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Paediatric head injury surveillance and control in Singapore – are we there yet?

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Title Page

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Abstract

Objective

To study the mechanisms of head injuries among the paediatric population in Singapore, and the association between mechanisms and mortality, need for airway or neurosurgical intervention.

Methods

Design This is an observational study utilizing the data from the trauma surveillance system from Jan 2011 to March 2015.

Setting Paediatric emergency departments (EDs) of KK Women's and Children's Hospital, and National University Health System.

Participants We included children presenting to the paediatric EDs aged < 16 years old who required a computed tomography (CT) scan or admission for monitoring of persistent symptoms. We excluded children who presented with minor mechanism and those whose symptoms had spontaneously resolved.

Primary and secondary outcome measures Primary composite outcome was defined as death, need for intubation or neurosurgical intervention. Secondary outcomes included length of hospital stay and type of neurosurgical intervention.

Results

We analysed 1049 children who met the inclusion criteria. The mean age was 6.7 (SD 5.2) years. 260 (24.8%) had a positive finding on CT. 17 (1.6%) children died, 55 (5.2%) required urgent intubation in the ED and 58 (5.5%) underwent neurosurgery. The main mechanisms associated with severe outcomes were motor vehicle crashes (OR 7.3, 95% 4.4-12.0) and non-accidental trauma (OR 5.6 95% CI 1.8-18.1). This remained statistically significant when we stratified to children aged < 2 years and performed a multivariable analysis including age and location of injury. For motor vehicle crashes, less than half of the children were using restraints.

Conclusions

Motor vehicle crashes and non-accidental trauma mechanisms are particularly associated with poor outcomes among children with paediatric head injury. Continued vigilance and compliance to injury prevention initiatives and legislature is vital.

Article Summary

Strengths

- This is the first report comprising combined paediatric data on head injuries from the trauma surveillance databases in both paediatric centers in Singapore.
- The mechanisms of injuries were prospectively collected

Limitations

- Details of injury data entry may have differed between the institutions
- This study describes the surveillance and circumstances surrounding paediatric head injuries, specifically. This is because paediatric head injuries are especially common and have long lasting consequences in children.

Introduction

Head injuries continue to impose a large burden on the healthcare system and on society. An estimated 4.8 million patient visits per year in the United States required evaluation for traumatic brain injuries (TBI) [1] Injury control initiatives in the last decade have resulted in a change in the injury landscape, reduced deaths from motor vehicle accidents and driven the institution of legislation to promote safety. [2] Other advances in the acute care and resuscitation of the severely head-injured patient have improved patient outcomes as a whole. However, severely head-injured patients continue to suffer death and long term neurological deficits from these injuries.

Children, in particular, are extremely susceptible to head injuries. The promise of a full life ahead can be shattered when the child is subjected to brain trauma, which can bring about long term effects not only on the child, but also on the family unit [3] and on society as a whole. Severe injuries may blunt the child's motor development and compromise the child's cognitive abilities [4]. Children with moderate – severe TBI generally experience a greater decrease in health-related quality of life immediately after the injury. [5] This study demonstrated that the effect was however mitigated by 18 months post-TBI. Even among mild head injuries, some have lamented the lack of knowledge surrounding long term effects of patients subjected to repeated insults. [6]

Children suffer head injuries from different mechanisms. In the United States, falls constitute the most frequent mechanism for children under 12 years of age, while the adolescents are more prone to assaults, motor vehicle crashes and sports injuries. [7] Motorcycles (including off-road motorcycling) in particular have received particular attention [8], with the lack of compliance to helmets disconcerting in some countries [9]. Concerning objects associated with significant head injuries, advocates have cautioned especially on (fallen or struck by) television-related injuries [10, 11] that range from concussion to intracranial bleeds and death. Among the sports that are associated with head injuries, ice hockey, soccer and football feature heavily. [12] Abusive head trauma (AHT), or non-accidental trauma (NAT) are an especially vulnerable group – these injured children are known to have poor outcomes, with a higher rate of mortality and multiple injuries. [13, 14]

In our own population, falls constitutes the most common mechanism among the paediatric head injured population, especially among those aged < 2 years old. Motor vehicle crashes independently predict for severe injury [15, 16].

In this study, we extended the previous work to include both paediatric emergency departments in the country. We aim to study the head injured paediatric population and in particular their mechanisms of injuries, correlating these mechanisms with the severity of outcomes. We hypothesize that although falls and sports injuries are common, children who suffer motor vehicle crashes and non-accidental trauma (NAT) are more likely to die and suffer brain injuries that require neurosurgical intervention.

Methodology

Design This is an observational study from January 2011 to March 2015, involving both tertiary paediatric centers in Singapore. KK Women's and Children's Hospital (KKH) and National University of Singapore (NUH) together see the bulk of paediatric injuries in the country, and are both Level 1 Trauma Centers. The injury surveillance was started in January 2011 as part of the National Trauma Registry, empowering prospective collection of data for all injured children that present to both institutions.

Patients were included from chart review once they fulfilled the necessary diagnosis codes for head injuries. **Inclusion Criteria** Children aged < 16 years old who presented to the Emergency Departments (EDs) with head injuries and who were admitted for further monitoring were included. **Exclusion Criteria** We excluded children with low mechanism falls and those who sustained minor contusion injuries to the face and scalp. Children whose symptoms (e.g. vomiting, headache) resolved and who were not admitted were excluded from this study.

Standardization of Definitions Children with decreased Glasgow Coma Scale (GCS) had CT ordered from the ED and were then subsequently admitted. At the start of the study period, both institutions did not practice ordering computed tomography (CT) brain at the level of the ED with the aim of discharge if the CT was negative. Both institutional protocols required for children with symptoms and signs suggestive of traumatic brain injury to be admitted for monitoring instead. Starting January 2013, one of the institutions (NUH) changed the head injury protocol to allow for monitoring in the ED for up to 6 hours, with the CT brain ordered from the ED if indicated, and if normal, patient could be discharged from the ED. Hence, we included the latter group that clinically warranted a CT scan from the ED but who were discharged when the CT was normal. Where there was contention whether the child's presentation was attributed to the head injury or other causes (e.g. seizures or altered mental status), this was highlighted to the team and resolved with a review of the medical records and patients' subsequent investigations.

Data Collection The following were collected as part of the prospective injury surveillance: Demographic details including the child's age, gender, and ethnicity. The intent of injury (unintentional, assault, self-harm or unknown) and the primary mechanism of injury (fall, motor vehicle crash, sports injury, non-accidental trauma, interpersonal violence, or others) were documented. If the child had suffered a fall, the height of the fall was documented. If the child was involved in a motor vehicle crash, it was recorded if he was a pedestrian, cyclist, motor vehicle front or back passenger, motorbike front or back passenger. The use of restraints (car child seat, seat belt, helmet) was included where documented. In our population we separated the non-accidental traumas (where the alleged perpetrator is a caregiver/custodian or trusted member in the household) and interpersonal violence – the later comprised mainly of assault incidents in school. Details surrounding the object involved in the trauma and the location of the injury were also studied. We reviewed the disposition from the ED, the specific intracranial injury, and the rates of CT brain being performed.

Assessment of Main Outcomes Severe outcomes were defined as death, the need for intubation or neurosurgical intervention. (We do not perform intubation only for neuroimaging studies in the head injured child) For children who died, we looked at the number of days after the head injury. We reviewed the specific neurosurgical intervention. For children who were admitted, we looked at the length of hospital stay.

Analytical Plan Categorical variables were represented in frequencies and percentages. Normality was assumed for continuous variables which were represented with mean and standard deviation (SD). Chi square tests were performed for categorical variables and independent sample t-test for continuous variables. Univariable logistic regression was performed to obtain the odds ratio (and 95% confidence intervals) for severe outcomes as defined by death, intubation and the need for neurosurgical intervention. Specifically, we stratified the analysis to study children aged less than 2 years old. We subsequently performed a multivariable logistic regression, adjusting for age and location of injury. Statistical significance was established at a p value of < 0.05. All statistical tests were performed using SPSS v19 (SPSS Inc, Chicago, III). We did not apply imputation or statistical models on missing values.

Ethics Approval was given by the Singhealth Centralised Institutional Review Board (CIRB) E, Paediatrics.

Results

A total of 1049 children met the inclusion criteria (Refer Figure 1). Among these, the mean age was 6.7 years (SD 5.2) with 268 (25.5%) children aged less than 2 years old. The demographics are detailed in Table 1. In this particular patient population, 501 patients (47.8%) underwent a computed tomography (CT), of which 260 (24.8%) had positive findings on the CT. These positive findings included focal intracranial bleeds, diffuse axonal injury (DAI) and skull fractures. 17 (1.6%) patients demised, of which 7 (0.7%) were pronounced dead in the EDs. 58 (5.5%) patients underwent neurosurgery while 55 (5.2%) required urgent intubation in the ED. (Table 1)

We did not have any missing information on the intent or mechanisms of injuries. Falls remain the most common cause of head injuries (753, or 71.8%) (Table 2). Among all the falls, 393 (52.2%) occurred in the home. This was especially prominent among children aged less than 2 years old, of whom 227 (84.7%) had injuries attributed to falls and 182(67.9%) occurred at home. The common objects included furniture (e.g. adult bed) and ground surface. With every meter increase in the height of the fall, the likelihood of sustaining a severe outcome was 1.4 times (95% CI 11.3-1.6) This was consistent across the individual severe outcomes of death (OR 1.5 95% CI 1.3-1.7) and need for intubation (OR 1.5 95% CI 1.3-1.7).

123 (11.7%) children suffered a head injury as a result of a motor vehicle crash. Among these, 67 (54.5%) were pedestrians, 24 (19.5%) were motor vehicle back passengers and 20 (16.3%) were cyclists. In this population, there was no statistically significant risk of severe outcomes among the pedestrians when compared to motor vehicle back passengers (OR 1.3 95% 0.5 – 3.7). We did note, however, that among 56 road users (cyclists or occupants of motor vehicles), 42 or 75% of the children were not using helmets nor restraints (infant capsules, car booster seats or seat belts). 3 patients did not have complete records on the use of restraints.

Among the 17 children subject to non-accidental trauma, the mean age was 6.2 years (SD 6.4). 4 had a subdural hemorrhage (SDH), 1 had diffuse axonal injury (DAI), 1 had an extradural hemorrhage (EDH) and 1 child had an isolated skull fracture. 4 patients suffered a severe outcome (2 children died) and 11 patients required a hospital stay of more than 72 hours.

Among the 17 deaths the mean age was 4.9 years (SD 5.9) with the mean number of days between injury and death being 5.9 days (SD 11.6).

Table 3 shows the univariable logistic regression on mechanism of injury associated with severe outcome. Compared to falls, motor vehicle crashes (OR 7.3, 95% 4.4-12.0) and non-accidental trauma (OR 5.6 95% CI 1.8-18.1) were more likely to result in death, need for airway or neurosurgical intervention. This remained statistically significant when we stratified the analysis to patients under 2 years old. We performed a multivariable logistic regression comprising age, mechanism of injury and location of injury. The above two mechanisms, as well as an injury occurring outside the home, remained statistically significant for poor outcome (Table 4).

Discussion

Childhood injuries are still an ever-growing problem in many parts of the world [17]. Childhood injury requires a life-cycle approach [18]. The likely mechanisms of injury (and types of injury) vary predictably as the child develops with age. For example, while drowning dominates fatal injuries in Asia among children aged 1-5 years old, motor vehicle crashes gain prominence as a killer among older age groups [19]. Injury surveillance and epidemiology allows us to gain a better understanding of injuries in our region, and can help to drive initiatives to prevent the precipitating events. We can minimize injury by making changes in the person, equipment or vehicle, or the environment. [20,21]

In this study, we focused on head injuries. Even though various mechanisms of injuries can result in different anatomical injuries, paediatric head injuries are particularly important because of the following: (i) Paediatric patients have a relatively larger head and are prone to head injuries, especially among the younger age groups (ii) Children are at a stage of rapid brain growth and neurocognitive development, therefore especially sensitive to injuries, and (iii) Traumatic brain injuries result not only in death, but also life-long physical, emotional, financial and social sequelae on the patient, caregivers, family and society.

The mechanisms of injuries among this patient population in Singapore are largely consistent with prior reports [16]. While falls are common, road traffic accidents tend to be associated with larger forces and more severe injuries. Our study showed that this effect was evident regardless of age or location of injury. In Singapore, it is mandatory for children riding bicycles on roadways to don helmets. It is also mandatory for children in motor vehicles to be appropriately restrained [22]. In this population of head injured children presenting to the emergency department, the compliance to road safety laws is still found wanting. This was recently similarly reported in the United States where only about half of the children with motor vehicle crash fatalities wore any child restraints [23]. Child safety programs initiated at the ED [24] have been reported and should be explored. Pedestrians, on the other hand, are known to be at high risk of severe injuries compared to other motorway users – This is especially applicable to older children who may not be supervised when crossing the roads.

We also chose to study those aged less than 2 years old, separately. This special group of young children is especially vulnerable to head injuries, and to the interventions (e.g. radiation from CT) imposed on them [25]. While they are especially sensitive to injuries, their complaints are usually non-specific and variable. Young children tend to have closer supervision in public areas, but they are most prone to injuries in the home, as evident in our results. Falls from adult beds, sofas and other furniture can result in traumatic brain injuries in this group. Child injury prevention strategies must therefore take an age-targeted approach. Although falls in the home were less likely to be associated with severe outcome, a greater awareness of the dangers at home would reduce the overall number of head injuries.

Non-accidental trauma in our country is diagnosed and managed along international standards [26]. They are confirmed at case conference, civil, family or criminal court proceedings, or by stated criteria, including multidisciplinary assessment [26]. In our patient population, the presence of abuse portended a more severe outcome, and a longer hospital stay. They must therefore be promptly recognized by all first-line physicians who must rapidly activate social help services and the corresponding law-enforcement agencies.

Of note, the CT rate in this study was particularly high (47.8%) because we had chosen to exclude children subject to lower forces of injuries, minor contusions, and those whose symptoms had resolved spontaneously while monitoring in the ED. We had previously reported that our CT rates (for overall paediatric head injuries) in one institution was closer to 1% [27].

We recognize the limitations of this study. Firstly, this study combined data between 2 tertiary institutions' trauma surveillance systems – there may have been differences in the details of documentation especially surrounding the object involved in the injury and the location. Secondly, the numbers of injuries secondary to road traffic accidents were relatively low in our population – this itself could be a result of legislature and increasing awareness, meaning that children who were appropriately restrained may have been protected from injuries, in the first place. Thirdly, we recognize that studying only head-injured children and their corresponding mechanisms may result in certain differences from all-encompassing injury surveillance. We believe however, that this group warrants special attention and necessary action to reduce overall childhood mortality and morbidity.

Moving forward, we are looking to extend this work to other centers in the Asian region, in the hope that a common platform for childhood injury surveillance will meet the current needs for robust surveillance, sharing of injury prevention strategies and evaluation of programs.

Contributors: CSL, CSY, FXY, CST, LN and OME contributed to the conception and design of the study, analysis and interpretation of data. CSL, CSY, FXY, TLP, and CST were directly involved in data acquisition. All the authors were involved in drafting of the article and revising it critically for important intellectual content. All authors have read and approved the final manuscript.

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Competing interests: None declared

Ethics approval: Singhealth Centralised Institutional Review Board (CIRB) E, Paediatrics.

Data Sharing Statement: No additional data available

References

1. Korley FK, Kelen GD, Jones CM, et al. Emergency Department Evaluation of Traumatic Brain Injury in the United States, 2009-2010. J Head Trauma Rehabil, 2015 Sep 10 [Epub ahead of print]
2. Johnston BD and BE Ebel. Child injury control: trends, themes, and controversies. Acad Pediatr, 2013. **13**(6): p. 499-507.
3. Bray L. Parents' experiences of hope following a child's brain injury. Nurs Child Young People, 2015. **27**(7): p. 22-6.
4. Ransom DM, Vaughan CG, Pratson L, et al. Academic effects of concussion in children and adolescents. Pediatrics, 2015. **135**(6): p. 1043-50.
5. Brown EA, Kenardy J, Chandler B, et al., Parent-Reported Health-Related Quality of Life in Children With Traumatic Brain Injury: A Prospective Study. J Pediatr Psychol, 2015.
6. Levin HS and RR Diaz-Arrastia. Diagnosis, prognosis, and clinical management of mild traumatic brain injury. Lancet Neurol, 2015. **14**(5): p. 506-17.
7. Quayle KS, Powell EC, Mahajan P, et al. Epidemiology of blunt head trauma in children in U.S. emergency departments. N Engl J Med, 2014. **371**(20): p. 1945-7.
8. Daniels DJ, Clarke MJ, Puffer R, et al. High occurrence of head and spine injuries in the pediatric population following motocross accidents. J Neurosurg Pediatr, 2015. **15**(3): p. 261-5.
9. Nnadi MO, OB Bankole, and BG Fente. Motorcycle-Related Traumatic Brain Injuries: Helmet Use and Treatment Outcome. Neurosci J, 2015. **2015**: p. 696787.
10. Befeler AR, Daniels DJ, Helms SA, et al. Head injuries following television-related accidents in the pediatric population. J Neurosurg Pediatr, 2014. **14**(4): p. 414-7.
11. Cusimano MD and N Parker. Toppled television sets and head injuries in the pediatric population: a framework for prevention. J Neurosurg Pediatr, 2015: p. 1-10.
12. Cusimano MD, Cho N, Amin K, et al. Mechanisms of team-sport-related brain injuries in children 5 to 19 years old: opportunities for prevention. PLoS One, 2013. **8**(3): p. e58868.
13. Hinds T, Shalaby-Rana E, Jackson AM, et al. Aspects of abuse: abusive head trauma. Curr Probl Pediatr Adolesc Health Care, 2015. **45**(3): p. 71-9.
14. Ward A, Iocono JA, Brown S, et al. Non-accidental Trauma Injury Patterns and Outcomes: A Single Institutional Experience. Am Surg, 2015. **81**(9): p. 835-8.
15. Chong SL, Liu N, Barbier S, et al. Predictive modeling in pediatric traumatic brain injury using machine learning. BMC Med Res Methodol, 2015. **15**: p. 22.
16. Chong SL, Barbier S, Liu N, et al. Predictors for moderate to severe paediatric head injury derived from a surveillance registry in the emergency department. Injury, 2015. **46**(7): p. 1270-4.
17. Peden M, Oyegbite K, Ozanne-Smith J, et al. World report on child injury prevention. 2008: World Health Organization.
18. http://www.unicef.org/eapro/activities_3598.html (accessed 28th October 2015)
19. Linnan M, Giersing M, Linnan H, et al. Child mortality and injury in Asia: policy and programme implications, 2007, Florence, UNICEF Innocenti Research Centre.
20. Haddon W Jr. Advances in the epidemiology of injuries as a basis for public policy. Public Health Rep, 1980. **95**(5): p. 411-21.
21. Ablewhite J, McDaid L, Hawkins A, et al., Approaches used by parents to keep their children safe at home: a qualitative study to explore the perspectives of parents with children aged under five years. BMC Public Health, 2015. **15**(1): p. 983.
22. http://statutes.agc.gov.sg/aol/search/display/view.w3p;ident=a098480b-5fbe-4841-b679-e397ebe31335;page=0;query=DocId%3A%22ba3acbce-2ce4-4b3f-8011-

5bfae19cfbbc%22%20Status%3Apublished%20Depth%3A0;rec=0#pr74-he-. (accessed 30th October 2015)
23. Lee LK, CA Farrell, and R. Mannix. Restraint use in motor vehicle crash fatalities in children 0 year to 9 years old. J Trauma Acute Care Surg, 2015. **79**(3 Suppl 1): p. S55-60.
24. Kiley K, Damian F, MacClaren W, et al., A computerized child passenger safety screening program in the emergency department. Pediatr Emerg Care, 2014. **30**(9): p. 631-5.
25. Kuppermann N, Holmes JF, Dayan PS, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet, 2009. **374**(9696): p. 1160-70.
26. Maguire SA, Kemp AM, Lumb RC, et al., Estimating the probability of abusive head trauma: a pooled analysis. Pediatrics, 2011. **128**(3): p. e550-64.
27. DW Thiam, Yap SH, and Chong SL. Clinical Decision Rules for Paediatric Minor Head Injury: Are CT Scans a Necessary Evil? Ann Acad Med Singapore 2015;44:335-41

Figure 1

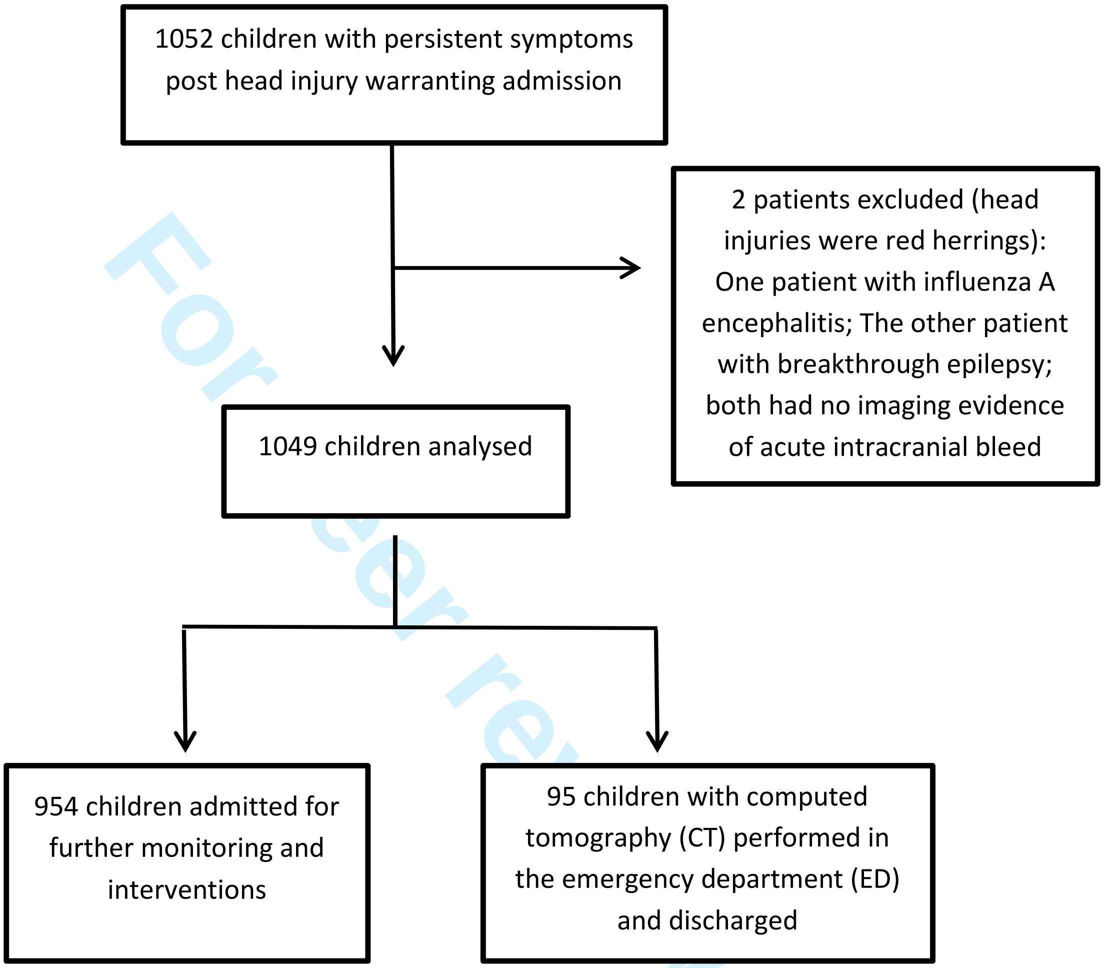
1052 children with persistent symptoms post head injury warranting admission
2 patients excluded (head injuries were red herrings): One patient with influenza A encephalitis; The other patient with breakthrough epilepsy; both had no imaging evidence of acute intracranial bleed
1049 children analysed
954 children admitted for further monitoring and interventions
95 children with computed tomography (CT) performed in the emergency department (ED) and discharged

Table 1: Patient characteristics, patient demographics and clinical outcomes

Patient age, mean (SD)	6.7 (5.2)
Gender, n (%)	661 (63.0)
CT brain performed, n (%)	501 (47.8)
Positive finding on CT brain, n (%)	260 (24.8)
Subdural hemorrhage (SDH)	75 (7.1)
Extradural hemorrhage (EDH)	52 (5.0)
Intracerebellar hemorrhage	27 (2.6)
Diffuse Axonal Injury (DAI)	26 (2.5)
Subarachnoid hemorrhage (SAH)	24 (2.3)
Brainstem/uncal herniation	5 (0.5)
Pneumocephalus	4 (0.4)
Skull fracture	176 (16.8)
ED disposition	
Intensive Care Unit	75 (7.1)
High Dependency Unit	68 (6.5)
General Ward	807 (76.9)
Morgue	7 (0.7)
Hospital length of Stay	
Less than 24 hours	644 (61.4)
24-48 hours	196 (18.7)
48-72 hours	61 (5.8)
More than 72 hours	148 (14.1)
Death, n (%)	17 (1.6)
Intubation, n (%)	55 (5.2)
Neurosurgical intervention, n (%)	58 (5.5)
Type of neurosurgical intervention, n (%)	
Monitoring of intracranial pressure	47 (4.5)
Evacuation of intracranial bleed	8 (0.8)
Elevation of skull fracture	6 (0.6)

Table 2: Mechanisms involved in Injury

	All patients (n=1049)	Children < 2 years (n = 268)
Primary Mechanism of injury, n (%)		
Fall	753 (71.8)	227 (84.7)
MVC	123 (11.7)	10 (3.7)
Sports	64 (6.1)	0 (0.0)
Interpersonal violence	24 (2.3)	0 (0.0)
Non-accidental trauma	17 (1.6)	7 (2.6)
Others	68 (6.5)	24 (9.0)
If fall, height (m), mean (SD)	0.7 (2.0)	0.6 (1.0)
If Motor Vehicle Crash		
Pedestrian	67 (54.5)	0 (0.0)
Cyclist	20 (16.3)	0 (0.0)
Motor vehicle front passenger	9 (7.3)	3 (30.0)
Motor vehicle back passenger	24 (19.5)	7 (70.0)
Motorbike rider/pillion	3 (2.4)	0 (0.0)
Location of injury		
Home	430 (41.0)	199 (74.3)
School/Child care centers	139 (13.3)	3 (1.1)
Public Places	141 (13.4)	21 (7.8)
Roadways	137 (13.1)	9 (3.4)

Table 3: Univariable Logistic Regression for Mechanism of Injury predicting for severe outcome

Mechanism of injury	Odds Ratio	95% CI	p value
Motor Vehicle Crash	7.3	4.4 - 12.1	< 0.001
Sports	0.6	0.1 - 2.5	0.475
Non Accidental Trauma	5.6	1.8 - 18.1	0.004
Others	1.5	0.6 - 3.8	0.448
For Children < 2 years old			
Motor Vehicle Crash	31.4	7.4-134.0	< 0.001
Non Accidental Trauma	12.6	2.1-76.4	0.006
Others	4.5	1.1-18.7	0.039

*Taking fall as the reference for mechanism of injury

Table 4: Multivariable Logistic Regression for Age, Mechanism of Injury and Location

	Adjusted Odds Ratio	95% CI	p value
Mechanism of Injury			
Motor Vehicle Crash	**6.0**	**3.4-10.6**	**< 0.001**
Sports	0.5	0.1-2.4	0.418
Non Accidental Trauma	**6.5**	**2.0-21.7**	**0.002**
Others	1.2	0.5-3.3	0.672
Age	1.0	0.9 – 1.0	0.068
Injury Outside the Home	**2.5**	**1.3-4.8**	**0.005**

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	6 (We included all patients who fit the criteria as explained under Methods)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6

		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12
		(b) Give reasons for non-participation at each stage	12
		(c) Consider use of a flow diagram	12
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,13
		(b) Indicate number of participants with missing data for each variable of interest	7
		(c) Summarise follow-up time (eg, average and total amount)	13
Outcome data	15*	Report numbers of outcome events or summary measures over time	7,13,15
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15
		(*b*) Report category boundaries when continuous variables were categorized	13
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7,15
Discussion			
Key results	18	Summarise key results with reference to study objectives	7,8
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	8,9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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A prospective surveillance of paediatric head injuries in Singapore - a dual-centre study

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Title Page

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A prospective surveillance of paediatric head injuries in Singapore - a dual-centre study

Abstract

Objective

To study the causes of head injuries among the paediatric population in Singapore, and the association between causes and mortality, need for airway or neurosurgical intervention.

Methods

Design This is a prospective observational study utilizing the data from the trauma surveillance system from January 2011 to March 2015.

Setting Paediatric emergency departments (EDs) of KK Women's and Children's Hospital, and National University Health System.

Participants We included children presenting to the paediatric EDs aged < 16 years old with head injuries who required a computed tomography (CT) scan, admission for monitoring of persistent symptoms, or who died from the head injury. We excluded children who presented with minor mechanisms and those whose symptoms had spontaneously resolved.

Primary and secondary outcome measures Primary composite outcome was defined as death, need for intubation or neurosurgical intervention. Secondary outcomes included length of hospital stay and type of neurosurgical intervention.

Results

We analysed 1049 children who met the inclusion criteria. The mean age was 6.7 (SD 5.2) years. 260 (24.8%) had a positive finding on CT. 17 (1.6%) children died, 52 (5.0%) required emergency intubation in the ED and 58 (5.5%) underwent neurosurgery. The main causes associated with severe outcomes were motor vehicle crashes (OR 7.2, 95% CI 4.3-12.0) and non-accidental trauma (OR 5.8, 95% CI 1.8-18.6). This remained statistically significant when we stratified to children aged < 2 years and performed a multivariable analysis adjusting for age and location of injury. For motor vehicle crashes, less than half of the children were using restraints.

Conclusions

Motor vehicle crashes and non-accidental trauma causes are particularly associated with poor outcomes among children with paediatric head injury. Continued vigilance and compliance to injury prevention initiatives and legislature is vital.

Article Summary

Strengths

- This is the first report comprising combined paediatric data on head injuries from the trauma surveillance databases in both paediatric centers in Singapore.
- The causes of injuries were prospectively collected.

Limitations

- Detailed coding of injury data may have differed between the institutions.
- This study describes the surveillance and circumstances surrounding paediatric head injuries, specifically. This is because paediatric head injuries are especially common and have long lasting consequences in children.

Introduction

Head injuries continue to impose a large burden on the healthcare system and on society. An estimated 4.8 million patient visits per year in the United States required evaluation for traumatic brain injuries (TBI). [1] Injury control initiatives in the last decade have resulted in a change in the injury landscape, reduced deaths from motor vehicle accidents and driven the institution of legislation to promote safety. [2] Other advances in the acute care and resuscitation of the severely head-injured patient have improved patient outcomes as a whole. However, severely head-injured patients continue to suffer death and long term neurological deficits from these injuries.

Children, in particular, are extremely susceptible to head injuries. Significant brain trauma can bring about long term consequences not only on the child, but also on the family unit [3] and on society as a whole. Severe injuries may blunt the child's motor development and compromise the child's cognitive abilities [4]. Children with moderate – severe TBI generally experience a greater decrease in health-related quality of life immediately after the injury. [5] This study demonstrated that the effect was however mitigated by 18 months post-TBI. Even among mild head injuries, some have lamented the lack of knowledge surrounding long term effects of patients subjected to repeated insults. [6]

Children suffer head injuries from different causes. In the United States, falls constitute the most frequent mechanism for children under 12 years of age, while the adolescents are more prone to assaults, motor vehicle crashes and sports injuries. [7] Motorcycles (including off-road motorcycling) in particular have received particular attention [8], with the lack of compliance to helmets disconcerting in some countries [9]. Concerning objects associated with significant head injuries, advocates have cautioned especially on (fallen or struck by) television-related injuries [10, 11] that range from concussion to intracranial bleeds and death. Among the sports that are associated with head injuries, ice hockey, soccer and football feature heavily. [12] Abusive head trauma (AHT), or non-accidental trauma (NAT) are an especially vulnerable group – these injured children are known to have poor outcomes, with a higher rate of mortality and multiple injuries. [13, 14]

In our own population, falls constitutes the most common mechanism among the paediatric head injured population, especially among those aged < 2 years old. Motor vehicle crashes independently predict for severe injury [15, 16].

In this study, we extended the previous work to include both paediatric emergency departments (EDs) in the country. We aim to study the head injured paediatric population and in particular their causes of injuries, correlating these causes with the severity of outcomes. We hypothesize that although falls and sports injuries are common, children who suffer motor vehicle crashes and non-accidental trauma (NAT) are more likely to die and suffer brain injuries that require airway and neurosurgical intervention.

Methodology

Design This is an observational study from January 2011 to March 2015, involving both tertiary paediatric centers in Singapore. KK Women's and Children's Hospital (KKH) and National University Health System (NUHS) together see the bulk of paediatric injuries in the country, and are both Level 1 Trauma Centers. The injury surveillance was started in January 2011 as part of the National Trauma Registry, empowering prospective collection of data for all injured children that present to both institutions.

Patients were included from chart review once they fulfilled the necessary ICD diagnosis codes for head injuries. **Inclusion Criteria** We included children aged < 16 years old who presented to the Emergency Departments (EDs) with head injuries and who were admitted for further monitoring. We also included all children who died in the ED due to head injuries. **Exclusion Criteria** We excluded children with low mechanism falls and those who sustained minor contusion injuries to the face and scalp. Children whose symptoms (e.g. vomiting, headache) resolved and who were not admitted were excluded from this study.

Standardization of Definitions Children with decreased Glasgow Coma Scale (GCS) had a computed tomography (CT) brain ordered from the ED and were then subsequently admitted. At the start of the study period, both institutions did not practise ordering CT brain at the level of the ED with the aim of discharge if the CT was negative. Both institutional protocols required for children with symptoms and signs suggestive of traumatic brain injury to be admitted for monitoring instead. Starting January 2013, one of the institutions (NUHS) changed the head injury protocol to allow for monitoring in the ED for up to 6 hours, with the CT brain ordered from the ED if indicated, and if normal, the patient could be discharged from the ED. Hence, we included the latter group that clinically warranted a CT scan from the ED but who were discharged when the CT was normal. Where there was contention whether the child's presentation was attributed to the head injury or other causes (e.g. seizures or altered mental status), this was highlighted to the team and resolved with a review of the medical records and patients' subsequent investigations.

Data Collection The following were collected as part of the prospective injury surveillance: Demographic details including the child's age, gender, and ethnicity. The intent of injury (unintentional, assault, self-harm or unknown) and the primary cause of injury (fall, motor vehicle crash, sports injury, non-accidental trauma, interpersonal violence, or others) were documented. If the child had suffered a fall, the height of the fall was documented. If the child was involved in a motor vehicle crash, it was recorded if he was a pedestrian, cyclist, motor vehicle front or back passenger, motorbike front or back passenger. The use of restraints (car child seat, seat belt, and helmet) was included where documented. In our population we separated the non-accidental traumas (where the alleged perpetrator is a caregiver/custodian or trusted member in the household) and interpersonal violence – the later comprised mainly of assault incidents in school. Details surrounding the object involved in the trauma and the location of the injury were also studied. We reviewed the disposition from the ED, the specific intracranial injury, and the rates of CT brain being performed.

Assessment of Main Outcomes Severe outcomes were defined as death, the need for intubation or neurosurgical intervention. (We do not perform intubation only for neuroimaging studies in the head injured child.) Intubation in these patients was specifically performed for the concerns of acute traumatic brain injury – the indications include low GCS, inability to maintain airway, or suspected raised ICP. Specifically, for monitoring of intracranial pressure (ICP), our center largely follows international guidelines. [17] For children who died, we looked at the number of days after the head injury. We reviewed the specific neurosurgical intervention. For children who were admitted, we looked at the length of hospital stay.

Analytical Plan Categorical variables were represented in frequencies and percentages. Normality was assumed for continuous variables which were represented with mean and standard deviation (SD). Chi square tests were performed for categorical variables and independent sample t-test for continuous variables. Univariable logistic regression was performed to obtain the odds ratio (and 95% confidence intervals) for severe outcomes as defined by death, intubation and the need for neurosurgical intervention. Specifically, we stratified the analysis to study children aged less than 2 years old. We subsequently performed a multivariable logistic regression, adjusting for age and location of injury. Statistical significance was established at a p value of < 0.05. All statistical tests were performed using SPSS v19 (SPSS Inc, Chicago, Ill). We did not apply imputation or statistical models on missing values.

Ethics Approval was given by the SingHealth Centralised Institutional Review Board (CIRB) E, Paediatrics and mutually recognised by National Health Group Domain Specific Review Board (DSRB).

Results

A total of 1049 children met the inclusion criteria (Refer Figure 1). Among these, the mean age was 6.7 years (SD 5.2) with 268 (25.5%) children aged less than 2 years old. The demographics are detailed in Table 1. In this particular patient population, 501 patients (47.8%) underwent a computed tomography (CT), of which 260 (24.8%) had positive findings on the CT. These positive findings included focal intracranial bleeds, diffuse axonal injury (DAI) and skull fractures. 17 (1.6%) patients demised, of which 7 (0.7%) were pronounced dead in the EDs. 58 (5.5%) patients underwent neurosurgery. 52 (5.0%) children required emergency intubation in the ED for the concerns of low GCS or suspected raised ICP. (Table 1)

We did not have any missing information on the intent or causes of injuries. Falls remain the most common cause of head injuries (753, or 71.8%) (Table 2). Among the falls specifically, 393 (52.2%) occurred in the home. This was especially prominent among children aged less than 2 years old, of whom 227 (84.7%) had injuries attributed to falls and 182 (67.9%) occurred at home. The common objects included furniture (e.g. adult bed) and ground surface. With every meter increase in the height of the fall, the likelihood of sustaining a severe outcome was 1.4 times (95% CI 1.3-1.6). This was consistent across the individual severe outcomes of death (OR 1.5, 95% CI 1.3-1.7) and need for intubation (OR 1.5, 95% CI 1.3-1.7).

123 (11.7%) children suffered a head injury as a result of a motor vehicle crash. Among these, 67 (54.5%) were pedestrians, 24 (19.5%) were motor vehicle back passengers and 20 (16.3%) were cyclists. In this population, there was no statistically significant risk of severe outcomes among the pedestrians when compared to motor vehicle back passengers (OR 1.3, 95% CI 0.5 – 3.7). We did note, however, that among 56 road users (cyclists or occupants of motor vehicles), 42 or 75% of the children were not using helmets nor restraints (infant capsules, car booster seats or seat belts). 3 patients did not have complete records on the use of restraints.

Among the 17 children subject to non-accidental trauma, the mean age was 6.2 years (SD 6.4). 4 had a subdural hemorrhage (SDH), 1 had diffuse axonal injury (DAI), 1 had an extradural hemorrhage (EDH) and 1 child had an isolated skull fracture. 4 patients suffered a severe outcome (2 children died) and 11 patients required a hospital stay of more than 72 hours.

Among the 17 deaths the mean age was 4.9 years (SD 5.9) with the mean number of days between injury and death being 5.9 days (SD 11.6). Among these, 8 patients died within 24 hours of arrival in the ED.

Table 3 shows the univariable logistic regression on cause of injury associated with severe outcome. Compared to falls, motor vehicle crashes (OR 7.2, 95% CI 4.3-12.0) and non-accidental trauma (OR 5.8, 95% CI 1.8-18.6) were more likely to result in death, need for airway or neurosurgical intervention. This remained statistically significant when we stratified the analysis to patients under 2 years old. We performed a multivariable logistic regression comprising age, cause of injury and location of injury. The above two causes, as well as an injury occurring outside the home, remained statistically significant for poor outcome (Table 4).

Discussion

Our study showed that motor vehicle crashes and non-accidental trauma are associated with severe head injury outcomes. This association remained statistically significant after adjusting for age and the location of the injury. This should assist the ED physician in risk stratification when facing children with head injuries from various causes, alerting the need for early intervention and closer monitoring. Also, this allows for careful prioritization of injury prevention strategies.

In this study, we focused on head injuries. Even though various causes of injuries can result in different anatomical injuries, paediatric head injuries are particularly important because of the following: (i) Paediatric patients have a relatively larger head and are prone to head injuries, especially among the younger age groups (ii) Children are at a stage of rapid brain growth and neurocognitive development, therefore are especially sensitive to brain injuries, and (iii) Traumatic brain injuries result not only in death, but also life-long physical, emotional, financial and social sequelae on the patient, caregivers, family and society.

The causes of injuries among this patient population in Singapore are largely consistent with prior reports [16]. While falls are common, road traffic accidents tend to be associated with larger forces and more severe injuries. Our study showed that this effect was evident regardless of age or location of injury. In Singapore, it is mandatory for children riding bicycles on roadways to don helmets. It is also mandatory for children in motor vehicles to be appropriately restrained [18]. In this population of head injured children presenting to the emergency department, the compliance to road safety laws is still found wanting. This was recently similarly reported in the United States where only about half of the children with motor vehicle crash fatalities wore any child restraints [19]. Child safety programs initiated at the ED [20] have been reported and should be explored. Pedestrians, on the other hand, are known to be at high risk of severe injuries compared to other motorway users – This is especially applicable to older children who may not be supervised when crossing the roads.

In our patient population, the presence of abuse portended a more severe outcome, and a longer hospital stay. Non-accidental trauma in our country is diagnosed and managed along international standards [21]. These are confirmed at case conference, civil, family or criminal court proceedings, or by stated criteria, including multidisciplinary assessment [21]. Since they are associated with worse outcomes, they must therefore be promptly recognized by all first-line physicians who must also rapidly activate social help services and the corresponding law-enforcement agencies.

We chose to study those aged less than 2 years old, separately. This special group of young children is especially vulnerable to head injuries, the interventions (e.g. radiation from CT) imposed on them [22], and have non-specific complaints. Although young children tend to have closer supervision in public areas, they are most prone to injuries in the home, as evident in our results. Falls from adult beds, sofas and other furniture can result in traumatic brain injuries in this group. Child injury prevention strategies must therefore take an age-targeted approach. Although falls in the home were less likely to be associated with severe outcome, a greater awareness of the dangers at home would reduce the overall number of head injuries.

Of note, the CT rate in this study was particularly high (47.8%) because we had chosen to exclude children subject to lower forces of injuries, minor contusions, and those whose symptoms had resolved spontaneously while monitoring in the ED. We had previously reported that our CT rate (for overall paediatric head injuries) in one institution was closer to 1% [23].

We recognize the limitations of this study. Firstly, this study combined data between 2 tertiary institutions' trauma surveillance systems – there may have been differences in the details of documentation especially surrounding the object involved in the injury and the location. Secondly, the numbers of injuries secondary to road traffic accidents were relatively low in our population – this itself could be a result of legislature and increasing awareness, meaning that children who were appropriately restrained may have been protected from injuries, in the first place. Thirdly, we recognize that studying only head-injured children and their corresponding causes may result in certain differences from all-encompassing injury surveillance. We believe however, that this group warrants special attention and necessary action to reduce overall childhood mortality and morbidity. Finally, we were unable to obtain complete long-term follow up data in this study population which would have added value to the outcome assessment.

Childhood injuries are still an ever-growing problem in many parts of the world [24]. In this study, motor vehicle crashes and non-accidental trauma causes are particularly associated with poor outcomes among children with paediatric head injury. We look forward to extending this work to other centers in the Asian region, in the hope that a common platform for childhood injury surveillance will meet the current needs for robust surveillance, sharing of injury prevention strategies and evaluation of programs.

Contributors: CSL, CSY, FXY, CST, LN and OME contributed to the conception and design of the study, analysis and interpretation of data. CSL, CSY, FXY, TLP, and CST were directly involved in data acquisition. All the authors were involved in drafting of the article and revising it critically for important intellectual content. All authors have read and approved the final manuscript.

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Competing interests: None declared

Ethics approval: SingHealth Centralised Institutional Review Board (CIRB) E, Paediatrics and National Health Group Domain Specific Review Board (DSRB).

Data Sharing Statement: No additional data available

References

1. Korley FK, Kelen GD, Jones CM, et al. Emergency Department Evaluation of Traumatic Brain Injury in the United States, 2009-2010. J Head Trauma Rehabil, 2015 Sep 10 [Epub ahead of print]
2. Johnston BD and BE Ebel. Child injury control: trends, themes, and controversies. Acad Pediatr, 2013. **13**(6): p. 499-507.
3. Bray L. Parents' experiences of hope following a child's brain injury. Nurs Child Young People, 2015. **27**(7): p. 22-6.
4. Ransom DM, Vaughan CG, Pratson L, et al. Academic effects of concussion in children and adolescents. Pediatrics, 2015. **135**(6): p. 1043-50.
5. Brown EA, Kenardy J, Chandler B, et al., Parent-Reported Health-Related Quality of Life in Children With Traumatic Brain Injury: A Prospective Study. J Pediatr Psychol, 2015.
6. Levin HS and RR Diaz-Arrastia. Diagnosis, prognosis, and clinical management of mild traumatic brain injury. Lancet Neurol, 2015. **14**(5): p. 506-17.
7. Quayle KS, Powell EC, Mahajan P, et al. Epidemiology of blunt head trauma in children in U.S. emergency departments. N Engl J Med, 2014. **371**(20): p. 1945-7.
8. Daniels DJ, Clarke MJ, Puffer R, et al. High occurrence of head and spine injuries in the pediatric population following motocross accidents. J Neurosurg Pediatr, 2015. **15**(3): p. 261-5.
9. Nnadi MO, OB Bankole, and BG Fente. Motorcycle-Related Traumatic Brain Injuries: Helmet Use and Treatment Outcome. Neurosci J, 2015. **2015**: p. 696787.
10. Befeler AR, Daniels DJ, Helms SA, et al. Head injuries following television-related accidents in the pediatric population. J Neurosurg Pediatr, 2014. **14**(4): p. 414-7.
11. Cusimano MD and N Parker. Toppled television sets and head injuries in the pediatric population: a framework for prevention. J Neurosurg Pediatr, 2015: p. 1-10.
12. Cusimano MD, Cho N, Amin K, et al. Mechanisms of team-sport-related brain injuries in children 5 to 19 years old: opportunities for prevention. PLoS One, 2013. **8**(3): p. e58868.
13. Hinds T, Shalaby-Rana E, Jackson AM, et al. Aspects of abuse: abusive head trauma. Curr Probl Pediatr Adolesc Health Care, 2015. **45**(3): p. 71-9.
14. Ward A, Iocono JA, Brown S, et al. Non-accidental Trauma Injury Patterns and Outcomes: A Single Institutional Experience. Am Surg, 2015. **81**(9): p. 835-8.
15. Chong SL, Liu N, Barbier S, et al. Predictive modeling in pediatric traumatic brain injury using machine learning. BMC Med Res Methodol, 2015. **15**: p. 22.
16. Chong SL, Barbier S, Liu N, et al. Predictors for moderate to severe paediatric head injury derived from a surveillance registry in the emergency department. Injury, 2015. **46**(7): p. 1270-4.
17. Kochanek PM, Carney N, Adelson PD et al. *Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents--second edition.* Pediatr Crit Care Med, 2012. **13 Suppl 1**: p. S1-82.
18. http://statutes.agc.gov.sg/aol/search/display/view.w3p;ident=a098480b-5fbe-4841-b679-e397ebe31335;page=0;query=DocId%3A%22ba3acbce-2ce4-4b3f-8011-5bfae19cfbbc%22%20Status%3Apublished%20Depth%3A0;rec=0#pr74-he-. (Accessed 30th October 2015)
19. Lee LK, CA Farrell, and R. Mannix. Restraint use in motor vehicle crash fatalities in children 0 year to 9 years old. J Trauma Acute Care Surg, 2015. **79**(3 Suppl 1): p. S55-60.
20. Kiley K, Damian F, MacClaren W, et al., A computerized child passenger safety screening program in the emergency department. Pediatr Emerg Care, 2014. **30**(9): p. 631-5.

21. Maguire SA, Kemp AM, Lumb RC, et al., Estimating the probability of abusive head trauma: a pooled analysis. Pediatrics, 2011. **128**(3): p. e550-64.
22. Kuppermann N, Holmes JF, Dayan PS, et al. Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet, 2009. **374**(9696): p. 1160-70.
23. DW Thiam, Yap SH, and Chong SL. Clinical Decision Rules for Paediatric Minor Head Injury: Are CT Scans a Necessary Evil? Ann Acad Med Singapore 2015;44:335-41
24. Peden M, Oyegbite K, Ozanne-Smith J, et al. World report on child injury prevention. 2008: World Health Organization.

Figure 1

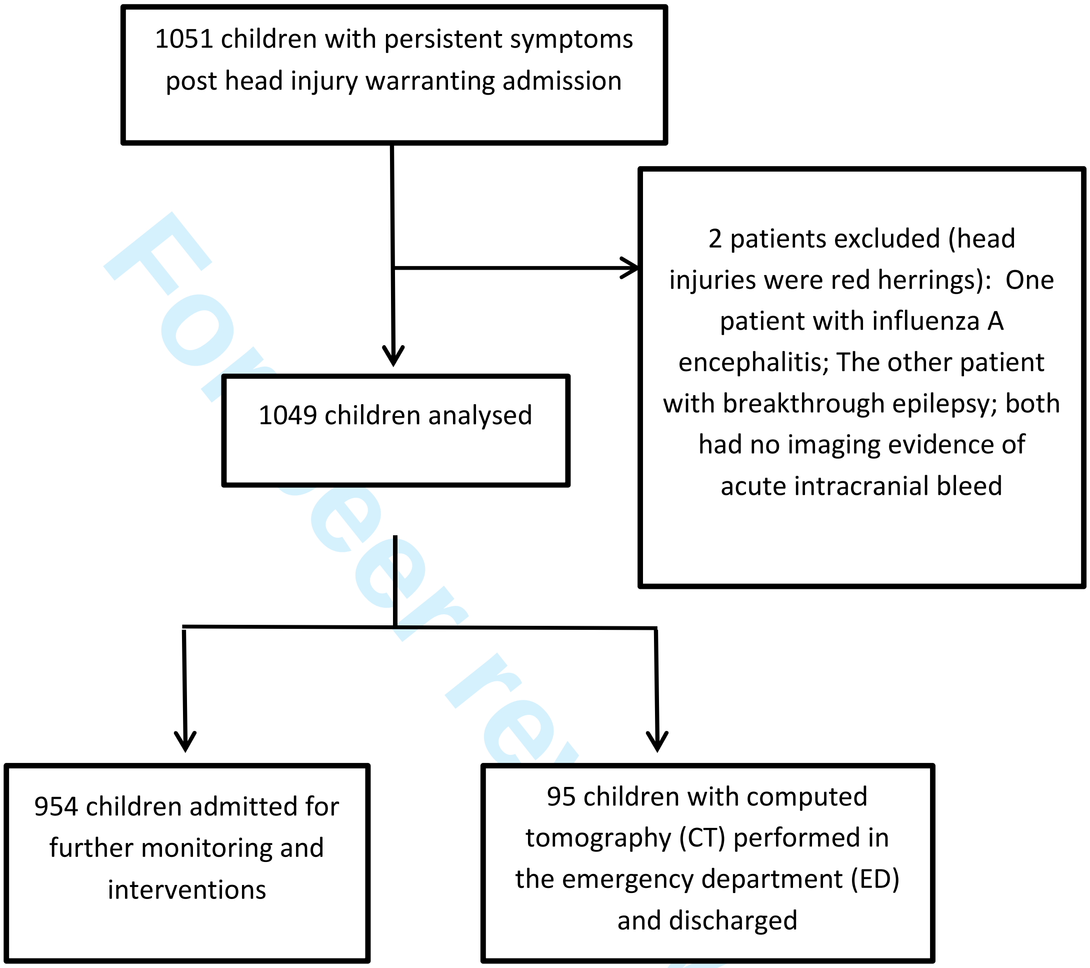
1051 children with persistent symptoms post head injury warranting admission
2 patients excluded (head injuries were red herrings): One patient with influenza A encephalitis; The other patient with breakthrough epilepsy; both had no imaging evidence of acute intracranial bleed
1049 children analysed
954 children admitted for further monitoring and interventions
95 children with computed tomography (CT) performed in the emergency department (ED) and discharged

Table 1: Patient characteristics, patient demographics and clinical outcomes

Patient age, mean (SD)	6.7 (5.2)
Gender (males), n (%)	661 (63.0)
CT brain performed, n (%)	501 (47.8)
Positive finding on CT brain, n (%)	260 (24.8)
Subdural hemorrhage (SDH)	75 (7.1)
Extradural hemorrhage (EDH)	52 (5.0)
Intracerebellar hemorrhage	27 (2.6)
Diffuse Axonal Injury (DAI)	26 (2.5)
Subarachnoid hemorrhage (SAH)	24 (2.3)
Brainstem/uncal herniation	5 (0.5)
Pneumocephalus	4 (0.4)
Skull fracture	176 (16.8)
ED disposition	
Intensive Care Unit	75 (7.1)
High Dependency Unit	68 (6.5)
General Ward	807 (76.9)
Morgue	7 (0.7)
Hospital length of Stay	
Less than 24 hours	644 (61.4)
24-48 hours	196 (18.7)
48-72 hours	61 (5.8)
More than 72 hours	148 (14.1)
Death, n (%)	17 (1.6)
Emergency Intubation, n (%)	52 (5.0)
Neurosurgical intervention, n (%)	58 (5.5)
Type of neurosurgical intervention, n (%)	
Monitoring of intracranial pressure	47 (4.5)
Evacuation of intracranial bleed	8 (0.8)
Elevation of skull fracture	6 (0.6)

Table 2: Causes involved in Injury

	All patients (n=1049)	Children < 2 years (n = 268)
Primary Cause of injury, n (%)		
Fall	753 (71.8)	227 (84.7)
MVC	123 (11.7)	10 (3.7)
Sports	64 (6.1)	0 (0.0)
Interpersonal violence	24 (2.3)	0 (0.0)
Non-accidental trauma	17 (1.6)	7 (2.6)
Others	68 (6.5)	24 (9.0)
If fall, height (m), mean (SD)	0.7 (2.0)	0.6 (1.0)
If Motor Vehicle Crash		
Pedestrian	67 (54.5)	0 (0.0)
Cyclist	20 (16.3)	0 (0.0)
Motor vehicle front passenger	9 (7.3)	3 (30.0)
Motor vehicle back passenger	24 (19.5)	7 (70.0)
Motorbike rider/pillion	3 (2.4)	0 (0.0)
Location of injury		
Home	430 (41.0)	199 (74.3)
School/Child care centers	139 (13.3)	3 (1.1)
Public Places	141 (13.4)	21 (7.8)
Roadways	137 (13.1)	9 (3.4)

Table 3: Univariable Logistic Regression for Cause of Injury predicting for severe outcome

Cause of injury	Odds Ratio	95% CI	p value
Motor Vehicle Crash	7.2	4.3 - 12.0	< 0.001
Sports	0.6	0.1 - 2.6	0.498
Non Accidental Trauma	5.8	1.8 - 18.6	0.003
Others	1.5	0.6 - 3.9	0.417
For Children < 2 years old			
Motor Vehicle Crash	31.4	7.3-134.0	< 0.001
Non Accidental Trauma	12.6	2.1-76.4	0.006
Others	4.5	1.1-18.7	0.039

*Taking fall as the reference for cause of injury

Table 4: Multivariable Logistic Regression for Age, Cause of Injury and Location

	Adjusted Odds Ratio	95% CI	p value
Cause of Injury			
Motor Vehicle Crash	**6.0**	**3.3-10.6**	**< 0.001**
Sports	0.6	0.1-2.5	0.461
Non Accidental Trauma	**6.7**	**2.0-21.2**	**0.002**
Others	1.3	0.5-3.4	0.626
Age	1.0	0.9 – 1.0	0.057
Injury Outside the Home	**2.4**	**1.3-4.7**	**0.007**

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	6 (We included all patients who fit the criteria as explained under Methods)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6

		(*d*) If applicable, explain how loss to follow-up was addressed	Not applicable
		(*e*) Describe any sensitivity analyses	6,14,15
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	12
		(b) Give reasons for non-participation at each stage	12
		(c) Consider use of a flow diagram	12
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,13
		(b) Indicate number of participants with missing data for each variable of interest	7
		(c) Summarise follow-up time (eg, average and total amount)	13
Outcome data	15*	Report numbers of outcome events or summary measures over time	7,13,15
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15
		(*b*) Report category boundaries when continuous variables were categorized	13
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7,15
Discussion			
Key results	18	Summarise key results with reference to study objectives	8,9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8,9
Generalisability	21	Discuss the generalisability (external validity) of the study results	8,9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.