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ORIGINAL RESEARCH

Emergency department management of severely injured children in New South Wales

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Abstract

Objective: Presentations to EDs for major paediatric injury are considerably lower than for adults. International studies report lower levels of critical intervention, including intubation, required in injured children. A New South Wales study demonstrated an adverse event rate of 7.6% in children with major injury. Little is known about the care and interventions received by children presenting to Australian EDs with major injury.

Methods: The ED care of injured children <16 years who ultimately received definitive care at a New South Wales Paediatric Trauma Centre between July 2015 and September 2016, and had an Injury Severity Score ≥9, required intensive care admission or died were included.

Results: There were 491 injured children who received treatment at 64 EDs, half (49.4%, $n = 243$) were treated initially in a Paediatric Trauma Centre. One third (32.8%) sustained an Injury Severity Score >12, more than half ($n = 251$, 51.1%) of children were classified as a triage category 1 or 2, and 38.3% received trauma team activation. Critical intervention was infrequent. Intubation was documented in 9.2% ($n = 45$), needle thoracostomy and activation of massive transfusion protocol in two (0.4%) and eight (1.6%) had intraosseous access established. Only a small proportion (14.7%, $n = 63$) had two or more observations outside the normal range.

Conclusion: A small proportion of children arriving in the ED post-major trauma have deranged clinical observations and receive critical interventions. The limited exposure in the management of trauma in paediatric patients requires measures to ensure clinicians have adequate training, skills and confidence to manage these clinical presentations in all EDs.

Key words: *critical intervention, emergency care, injury, paediatric.*

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Key findings

- Critical interventions are infrequently performed in the delivery of emergency care to critically injured children.
- Trauma team activation occured in less than half of children presenting following injury.
- Observations at intial assessment post triage were poorly documented.

Introduction

Injury and poisoning accounted for almost one third of emergency presentations for children <15 years of age in Australia between 2018 and 2019.[1] The incidence of major paediatric trauma in Australia is considerably lower than that of the adult population.[2] While the principles of management and assessment of the paediatric trauma patient are the same as that of adults, the wide range in injury pattern, anatomy and physiology require consideration. This variability combined with low volume creates challenges for clinicians in the treatment of injured children.[3]

Optimal trauma care results in improved outcomes following injury. The NSW Health trauma services model recommends children with major injury receive definitive care at a Paediatric Trauma Centre (PTC).[4] Depending on the severity of injury, and distance to the nearest PTC, injured children may receive initial care and stabilisation measures at a rural, regional or metropolitan hospital before being transferred. In a study of 625 children in New South Wales (NSW) sustaining major injury, there was no survival benefit for children receiving definitive care at a PTC.[5] However, peer review of a cohort children from the same study demonstrated an overall adverse event (AE) rate of 7.6%. Of these cases, 37% were determined to be a near miss that did not result in death, 15% preventable errors that resulted in lasting disability, and one case a near miss[6] of death. Staff action (lack of skill, delays to diagnosis, treatment, imaging or transfer) and organisational (work practice, policies or guidelines unclear or no guidelines, inadequate or lack of training) were the most frequent causal factors attributed to the AEs.[7]

Paediatric trauma is an Australian health and research priority,[8] yet other than the incidence of paediatric intubation in EDs,[9] there is limited information around other critical procedures.[10] The present study sought to explore the treatment received by children in ED following injury, to highlight training and support needs for emergency clinicians.

This paper examined the following research hypotheses: (i) time to intervention, such as intubation and head computed tomography (CT), would be longer for children treated outside a PTC; (ii) time to intubation would be shorter for children who were more severely injured, as measured by the Injury Severity Score (ISS) and Glasgow Coma Scale (GCS) ≤8, in line with recommended standard of care;[11] and (iii) ED length of stay (LOS) is shorter for children with increased injury severity.

Methods

The present study, undertaken as part of the aforementioned larger longitudinal study,[5] included children who ultimately received definitive care at a NSW PTC, <16 years requiring ICU or an ISS ≥9 treated in NSW or who died following injury between July 2015 and September 2016. The 491 children identified via NSW PTCs, account for 79% of the longitudinal study cohort, and were included as their medical records were accessible. The care provided at the initial ED, and the PTC was reviewed where documentation was available. Ethics approval was obtained through NSW Population and Health Services Research Ethics committee (HREC/15/CIPHS/6).

Setting

NSW encompasses an area of around 800 000 km^2, it is the most populous Australian state with 1.59 million children less than 16 years at June 2019.[12] The NSW trauma network includes three PTCs, all located within major city regions on the east coast of NSW equipped to provide the full spectrum of trauma care.[13]

Medical record review

Care provided at the referring EDs and PTC ED were reviewed at the PTCs by registered nurses experienced in emergency and trauma care and case audit. Data extracted included injury mechanism, mode of arrival, time of arrival and departure, clinical observations on arrival, Australasian Triage Scale,[14] trauma team activation (TTA), interventions and imaging in ED. At two PTCs more than one nurse completed data collection. At these sites, inter-rater reliability was completed on 10% of randomly selected records, with 83.1% agreement demonstrated overall and 89.0% for data related to ED care.[15] The variables selected to conduct the inter-rater reliability included those that required interrogation and sometimes interpretation of the medical record. For example: Was the child intubated in ED? Was a trauma team activated? Was the FAST positive or negative? Was fluid management appropriate? Where there were conflicting responses, these were reviewed by the project manager (an experienced trauma clinician) and a decision made.

Injury severity and physiology

The Abbreviated Injury Scale (AIS) was used to calculate ISS and new ISS.[16] Severe head injury was defined as head injury with an AIS >2 and polytrauma as injury to three or more body regions.[17] Abnormalities in physiology (i.e. heart rate/blood pressure/respiratory rate/neurology) were determined per the NSW Health between the flags (BTF) paediatric observation ranges.[18] Neurology was recorded using the GCS or AVPU (Alert, Verbal, Pain or Unresponsive).

Data analysis

Analyses were completed using SPSS v26 (IBM, Armonk, NY, USA). Mean and standard deviation are reported for normally distributed continuous variables and median and interquartile range (IQR) reported where continuous variables were skewed. Bivariate analysis was completed using chi-squared (χ^2) for relationships between categorical variables, and Mann–Whitney *U* or Kruskal-Wallis for differences in continuous variables. The type I error rate was 5%. Bonferroni adjustments were applied where multiple comparisons were conducted to examine no abnormal observations with the number of abnormal observations and ED LOS. Three multiple comparisons were analysed, level of significance $P = 0.016$, to limit the potential risk of family-wise errors.

Time to CT brain from ED arrival was evaluated based on GCS <14, a high-risk feature indicative of need for urgent imaging in children.[19] To capture injuries associated with a primary traumatic cause, with imaging required to inform management, children deceased in ED ($n = 6$) or injuries due to drowning, burns, ingestion or other mechanism were excluded ($n = 105$). Of the remaining 386 children, 54 were identified with a GCS <14.

Results

Initial treatment was provided at 64 different EDs to 491 children who met inclusion post-injury. More than half (53.6%) of the children were injured in a major city and 51.5% ($n = 252$) initially treated at a trauma centre (adult/regional) or a non-trauma centre and required interhospital transfer to a PTC. The majority (82.5%) of injuries

TABLE 1. *Patient demographics and injury mechanism*

	n = 491
Age (years), mean (SD)	6.70 (5.1)
Sex, n (%)	
Female	137 (27.9)
Male	354 (72.1)
Injury location, n (%)	
Major city	263 (53.6)
Inner Regional	91 (18.5)
Outer Regional/remote	59 (12.0)
Unknown	73 (14.9)
Outside NSW	5 (1.0)
Injury type, n (%)	
Blunt	405 (82.5)
Penetrating	5 (1.0)
Other†	81 (16.5)
Mechanism of injury, n (%)	
Fall	189 (38.5)
Motorcycle/motor vehicle collision	56 (11.4)
Pedal cyclist/scooter/skateboard	53 (10.8)
Pedestrian	38 (7.7)
Drowning	35 (7.1)
Sports	31 (6.3)
Burns (inhalational/contact)	29 (5.9)
Other incident‡	28 (5.7)
Assault	19 (3.9)
Ingestion	13 (2.6)
Injury profile	
Injury Severity Score, median (IQR)	9 (9–16)
New Injury Severity Score, median (IQR)	11 (9–18)
Polytrauma, n (%)	102 (20.8)
Head injury (Abbreviated Injury Scale >2), n (%)	148 (30.1)
Intensive care admission, n (%)	140 (28.5)
Outcome, n (%)	
Survived to hospital discharge	473 (96.3)
Deceased	18 (3.7)

†Other injury type includes drowning, ingestion, burns, other incidents not elsewhere classified. ‡Other incident includes crush/caught between objects, struck by object, asphyxiation, choking, explosion, electrical injury. IQR, interquartile range; SD, standard deviation.

were blunt, with falls the leading cause (38.5%) of injury followed by motor cycle/vehicle collisions (n = 56, 11.4%). Over two thirds (n = 330, 67.2%) had an ISS ≤12, and 27.7% (n = 136) an ISS >15 (Table 1).

Condition on arrival to emergency

On arrival to the ED more than half (n = 251, 51.1%) of children were allocated a triage category 1 or 2 per the Australasian Triage Scale. There was documented TTA for 38.3% (n = 188) of children on arrival to the ED; for 17.3% (n = 85) TTA could not be determined. Half the children initially treated at a PTC 53.1% (n = 129) had a TTA recorded, whereas TTA were only recorded for 23.8% (n = 59) treated outside a PTC. Of the most severely injured (ISS >12), 62.7% (n = 101/161) received a triage category 1 or 2 and 57.1% (n = 92/161) a TTA at their first ED.

Eight children (1.6%) had CPR in progress on arrival to the ED. For the remaining children, there were 429 records available with clinical observations documented post-triage (Table 2). Of these children 34.5% (n = 148) had a full set of observations documented. More than one third (36.6%) of children had no blood pressure documented with initial assessment, especially in the younger age groups (52.2% [n = 24] <1 year and 63.4% [n = 85] 1–5 years). Few children (14.7%, n = 63) had two or more initial observations outside the BTF parameters. A further 27.0% (n = 116) had one abnormal observation documented outside normal parameters.

Treatment in emergency

Forty-seven children (9.6%) required intubation in the ED, including two children intubated prehospital requiring re-intubation. In 10.6% of cases, mechanical ventilation was recorded, and massive transfusion protocol activation was only recorded in 0.4% cases during the ED stay. Table 3 reports documented interventions completed in the first treating ED. The median time to intubation from arrival at the ED was 34.5 min (IQR 15.3–81.8). Bivariate analysis of time to intubation demonstrated children with an ISS >12 or GCS ≤8 had a shorter time to intubation (P < 0.001), and children treated at PTC, adult

TABLE 2. *Observations on arrival for children not requiring CPR*

Clinical observations documented	n = 429, n (%)	ISS >12, n = 136, n (%)
Heart rate		
Normal	383 (89.3)	116 (85.3)
Abnormal	34 (7.9)	15 (11)
Missing	12 (2.8)	5 (3.7)
Systolic blood pressure		
Normal	234 (54.5)	97 (71.3)
Abnormal	38 (8.9)	18 (13.2)
Missing	157 (36.6)	21 (15.4)
Respiratory rate		
Normal	363 (84.6)	103 (75.7)
Abnormal	23 (5.4)	12 (8.8)
Missing	43 (10.0)	21 (15.4)
Oxygen saturations		
Normal	365 (85.1)	109 (80.1)
Abnormal <95	17 (4.0)	9 (6.6)
Missing	47 (11.0)	18 (13.2)
Neurology (GCS or AVPU)		
Normal	233 (54.3)	68 (50)
Abnormal	70 (16.3)	44 (32.4)
Missing	126 (29.4)	24 (32.4)
Temperature		
>37.2	36 (8.4)	10 (7.4)
36–37.2	223 (52)	59 (43.4)
<36	53 (12.4)	26 (19.1)
Missing	117 (27.3)	41 (30.1)

AVPU, Alert, Verbal, Pain or Unresponsive; GCS, Glasgow Coma Scale; ISS, Injury Severity Score.

trauma centre or metropolitan hospital all had a shorter time to intubation compared to those at Regional Trauma Centres or rural/remote health services ($P = 0.024$) (Table 4).

Imaging

Three hundred and eleven children had some form of radiological imaging in their first ED. More than half of these (56.6%, $n = 176$) had CXR, 47.6% ($n = 148$) lower limb imaging, 36.3% ($n = 113$) pelvic X-ray, 17.4% ($n = 54$) c-spine X-ray and 11 (3.5%) had an abdominal X-ray. Of the children who had c-spine X-rays, 20 (37%) went on to have a CT of the c-spine or panscan (head/neck/chest/abdomen/pelvis CT) at the same ED. Of the 203 children who had CT imaging, 70.4% ($n = 143$) received a CT brain, 31.0% ($n = 63$) a CT cervical-spine and 14.8% ($n = 30$) a panscan. Children with an ISS >12 accounted for 80% ($n = 24$) of the children who received a panscan. Repeat CT brain imaging within 72 h occurred for 36 (14.7%) children. There were 54 children with a GCS <14 or scoring verbal response or lower on the AVPU scale on initial assessment in the ED (excluding drowning, burns, ingestion) and 87% ($n = 47$) received a CT brain. The median (IQR) time to CT brain for a PTC was 48.5 min (38–61.5) compared to 44 min (37–105) at a non-PTC ($P = 0.89$).

ED length of stay

Six children died in the ED, the median time from arrival to being pronounced deceased was 19 min (IQR 7.5–54.5). All six children had CPR in progress on arrival. Excluding the deceased, the median ED LOS in the first ED was 241.0 min (IQR 161.0–375.5) ($n = 468$). Bivariate analysis demonstrated a shorter ED LOS for children with ISS >12 ($P = 0.016$), abnormal neurology ($P < 0.001$), abnormal heart rate ($P = 0.006$) or abnormal systolic blood pressure ($P = 0.045$). Comparison with children with no abnormal observations and one, two and three or more abnormal observations demonstrated a significant relationship ($P \leq 0.001$). Multiple comparisons demonstrated a significantly shorter median ED LOS for those with one (198.5 min [IQR 109–314], $P < 0.001$), two (175 min [IQR 74–245], $P < 0.001$) and three or more (98.5 min [IQR 38–208.5], $P = 0.002$) abnormal observations when compared to the ED LOS for children with no abnormal observations, 277 min (IQR 184–410). No significant bivariate relationship was found with age, polytrauma, head injury AIS >2 or hospital type (trauma centre/non-trauma centre) (Appendix S1).

Discussion

This descriptive paper provides an overview of the characteristics and ED treatment of children with major injuries identified through three NSW PTCs. Critical interventions were infrequent, TTA was inconsistent and documentation of vital signs was poor.

Critical interventions

Critical interventions such as intubation, needle/finger thoracostomy and intraosseous cannulation are essential, time critical procedures.[10] Only

TABLE 3. *Interventions at first ED*

Interventions	Overall, $n = 491$, n (%)	PTC, $n = 243$, n (%)	Other facility,† $n = 248$, n (%)
Airway			
Intubation	45 (9.2)	15 (6.2)	30 (12.1)
Spinal immobilisation			
ED	98 (20.0)	56 (23.0)	42 (16.9)
Prehospital	44 (9.0)	31 (12.8)	13 (5.2)
Breathing			
Mechanical ventilation	66 (10.6)	39 (16.0)	27 (10.9)
Needle thoracostomy	2 (0.4)	1 (0.4)	1 (0.4)
Chest drain	3 (0.6)	2 (0.8)	1 (0.4)
Arterial blood gas	185 (37.7)	121 (49.8)	64 (25.8)
End tidal CO_2	71 (14.5)	45 (18.5)	26 (10.5)
Circulation			
Intravenous access‡	295 (60.1)	159 (65.4)	136 (54.8)
Intraosseous	8 (1.6)	3 (1.2)	5 (2.0)
Arterial line	6 (1.2)	1 (0.4)	5 (2.0)
Blood products	7 (1.4)	5 (2.1)	2 (0.8)
MTP activation	2 (0.4)	2 (0.8)	—
FAST	113 (23)	67 (27.6)	46 (18.5)
Fracture reduction/splinting	84 (17.1)	41 (16.9)	43 (17.3)

†Other facility includes adult trauma centres, regional trauma centres, metropolitan, region/remote hospitals and interstate facilities. ‡$n = 4$ had both intravenous and intraosseous access. FAST, focussed assessment with sonography for trauma; MTP, massive transfusion protocol; PTC, paediatric trauma centre.

a small number of critical interventions were required in this cohort. Critical interventions may have been performed prior to patient arrival, and the ED is responsible for confirming the effectiveness of these interventions, such as endotracheal tube placement. In the prehospital setting, critical interventions were infrequent for this cohort, intubation was most common.[20] A 5-year review of the Australian and New Zealand Emergency Department Airway Registry, for children ≤15 years, reported most EDs performed less than 10 intubations per year, with AEs in 26–33% of cases.[9] The semi elective nature of intubation for some children requiring transfer, likely influenced the longer time to intubation. A previous review demonstrated problems with airway management at referring facilities.[7] A 2020 study identified significant variation in clinical practice in Australian and New Zealand EDs and ICUs, with further research recommended to determine best practice in paediatric airway management.[21]

Challenges in paediatric trauma care include low exposure and associated reduced confidence which impacts proficiency to delivery of appropriate care.[7] Clinical experience alone is not sufficient to maintain skill competence and there is a need to implement strategies, such as high fidelity simulation, to support maintenance of critical skills.[22] There is little evidence on the most appropriate methods to achieve this.

Imaging

Diagnostic imaging in the evaluation of trauma is widely used; however, the attributable cancer risk for paediatric patients with higher doses of ionising radiation associated with CT requires consideration.[23] The present study found 41% of children underwent CT imaging, with 6% receiving a panscan. Where panscan was completed over three quarters sustained an ISS >12, indicating that this imaging is largely used in the more severely injured cohort as expected. Clinical practice guidelines for the management of head injury in children stipulate that those classified as high risk require a head CT.[19] The present study found no significant difference in the time to CT for children managed initially outside a PTC. For children with a decreased LOC, 87% had a CT brain, in a median time of less than an hour, within the recommended timeframe per the NICE guidelines.[24] With changes in clinical coding guidelines, common procedures such as CT brain will no longer be

TABLE 4. *Facility and injury severity characteristics with a significant bivariate relationship with time to intubation from arrival in ED (minutes)*

	Valid, *n*	Time to intubation, median (IQR)	*P*-value†
Time to intubation			
Hospital facility‡			0.024
Paediatric trauma	15	20 (15–52)	
Adult trauma	4	13 (5.5–18.5)	
Regional trauma	8	72.5 (47.5–129)	
Major city	3	25 (10–81)	
Regional/remote	4	94.5 (59.5–122.5)	
Injury Severity Score			<0.001
≤12	12	95.5 (70–122.5)	
>12	24	19 (14–44.5)	
Glasgow Coma Scale			<0.001
>8	10	72.5 (50–125)	
≤8	15	15 (11–20)	

†Analysis completed using Mann–Whitney *U* and Kruskal-Wallis where more than two groups. ‡First treating health facility. IQR, interquartile range.

routinely coded,[25] this will make ongoing monitoring of CT imaging difficult in Australia. Should imaging continue to be considered a quality indicator in trauma management, local and national trauma registries will become the only place these data are available and should be adequately resourced.

Trauma team activation

TTA is a firmly established standard of care for trauma patients that results in improved patient and health service outcomes.[26] TTA occurred in 38% of cases, this is generated from a range of different health facilities which likely contributed to the result, along with potential variability in TTA criteria, or even the existence of a trauma team. A one size fits all approach to hospital-based trauma team response is difficult and likely to be influenced by expected case mix, experience and available staffing. Capacity to evaluate is limited with no standardised TTA criteria in NSW, and slightly different protocols exist even at PTCs.

Clinical observations

Just over one third of children had all vital signs documented on initial assessment post-triage, and one third had no blood pressure documented. The high number of missing blood pressure are potentially reflective of NSW Health policy which stipulated paediatric patients require a blood pressure on a minimum of one occasion during the ED stay, attended as soon as practical after triage for category 1 or 2 patients.[27] However, a previously published peer review from this cohort highlighted inadequate assessment and monitoring as a causal factor to AEs in eight cases.[7] Only a very small proportion of children had multiple observations documented outside of the BTF parameters for their age range[18] illustrating the potential for significant injury with no alteration in clinical observations. This highlights the deficiencies in detecting severe trauma-related hypovolaemic shock based on age-adjusted tachycardia or systolic blood pressure. Some authors have suggested using an age-adjusted paediatric shock index which may have some merit.[28]

Suboptimal monitoring in the ED is linked to adverse outcomes.[29] The lack of documentation of vital signs could be to the result of monitoring occurring not being documented due to the known time constraints in the resuscitation context, it takes at least 5 min to perform and record a set of vital signs uninterrupted.[30] Review of paediatric trauma cases previously recommended 1:1 nurse–patient ratios for paediatric trauma patients in the resuscitation area.[7] A solution would be automated downloading of vital signs from the monitoring systems to the electronic medical record in ED, similar to processes used in ICUs around Australia.[31]

Emergency length of stay

Prolonged ED LOS is associated with poorer outcomes. While most research relates to adults, ED LOS and overcrowding can compromise care for paediatric patients.[32] The median LOS for children presenting post-injury to the ED was just over 4 h. The present study demonstrated children with higher ISS and/or abnormalities in clinical observations had a shorter ED LOS, albeit 14 min; however, this is clinically significant when a child requires time critical surgical intervention. From an ED flow and patient safety perspective this is also important, considering the human resources required to provide care for a child with complex injuries. From these results it could be considered that children sustaining more injuries requiring time critical management were managed expeditiously.

Limitations

Medical records were reviewed at the PTCs, information related care at referring hospitals was limited to that transferred with the patient. Although data collection was guided by a data dictionary and inter-rater reliability (albeit 89%) was completed for records at sites with multiple data collectors, retrospective review is a limitation, as clinical documentation does not always accurately reflect the interventions completed in practice.

Conclusion

The present study provides an overview of the management of severely injured children treated in 64 EDs post-injury in NSW, Australia. Only a small number of children required resuscitation and critical interventions. This highlights the challenge for clinicians with such limited exposure and indicates the need for ongoing education through simulation and other approaches to maintain key skills.

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Competing interests

None declared.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting information

Additional supporting information may be found in the online version of this article at the publisher's web site:

Appendix S1. Variables with significant bivariate relationship with ED length of stay (minutes).