were recorded for each child, as well as 1) surgery (neurosurgical), 2) intracranial pressure monitoring, 3) hypothermia (to 33°C), 4) inotropic support, 5) high frequency oscillatory ventilation, 6) external cardiac massage and 7) surgery (other). Length of stay in the ICU and total hospital stay were also recorded.

Outcome

Using information contained in the hospital record, the POPC score was used to assess the functional outcome of each child approximately one year after admission to intensive care. Outcome categories were defined as good overall performance, mild overall disability, moderate overall disability, severe overall disability, coma or vegetative state, and brain death.[14] Children who survived with a good overall performance or a mild or moderate overall disability were regarded as having a favourable outcome, while those who survived with a severe overall disability or in a vegetative state were considered to have an unfavourable outcome. This categorisation was based on the distinction made in the POPC score between children who survive as functionally independent and those who are dependent on others for activities of daily living. The nature of disability was categorised as motor, cognitive, behavioural, cardiorespiratory or sensory (the presence of bilateral deafness or severe visual impairment). The functional outcome of each child was compared to their pre-existing functional status, also classified in accordance with the POPC score.

Cause of death was classified as 1) cardiovascular collapse, 2) neurological collapse, 3) respiratory collapse or 4) elective discontinuation of treatment for brain death or poor prognosis. Time and place of death in relation to admission to intensive care was noted.

Ethics approval for the study was obtained from the Royal Children's Hospital Human Research Ethics Committee (HREC number 32083).

Results

Forty-nine children, admitted to the PICU from 1 January 2005 to 31 December 2013, had been assigned a "non-accidental injury" code. Of these children, 46 were eligible to be included in the study as an inflicted injury was determined as the likely cause of injury in these children. Of the three children not eligible for inclusion, the most likely cause of injury was a disease process in two children and an accident in one child.

Characteristics of children

The median age of the 46 children on admission to intensive care was 6.8 months (range, 1 month to 15 years). Twenty-eight (60.9%) children were aged under 12 months. Twenty-seven (58.7%) children were male and 19 (41.3%) were female. Six (13%) children were the product of a multiple birth. Of the 40 children who were aged under three years at the time of admission to intensive care, 12 (30%) children had been born prematurely (range, 24–36 weeks' gestation). Nine (19.6%) of the 46 children had a pre-existing, chronic illness or congenital abnormality. Pre-existing disability was evident in five children: mild disability (3), moderate disability (1) and severe disability (1). One child had bilateral deafness. Overall, 17 (37%) children had a history of one or more of the following: premature birth, the product of a multiple birth, disability or chronic illness/congenital abnormality.

Pattern of injury

The principal injury sustained by children was a head injury (38), chest injury (1), skeletal injury (1), burns (2), near drowning (2) and dehydration (2). The type of head injury and the pattern of intracranial injury in children is shown in Table 1.

Bruising on the skin beyond the primary injury site was evident in 25 (54.3%) of the 46 children. Rib fractures were seen in 14 (30.4%) children. Of the 43 children who received a bone scan and/or skeletal survey, metaphyseal fractures were seen in nine (20.9%) children. A fundoscopy was performed on 39 children, with retinal haemorrhages seen in 27 (69.2%) children; 24 haemorrhages were bilateral. Of the 32 children who sustained a subdural haemorrhage, 12 (37.5%) children had both retinal haemorrhages and rib fractures. Five (10.9%) of the 46 children had sustained an out-of-hospital cardiac arrest prior to hospital admission. The overall pattern of injury in children admitted to intensive care following an inflicted injury is shown in Table 2.

Documented suspicion that a child's injuries were inflicted occurred prior to admission to intensive care (20), during the intensive care admission (24) and after discharge from intensive care (2). Where suspicion occurred after discharge from intensive care, both children had an intensive care stay less than 12 hours.

Pre-existing injury

Twenty-three (50%) children had radiological findings suggestive of pre-existing, inflicted injury in the form of intracranial collections of varying ages in 18 (39.1%) children and fractures in 14 (30.4%) children. Ten (21.7%) children had findings suggestive of both pre-existing fractures and previous intracranial injury. Of the 14 children with fractures, fractures were located in the rib (10), extremities (8), skull (2), clavicle (2) and scapula (1). Eight (17.4%) children had radiological findings suggestive of pre-existing fractures in more than one location.

Intensive care management

Forty-one (89.1%) children required intubation and mechanical ventilation. Other forms of intervention included surgery (neurosurgical) (21), intracranial pressure monitoring (11), hypothermia (7), inotropic support (17), high frequency oscillatory ventilation (2), external cardiac massage (3) and surgery (other) (4). The median length of stay in the ICU was 68.5 hours (range, 6.2–715.5 hours) and the median hospital stay was 439.8 hours (range, 8.5–8160.3 hours).

Table 1. Head injury by type (*n* = 38) and pattern of intracranial injury (*n* = 36)

| | Pattern of intracranial injury | | | | | | |
| | Extra-axial* | | | Intra-axial | | | |
Type of head injury	Extradural haemorrhage	Subdural haemorrhage	Subarachnoid haemorrhage	Haemorrhage	Oedema	Infarction or ischaemia	Shearing or diffuse axonal injury
Intracranial injury without skull fracture (*n* = 19)	2	17	5	1	11	9	1
Intracranial injury with skull fracture (*n* = 17)	3	15	9	8	10	9	4
Skull fracture only (*n* = 2)	–	–	–	–	–	–	–

* 13 children had an extra-axial haemorrhage in more than one location.

Table 2. Pattern of injury in children admitted to intensive care after an inflicted injury (*n* = 46)											
	Associated injuries										
	Rib fractures (any age)		Metaphyseal fractures (any age)			Retinal haemorrhages				Bruising	
Principal injury	Y	N	Y	N	Not assessed	Y	B	N	Not assessed	Y	N
Head injury (*n* = 38)	13	25	8	29	1	27	24	8	3	19	19
Chest injury (*n* = 1)	0	1	–	–	1	–	–	–	1	0	1
Skeletal injury (*n* = 1)	0	1	0	1	0	0	0	1	0	1	0
Burns (*n* = 2)	0	2	–	1	1	–	–	1	1	1	1
Near drowning (*n* = 2)	1	1	1	1	0	–	–	1	1	2	0
Dehydration (*n* = 2)	0	2	0	2	0	–	–	1	1	2	0
Total	*14*		*9*			*27*	*24*			*25*	

Y = yes. N = no. B = bilateral.

Outcome

Follow-up information was available for 41 (89.1%) of the 46 children. Of those evaluated, 31 (75.6%) children were alive at the time of follow-up and 10 (24.4%) had died. Among survivors, outcome was evaluated at a median of 11.3 months (range, 1.5–23.1 months) after admission to intensive care.

Using the POPC score, the functional outcome of the 31 survivors was favourable in 23 (74.2%) children; a good overall performance in nine (29%) children, a mild overall disability in six (19.4%) children and a moderate overall disability in eight (25.8%) children. Eight (25.8%) children had an unfavourable outcome with a severe overall disability. No child survived in a coma or persistent vegetative state. The post-injury functional outcome of children by diagnostic category is shown in Table 3.

Twenty-two (71%) of the surviving children lived with a disability. Physical disabilities affected 20 children, cognitive disabilities 14 children, behavioural disabilities five children and cardio-respiratory disabilities one child. Seven children survived with a sensory disability; five with severe visual impairment and two with bilateral deafness. Sixteen children had more than one disability. The relationship between children's pre-existing functional status and post-injury functional outcome is shown in Table 4.

Of the 10 children who died, cause of death was neurological collapse (1), respiratory collapse (1), elective discontinuation of treatment for brain death (1) and elective discontinuation of treatment for poor prognosis (7). Nine of the children died in the ICU and one child died in the hospital ward. Seven children died within the first week after admission to intensive care, with death occurring within the first 48 hours in five children. Death after one week after admission to intensive care occurred in three children.

Discussion

The majority of children admitted to our ICU following an inflicted injury were infants, with 61% of children aged under 12 months. Overall, 83% of children required admission to intensive care following a head injury, with a subdural haemorrhage the most common form of intracranial collection; these findings are consistent with those of other international studies.[3,5] However, it is of interest that despite the high incidence of head injury, 17% of children were admitted with a skeletal injury, chest injury, burns, near drowning or dehydration.

Table 3. Post-injury functional outcome of children, by diagnostic category (*n* = 46)						
	Post-injury functional outcome					
Diagnostic category	Good	Mild disability	Moderate disability	Severe disability	Death	Not assessed
Head injury (*n* = 38)	8	5	8	7	8	2
Chest injury (*n* = 1)	0	0	0	0	0	1
Skeletal injury (*n* = 1)	0	1	0	0	0	0
Burns (*n* = 2)	0	0	0	1	0	1
Near drowning (*n* = 2)	0	0	0	0	1	1
Dehydration (*n* = 2)	1	0	0	0	1	0

Table 4. Relationship between children's pre-existing functional status and post-injury functional outcome (*n* = 46)

	Post-injury functional outcome					
	Good	Mild disability	Moderate disability	Severe disability	Death	Not assessed
Good (*n* = 41)	9	5	6	6	10	5
Mild disability (*n* = 3)	0	1	1	1	0	0
Moderate disability (*n* = 1)	0	0	1	0	0	0
Severe disability (*n* = 1)	0	0	0	1	0	0

In addition to children's primary injury, retinal haemorrhages were seen in 69% of children, rib fractures in 30% and metaphyseal fractures in 21% of children; the frequency of these injuries is similar to those reported elsewhere.[5] Fifty percent of children had radiological findings suggestive of pre-existing, inflicted injury in the form of fractures and/or intracranial collections of varying ages. Signs of pre-existing brain injury in children with inflicted traumatic brain injuries have been previously reported.[15,16] Interestingly, these have only been found in children with inflicted traumatic brain injuries and not in children with traumatic brain injuries from other causes.[16] Notwithstanding the difficulty in accurately determining the timing of fractures in children in light of individual variability in bone healing and differences in the force and mechanism of injury,[17] fractures of varying ages and pre-existing brain injury contribute to the understanding that children's pattern of injury may reflect the consequence of serial injury, rather than a single episode of assault.

Despite a high rate of mortality, most children in this study survived their injuries; 74% of survivors had a favourable outcome and were likely to be independent. However, 61% of these children had some form of disability. Unfortunately, 26% of survivors had an unfavourable outcome and were likely to be dependent on care for activities of daily living. In considering these outcomes, it is important to note that children with inflicted traumatic brain injury often have emergent developmental delay and progressive deterioration in functional outcome over time.[18,19]

This study has several limitations. Firstly, all data was retrospectively collected from the hospital records of each child and dependent on the accuracy of documentation by health workers. Prospective studies involving the follow-up of children after inflicted injury are potentially problematic, given that many cases remain under investigation or are subject to legal process for considerable time.[18] In addition, follow-up is often hindered by the relocation of families, subsequent loss of contact information and the failure of families to attend outpatient appointments. However, recent studies have shown that follow-up in this group of children is more accepted when a perpetrator has been identified and when the child is under the care of foster or adoptive parents.[19,20]

Secondly, the number of children admitted to the ICU in our hospital following an inflicted injury was possibly more or less than the number included in our study. Some cases of inflicted injury may have been missed or, following further forensic investigation subsequent to children's discharge from hospital, a child's injuries may have been determined as resulting from other causes.

This study is currently the first to describe the population of children admitted to intensive care in Australia following an inflicted injury. It is hoped that this study will increase awareness of this patient group within the intensive care community and support early identification of all children admitted to intensive care with inflicted injuries. Future research, using prospective methods, will create greater opportunity to further knowledge about the characteristics, pattern of injury and outcome of these vulnerable children.

Conclusion

The majority of children admitted to intensive care following an inflicted injury are aged under 12 months. Children most commonly require intensive care for management of a head injury but may present with other injuries. Alongside children's primary injury, retinal haemorrhages, rib fractures, metaphyseal fractures and bruising are common. Moreover, many children have radiological findings suggestive of pre-existing inflicted injury. Despite high mortality, the majority of children survive. While most are likely to be independent, many children will have residual disabilities.

Competing interests

None declared.

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References

1 Jenny C, Hymel K, Ritzen A, et al. Analysis of missed cases of abusive head trauma. *JAMA* 1999; 282: 621-6.

2 Maguire S, Pickerd N, Farewell D, et al. Which clinical features distinguish inflicted from non-inflicted brain injury? A systematic review. *Arch Dis Child* 2009; 94: 860-7.

3 Irazuzra J, McJunkin J, Danadian K, et al. Outcome and cost of child abuse. *Child Abuse Neglect* 1997; 21: 751-7.

4 Zenel J, Goldstein B. Child abuse in the pediatric intensive care unit. *Crit Care Med* 2002; 30: S515-23.

5 Keenan H, Runyan D, Marshall S, et al. A population-based comparison of clinical and outcome characteristics of young children with serious inflicted and noninflicted traumatic brain injury. *Pediatrics* 2004; 114: 633-9.

6 Deans K, Minneci P, Lowell W, Groner J. Increased morbidity and mortality of traumatic brain injury in victims of nonaccidental trauma. *J Trauma Acute Care Surg* 2013; 75: 157-60.

7 Keenan H, Runyan D, Nocera M. Child outcomes and family characteristics 1 year after severe inflicted or noninflicted traumatic brain injury. *Pediatrics* 2006; 117: 317-24.

8 Keenan H, Runyan D, Marshall S, et al. A population-based study of inflicted traumatic brain injury in young children. *JAMA* 2003; 290: 621-6.

9 Pierce M, Kaczor K, Aldridge S, et al. Bruising characteristics discriminating physical child abuse from accidental trauma. *Pediatrics* 2010; 125: 67-74.

10 Australian and New Zealand Intensive Care Society. Centre for Outcomes and Resource Evaluation — Australian and New Zealand Paediatric Intensive Care Registry. Melbourne: ANZICS, 2016. http://www.anzics.com.au/pages/CORE/ANZPICR-registry.aspx (accessed Feb 2016).

11 Australian and New Zealand Paediatric Intensive Care Registry. ANZPIC Diagnostic Codes Table — 2015. Melbourne: ANZICS, 2015. http://www.anzics.com.au/Downloads/ANZPIC%20Diagnoses%20Codes.pdf (accessed Apr 2016).

12 Australian Institute of Health and Welfare. A picture of Australia's children 2012. Canberra: AIHW, 2012. Cat. no. PHE 167. http://www.aihw.gov.au/WorkArea/DownloadAsset.aspx?id=10737423340 (accessed May 2016).

13 Australian Institute of Family Studies. Risk and protective factors for child abuse and neglect. Child Family Community Resource Sheet March 2013. Melbourne: AIFS, 2013. http://aifs.gov.au/cfca/publications/risk-and-protective-factors-child-abuse-and-neglect (accessed April 2016).

14 Fiser D, Long N, Roberson P, et al. Relationship of pediatric overall performance category and pediatric cerebral performance category scores at pediatric intensive care unit discharge with outcome measures collected at hospital discharge and 1- and 6-month follow-up assessments. *Crit Care Med* 2000; 28: 2616-20.

15 Ilves P, Lintrop M, Talvik I. Predictive value of clinical and radiological findings in inflicted traumatic brain injury. *Acta Paediatr* 2010; 99: 1329-36.

16 Ewing-Cobbs L, Kramer L, Prasad M, et al. Neuroimaging, physical, and developmental findings after inflicted and noninflicted traumatic brain injury in young children. *Pediatrics* 1998; 102: 300-7.

17 Pickett T. The challenges of accurately estimating time of long bone injury in children. *J Forensic Leg Med* 2015; 33: 105-10.

18 Rhine T, Wade S, Makoroff K, et al. Clinical predictors of outcome following inflicted traumatic brain injury in children. *J Trauma Acute Care Surg* 2012; 23: S248-53.

19 Chevignard M, Lind K. Long-term outcome of abusive head trauma. *Pediatr Radiol* 2014; 44 (Suppl 4): S548-58.

20 Barlow K, Thompson E, Johnson D, Minns R. The neurological outcome of non-accidental head injury. *Pediatr Rehabil* 2004; 7: 195-203. ❏