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Epidemiology of Paediatric Head Injuries – A Pan Asian Trauma Outcome Study (PATOS) Collaboration

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Epidemiology of Paediatric Head Injuries – A Pan Asian Trauma Outcome Study (PATOS) Collaboration

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ABSTRACT

Objective We aim to study the epidemiology of paediatric head injuries among participating centres in the Pan Asian Trauma Outcome Study (PATOS) and the association between mechanism of injury and severe outcomes.

Design and Setting We performed a retrospective review of medical records among emergency departments (EDs) and paediatric offices of eight PATOS centres, from September 2014 – August 2015.

Participants We included children < 16 years old who presented within 24 hours of head injury and who were admitted for observation or who required a computed tomography (CT) of the brain from the ED. We excluded children with known coagulopathies, neurological co-morbidities or prior neurosurgery. We reviewed the mechanism, location and object involved in each injury, and the patients' physical findings on presentation.

Outcomes Primary outcomes were death, endotracheal intubation or neurosurgical intervention. Secondary outcomes included hospital and ED length of stay.

Results 1438 children were analysed. 953 children (66.3%) were male and the median age was 5.0 years (IQR 1.0-10.0). Falls were the most common mechanism of injury (957 children, 66.6%), particularly among children less than 2 years old (344, 82.9%). Traffic injuries accounted for 310 patients with head injuries (21.6%). In this study, 143 children (9.9%) had a Glasgow coma scale (GCS) of < 8 and 474 (33.0%) had positive

CT findings. 55 children (3.8%) died, 115 (8.0%) underwent neurosurgical intervention and 169 (11.8%) required endotracheal intubation. After adjusting for age and gender, traffic injuries (OR 6.00, 95% CI 4.32-8.33) and child abuse (OR 8.39, 95% CI 2.90-24.29) were associated with severe outcomes.

Conclusions Among children with head injuries, traffic injuries and child abuse are independently associated with death, the need for endotracheal intubation and neurosurgery. This collaboration among Asian centres holds potential for future prospective childhood injury surveillance.

Keywords: Traumatic Brain Injury; Paediatrics; Non-accidental Injury; Neurosurgery

Article Summary

Strengths

- This study by the Pan Asian Trauma Outcomes Study (PATOS) is a first effort to bring together paediatric head injury clinical data from different countries in Asia
- Data were obtained using a common electronic platform

Limitations

- National-level data with details of injuries and clinical outcomes are not available in many countries in Asia, where trauma databases are currently being established

INTRODUCTION

Injuries continue to threaten the wellbeing of children, worldwide. Despite the progress made in injury control,[1] childhood injuries remain a regrettable source of disability and premature death. In Asia, the problem is exacerbated by inadequate surveillance in many countries. According to WHO autopsy reports, up to a quarter of trauma deaths occurred in children younger than 15 years old.[2] These were dominated by transport-related injuries in many parts of Asia and Africa, where fatalities and injuries from road traffic injuries are increasing.[3]

Paediatric head injuries are anatomically critically important because of the high mortality risk, and among survivors, the potential for lifelong neurological devastation.[4-5] A child who survives a severe traumatic brain injury may be subject to years of lost productivity and compromised quality of life. Severe traumatic brain injury slows down processing speed and adaptive functioning in the long term,[6] and may increase the risk for attention deficit hyperactivity disorder.[7] These irreversible effects are keenly felt by the child, the family and society at large.

In this multicentre study, we aim to: (1) Examine the injury epidemiology of children presenting with head injuries to participating centres in the Pan Asian Trauma Outcomes Study (PATOS), and (2) Study the association between the mechanism of injury and severe outcomes as defined by death, the need for intubation and neurosurgical intervention.

MATERIALS AND METHODS

Design and Setting This was a retrospective chart review among the participating centres of PATOS, from September 2014 to August 2015. Centres participating in this study are from the following countries: Singapore, Pakistan, India, South Korea, China, Malaysia, and Vietnam. (Figure 1) Countries were grouped into high, upper-middle and lower-middle income economies by per capital gross national income (GNI) based on the World Bank classification.[8]

Ethics approval was obtained for each centre, with the coordinating centre obtaining approval from the Singapore SingHealth Centralised Institutional Review Board (CIRB, E).

Patients We included children < 16 years old who presented to participating emergency departments (EDs) and paediatric offices within 24 hours of the head injury. Patients with all severities of head injury who were admitted, or who underwent observation in the emergency department and required a computed tomography (CT), were included. Patients with known coagulopathies, prior neurosurgery, neurological deficits or developmental delay were excluded. We also excluded trivial injuries in children whose symptoms had resolved while in the ED and who did not clinically warrant further monitoring or investigations. Patients with a low Glasgow Coma Scale (GCS) score were confirmed to have altered consciousness due to an intracranial injury, as defined by an abnormal CT scan consisting of an intracranial bleed, cerebral oedema, diffuse axonal injury or skull fracture. In the case of death, the post mortem must have proven an intracranial injury for the patient to be included.

Variables: The primary mechanism of injury was collected for all patients, including the following: Fall, road traffic injury, sports injury and assault (specifically, we differentiated child abuse cases by caregivers from other forms of assault that occurred in schools or by strangers). For falls, the height of the fall was documented. In the case of road traffic injuries, the injured person type (pedestrian, cyclist, motor vehicle passenger, motorbike user) and the use of restraints (helmets or car seats) were collected. The object involved in the trauma and the location of occurrence (home, school, public road, and playground) were also recorded. We followed the International Classification of External Causes of Injury (ICECI) classification [9] and established common data points across the PATOS centres. The patient's presenting GCS and physical examination findings were documented.

Main outcome measures: The primary outcome measures were: Death, need for endotracheal intubation or neurosurgical intervention. We also reviewed the hospital and ED length of stay.

Analysis: Categorical data were presented as frequencies and percentages. Continuous data were presented using means (with standard deviation) or medians (with interquartile ranges, IQR), depending on normality of distribution. We presented all children with head injuries and children < 2 years separately. The latter group is important because younger children are preverbal, developing ambulatory skills and are predisposed to different mechanisms of injury. Measures of association between the outcomes and categorical variables were analysed using Chi Square test or Fisher's Exact test, while that of continuous variables were analysed using either student t-test or Mann Whitney U. Statistical significance was established at $p < 0.05$. We presented p values and 95% confidence intervals (CI) for each point estimate. A univariable logistic regression was performed to establish the association between the mechanism of injury and severe in-hospital outcomes. In the multivariable logistic regression, we adjusted for age and gender. Data were analysed using IBM SPSS Statistics Version 19.0. SPSS Inc, Chicago.

RESULTS

A total of 1438 children met the inclusion criteria. 953 children (66.3%) were male and the median age was 5.0 years (IQR 1.0-10.0). Among these, 261 (18.2%) were infants, 512 (35.6%) were 1-5 years' old, 328 (22.8%) were 6-10 years' old and 337 (23.4%) were older than 10 years old. Patient demographics and primary mechanisms of injury are elaborated in Table 1. (The breakdown of patient contribution by individual hospital is described in the Supplementary Table.) We did not have missing data for primary mechanism of injury.

Falls were the most common mechanism. Specifically among children aged less than 2 years old, most of the head injuries were a result of falls (344,or 82.9%) that occurred in the home (299, or 72.0%). Among children involved in traffic injuries, the majority of these were pedestrian injuries (96 children, 31.0%). Among non-pedestrian traffic injuries (n=214), only 29 children (13.5%) were restrained (referring to the use of baby convertibles, child car seats, seat belts or helmets), 48 (22.4%) were not restrained and 137 children (64.0%) did not have documentation on the use of restraints. Among vehicle occupant injuries, 29 (36.3%) involved airbag activations during collision. Among children who were on motorcycles, only 14 (17.1%) were documented to be wearing helmets.

Table 2 shows the physical examination findings and the in-hospital outcomes for children in our study. Eight-five (5.9%) patients were documented to have polytrauma, among whom intra-thoracic and long bone fractures were the most common (each 27 patients, or 1.9%). 279 children (19.4%) required admission to higher acuity care (intensive care or high dependency) after stabilization in the ED. Among 115 children who underwent neurosurgery, 75 (65.2%) had a craniotomy, 55 (47.8%) had their intracranial bleeds evacuated and 17 (14.8%) underwent elevation of depressed skull fractures. Among the 55 children who died, the median days of death post injury was 3 days (IQR 1.0-7.0). 19 children (1.3%) who died were documented to have concomitant polytrauma, mainly intra-thoracic injuries (7 patients, or 0.5%).

Specifically among the children subject to child abuse, 5 (33.3%) required intubation, 4 (26.7%) received neurosurgical intervention and 2 children (13.3%) died. The median age of the abused child was 7 years (IQR 0.0-14.0).

Table 3 elaborates on the primary mechanism of injury when stratifying by GNI. Falls comprised a larger proportion (745, or 74.5%) of paediatric head injuries seen in the EDs of high-income countries. Traffic injuries were common throughout all countries. The 'Others' mechanism (23 children, or 1.6%) comprised primarily of cases where the mechanism of injuries could not be obtained or categorized from retrospective chart review. Severe outcomes stratified by per capita gross national income (GNI) are shown in Table 3.

Traffic injuries and injuries with the intent of child abuse were significantly associated with the severe outcomes of death, endotracheal intubation or need for neurosurgery (Table 4). This remained statistically significant after adjusting for age and gender. Among children who were involved in a traffic injury, we did not demonstrate a significant association between motorcycle users (unadjusted OR 0.85, 95% CI 0.50 – 1.47, p=0.57), nor pedestrian injuries (unadjusted OR 1.20, 95% CI 0.72 – 1.99, p=0.48) and severe outcomes.

DISCUSSION

In our study, a significant number (415, or 28.9%) of head injuries occurred among preverbal children. Falls were the most common mechanism of injury, particularly among children < 2 years' old. Traffic injuries, while less common than falls, were significantly associated with death and severe in-hospital outcomes.

Our study reinforces the findings of a national study from the United Kingdom.[10] Falls among preverbal children occur mainly in the home, involving ground surfaces and furniture. Although most falls occur from a low height, they still result in physical injuries and urgent care attendances. This suggests the need to relook at home safety and caregiver awareness.

The association between traffic injuries and severe outcomes emphasizes that road traffic injuries remain a pressing public health concern in Asia. There was an extremely low rate of documented restraint use in this study. This emphasizes the need for better injury documentation and surveillance, and improved traffic law enforcement.[11-12] Among all road users, motorcycle riders and pillions are at high risk for severe injuries.[13] In many countries in Asia, families tend to overload motorcycles, with the children seldom donning helmets.[14] Adolescents are also known to engage in high risk behaviour while racing motorcycles.[15-17] In our study, we were unable to demonstrate a significant association between motorcycle users and poor outcomes. The latter could have been due to the relatively smaller number of motorcycle injuries accrued from this 1-year retrospective study.

Our findings on child abuse build on previous reports that such injuries are associated with death and long term neurological compromise.[18-19] Early clinical recognition is tantamount for holistic care of the child,[20] and such cases must be readily identified by emergency medicine providers acting as advocates for this vulnerable population. In our study, we recognize that child abuse cases may be under-diagnosed and under-reported, due to varying definitions and protocols in Asia. Moving forward, we recognize the need to gain common ground, including the multi-disciplinary assessment required for accurate case definitions.[21]

When categorizing by GNI, a larger proportion of the paediatric head injuries were attributed to falls in the PATOS centres from high-income countries. We postulate that this may be due to differences in health care delivery – with lower acuity injuries from falls more likely to present to the EDs of high income compared to middle income countries. There were more deaths and severe in-hospital outcomes among middle-income countries, despite a smaller total number of injuries. The latter could be attributed to a higher proportion of traffic injuries in these countries. We did not collect data on interventional strategies for traumatic brain injuries in this study.

CT scan rates here appear relatively high compared to other studies.[22] This was likely because we excluded mild cases that had symptom resolution. In our study, 258 children (17.9%) had a GCS of 13 and below. There was also a positive CT rate of 33.0% (474 out of 1438 patients) and a positive event rate (death, intubation or neurosurgery) of 15.4% (222 out of 1438 patients).

We recognize the following limitations of this study. This retrospective design could not preclude bias with medical record review. Investigators were not blinded to the aims of the study. Details surrounding the use of restraints were missing in some countries that do not have routine surveillance data. The impact of different countries' traffic laws on the rate and types of injuries were not explored here. We also recognize that hospital-based studies are limited and should extend to more systematic surveillance in each country that can translate into practical safety measures.[23] Finally, we were not able to report out-of-hospital outcomes because of the variability in patient follow-up between centres.

To our knowledge, this is the first attempt to collate paediatric head injury surveillance data from different centres in Asia. The data collection was performed in a uniform fashion using a combined electronic data form with the variables explored a priori for common understanding. Importantly, this paves the way for further prospective surveillance studies to be performed among the PATOS centres.

After infancy, childhood injuries remain high on the list of killers in various parts of Asia.[24] WHO has recommended strengthening the role of the health sector in evidence-based advocacy and service provision for victims of such trauma.[25] Continual collaboration between countries hold promise to power studies that involve severe childhood injuries, and allow for the sharing of surveillance infrastructure.

Contribution: CSL, URK, IS, and MEHO made substantial contributions to the conception and design of the work. CSL, URK, IS, SJS, WQ, SFJ, HTAQ, and CSY contributed in the data acquisition. CSL, URK, IS, CSY and MEHO contributed in the analysis and interpretation of the data. All authors revised it critically for important intellectual content and approved of the final version to be published.

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Competing interests: The authors have no conflict of interest to declare.

Data sharing statement: There is no additional unpublished data from this study available currently.

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Figure 1. Map of participating Pan Asian Trauma Outcome Study (PATOS) centres

Table 1. Patient Demographics, Intent and Mechanism of Injury

Patient Demographics		
Age, median (IQR)	5.0 (1.0-10.0)	
Male Gender, n (%)	953 (66.3)	
By Per Capita GNI*, n (%)		
High Income	1000 (69.5)	
Upper Middle Income	208 (14.5)	
Lower Middle Income	230 (16.0)	
Intent and Primary mechanism of injury		
	All N=1438	Children < 2 years' old N=415
Intent of Injury, n (%)		
Unintentional	1377 (95.8)	397 (95.7)
Assault – Child Abuse	15 (1.0)	6 (1.4)
Assault – Others	14 (1.0)	1 (0.2)
Intentional Self-Harm	1 (0.1)	0 (0.0)
Unknown	31 (2.2)	11 (2.7)
Primary Mechanism of Injury, n (%)		
Fall	957 (66.6)	344 (82.9)
Traffic Injury	310 (21.6)	46 (11.1)
Struck by Object or Person	117 (8.1)	15 (3.6)
Sports Injury	25 (1.7)	0 (0.0)
Gun Shot	2 (0.1)	0 (0.0)
Others	23 (1.6)	10 (2.4)
Among Traffic Injuries: Type of Road User, n (%)		
Pedestrian	96 (31.0)	10 (21.7)
Motorcyclist	82 (26.5)	7 (15.2)
Vehicle Occupant	80 (25.8)	26 (56.5)
Pedal Cyclist	48 (15.5)	3 (6.5)
Among Falls: Height of Fall in meters, median (IQR)	0.5 (0.0-1.0)	0.7 (0.5-1.0)
Object involved in Injury, n (%)		
Ground Surface	381 (26.5)	87 (21.0)
Land Transport/Means of Land Transport	249 (17.3)	39 (9.4)
Furniture	222 (15.4)	128 (30.8)
Building Component or Fitting	195 (13.6)	60 (14.5)
Animal, Plant or Person	145 (10.1)	34 (8.2)
Equipment for Sports or Recreational Activity	68 (0.5)	1 (0.2)
Infant or Child Care Product	51 (3.5)	34 (8.2)
Location of Injury, n (%)		
Home	650 (45.2)	299 (72.0)
Street, Highway or Road	319 (22.2)	43 (10.4)
School	179 (12.4)	10 (2.4)
Public Playground or Amusement Park	69 (4.8)	8 (1.9)
Sports or Athletics Areas	51 (3.5)	1 (0.2)

*GNI – Gross National Income [8]

Table 2. Physical Examination and Outcome Measures

	All Children N = 1438	Children < 2 years' old N = 415
Presenting GCS, n (%)		
GCS 14-15	1179 (82.0)	342 (82.4)
GCS 8-13	115 (8.0)	24 (5.8)
GCS < 8	143 (9.9)	48 (11.6)
Physical Examination Findings, n (%)	525 (36.5)	172 (41.4)
Contusion or Hematoma	303 (21.1)	89 (21.4)
Abrasion	108 (7.5)	33 (8.0)
Palpable Skull Fracture	108 (7.5)	15 (3.6)
Laceration		
CT Brain Performed*, n (%)	847 (58.9)	187 (45.1)
Positive CT brain Findings	474 (33.0)	151 (36.4)
Endotracheal Intubation, n (%)	169 (11.8)	55 (13.3)
Blood Products Required, n (%)	78 (5.4)	25 (6.0)
ED LOS (in hours), median (IQR)	2.3 (1.4-5.0)	2.7 (2.0-4.2)
ED Disposition, n (%)		
ICU/HD^ Admissions	279 (19.4)	88 (21.2)
Transfer to Operating Theatre	35 (2.4)	2 (0.5)
Transfer to Other Medical Centres	26 (1.8)	8 (1.9)
Neurosurgical Intervention, n (%)	115 (8.0)	31 (7.5)
Death, n (%)	55 (3.8)	25 (6.0)
Hospital LOS (in days) for Admitted Patients, median (IQR)	1.0 (1.0-3.0)	1.0 (1.0-2.0)

*CT – Computed Tomography
#LOS – Length of Stay
^ICU/HD – Intensive Care Unit/High Dependency

Table 3. Mechanism of Injury and Severe Outcomes by Gross National Income (GNI)

Primary Mechanism of injury					
	Lower Middle Income, n (%)	**Upper Middle Income, n (%)**	**High Income, n (%)**	**Total, n (%)**	**p value**
Fall	122 (53.0)	90 (43.3)	745 (74.5)	957 (66.6)	p<0.001
Traffic Injury	94 (40.9)	107 (51.4)	109 (10.9)	310 (21.6)	
Struck by Person or Object	5 (2.2)	8 (3.8)	104 (10.4)	117 (8.1)	
Sports Injury	2 (0.9)	1 (0.5)	22 (2.2)	25 (1.7)	
Stab or Cut	0 (0.0)	0 (0.0)	4 (0.4)	4 (0.3)	
Gun Shot	2 (0.9)	0 (0.0)	0 (0.0)	2 (0.1)	
Others	5 (2.2)	2 (1.0)	16 (1.6)	23 (1.6)	
Total	230	208	1000	1438	
Severe Outcomes					
Endotracheal Intubation	49 (21.4)	97 (46.6)	23 (2.3)	169 (11.8)	p<0.001
Neurosurgical Intervention	20 (10.4)	71 (34.1)	24 (2.4)	115 (8.2)	p<0.001
Death	13 (5.7)	35 (16.8)	7 (0.7)	55 (3.8)	p<0.001

Table 4. Logistic Regression for Death, Intubation or Neurosurgical Intervention

	Unadjusted OR (95% CI)	p value	**Adjusted OR** (95% CI)	p value
Age	0.99 (0.96-1.02)	p=0.404	0.94 (0.91-0.97)	p<0.001
Male Gender	1.61 (1.17-2.23)	p=0.004	1.65 (1.17-2.32)	p=0.004
Traffic Injury	4.75 (3.51-6.44)	p<0.001	6.00 (4.32-8.33)	p<0.001
Intent: Assault – Child Abuse	4.91 (1.76-13.69)	p=0.002	8.39 (2.90-24.29)	p<0.001

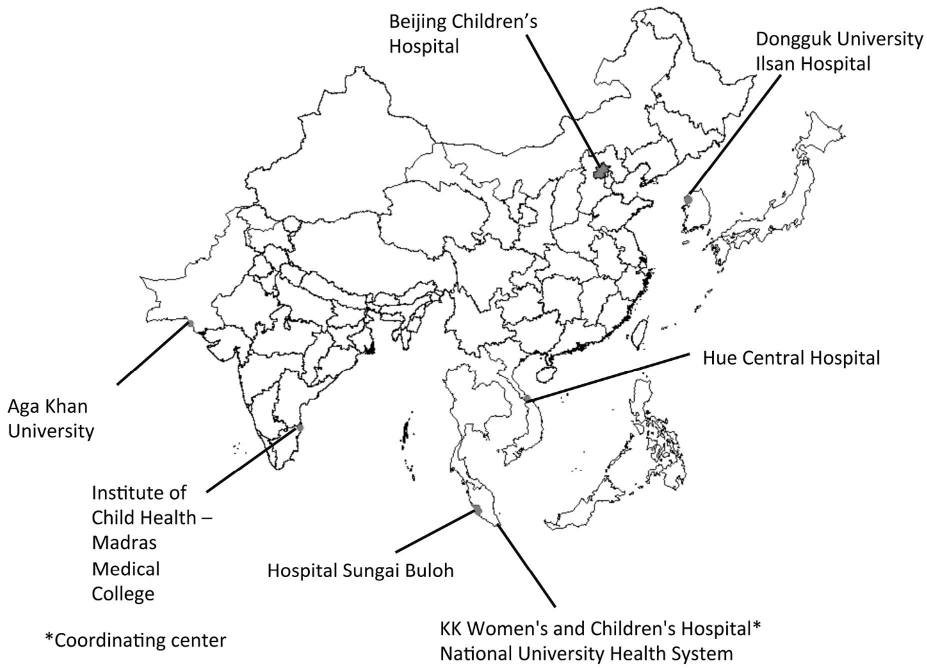

Figure 1. Map of participating Pan Asian Trauma Outcomes Study (PATOS) centres

198x139mm (300 x 300 DPI)

Supplementary Table. Number of Patients Analysed from each Participating PATOS Centre

Lower Middle Income	n (%)	Upper Middle Income	n (%)	High Income	n (%)
Aga Khan University (Pakistan)	101 (7.0)	Beijing Children's Hospital (China)	137 (9.5)	Dongguk University Ilsan Hospital (South Korea)	185 (12.9)
Hue Central Hospital (Vietnam)	84 (5.8)	Hospital Sungai Buloh (Malaysia)	71 (4.9)	KK Women's and Children's Hospital (Singapore)	628 (43.7)
Institute of Child Health – Madras Medical College (India)	45 (3.1)			National University Health System (Singapore)	187 (13.0)
Total	230 (16.0)	Total	208 (14.5)	Total	1000 (69.5)

PATOS – Pan Asian Trauma Outcome Study

Countries are categorised by GNI – Gross National Income [8]

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 6-7
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	6-7
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	8
Objectives	3	State specific objectives, including any prespecified hypotheses	8
Methods			
Study design	4	Present key elements of study design early in the paper	9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	9-10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	9
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-10
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	9-10
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10-11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10-11
		(*b*) Describe any methods used to examine subgroups and interactions	10-11
		(*c*) Explain how missing data were addressed	11

		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	11,22

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	11
		(b) Give reasons for non-participation at each stage	(Epidemiology study, all who fit inclusion criteria, Page 9-10)
		(c) Consider use of a flow diagram	As above
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12, 22-24
		(b) Indicate number of participants with missing data for each variable of interest	11
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	13
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	13,25
		(*b*) Report category boundaries when continuous variables were categorized	13.25
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11,12, 22-24
Discussion			
Key results	18	Summarise key results with reference to study objectives	13-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16

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	17

*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 Retrospective Review of Paediatric Head Injuries in Asia – A Pan Asian Trauma Outcomes Study (PATOS) Collaboration

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A Retrospective Review of Paediatric Head Injuries in Asia – A Pan Asian Trauma Outcomes Study (PATOS) Collaboration

Title Page

A Retrospective Review of Paediatric Head Injuries in Asia – A Pan Asian Trauma Outcomes Study (PATOS) Collaboration

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ABSTRACT

Objective We aim to examine the mechanisms of head-injured children presenting to participating centres in the Pan Asian Trauma Outcomes Study (PATOS) and to evaluate the association between mechanism of injury and severe outcomes.

Design and Setting We performed a retrospective review of medical records among emergency departments (EDs) of eight PATOS centres, from September 2014 – August 2015.

Participants We included children < 16 years old who presented within 24 hours of head injury and were admitted for observation or required a computed tomography (CT) of the brain from the ED. We excluded children with known coagulopathies, neurological co-morbidities or prior neurosurgery. We reviewed the mechanism, location and object involved in each injury, and the patients' physical findings on presentation.

Outcomes Primary outcomes were death, endotracheal intubation or neurosurgical intervention. Secondary outcomes included hospital and ED length of stay.

Results 1438 children were analysed. 953 children (66.3%) were male and the median age was 5.0 years (IQR 1.0-10.0). Falls predominated especially among children younger than 2 years (82.9%), while road traffic injuries were more likely to occur among children 2 years and above compared to younger children (25.8% vs 11.1%). Centres from upper and lower middle-income countries were more likely to receive head injured children from road traffic injuries compared to those from high-income countries

(51.4% and 40.9%, vs 10.9%, p<0.0001) and attended to a greater proportion of children with severe outcomes (58.2% and 28.4%, vs 3.6%, p<0.0001). After adjusting for age, gender, intent of injury and gross national income, traffic injuries (adjusted OR 2.183, 95%CI 1.448-3.293) were associated with severe outcomes, as compared to falls.

Conclusions Among children with head injuries, traffic injuries are independently associated with death, endotracheal intubation and neurosurgery**.** This collaboration among Asian centres holds potential for future prospective childhood injury surveillance.

Keywords: traumatic brain injury; child; non-accidental Injury; neurosurgery

Article Summary

Strengths

- In this pioneer collaboration, mechanisms of head injury and patient outcomes were compared between diverse centres in Asia.
- Data were obtained through a common electronic platform using a standardised form.

Limitations

- Heterogeneity in trauma documentation exists among different centres.
- We presented hospital-based clinical data because national data of this nature are not available in many countries in Asia, where trauma databases are being established.

INTRODUCTION

Childhood injury remains a regrettable source of premature death and disability worldwide. Despite the progress made in injury control, the scale of paediatric trauma remains significant.[1] According to WHO autopsy reports, up to a quarter of deaths from external causes occurred in children younger than 15 years old.[2] These were dominated by transport-related injuries in many parts of Asia and Africa,[2] where fatalities and injuries from road traffic injuries are increasing.[3]

Paediatric head injuries are critically important because of the high mortality risk.[4] Among survivors, the potential for lifelong neurological devastation could mean years of lost productivity, compromised quality of life and dependence on others for activities of daily living.[5] Severe traumatic brain injury slows down processing speed and adaptive functioning in the long term.[6,7] These irreversible effects are keenly felt by the child, the family and society at large.

A significant proportion of severe paediatric head injuries occur in Asia, yet surveillance in this region remains inadequate. In this multicentre study, we aim to: (1) Examine the injury epidemiology of children presenting with head injuries to participating centres in the Pan Asian Trauma Outcomes Study (PATOS), and (2) Study the association between the mechanism of injury and severe outcomes as defined by death, the need for endotracheal intubation and neurosurgical intervention.

MATERIALS AND METHODS

Design and Setting This was a retrospective chart review among the participating centres of PATOS, from September 2014 to August 2015. PATOS is an Asian clinical research network with data collection based on a multicentre trauma registry.[8] Centres participated in this study on a voluntary basis and are from the following countries: Singapore, Pakistan, India, South Korea, China, Malaysia and Vietnam. (Figure 1) Countries were grouped into lower middle, upper middle and high-income economies by per capital gross national income (GNI) based on the World Bank classification.[9] The data collection was performed in a uniform fashion using a standardised electronic data form with the variables explored a priori for common understanding.

Ethics approval was obtained for each centre, with the coordinating centre obtaining approval from the Singapore Singhealth Centralised Institutional Review Board (CIRB, E).

Patients We included children < 16 years old who presented to participating emergency departments (EDs) within 24 hours of head injury. Patients with all severities of head injury who were admitted, or who underwent observation in the emergency department and required a computed tomography (CT), were included. Patients with known coagulopathies, prior neurosurgery, neurological deficits or developmental delay were excluded. We chose to exclude the above patients because of increased complexity in neurological assessment and different thresholds for investigations and hospitalisation. We also excluded trivial injuries in children whose symptoms had resolved while in the

ED and who did not clinically warrant further monitoring or investigations. Patients with a low Glasgow Coma Scale (GCS) score (13 and below) or with persistence of symptoms including headache or vomiting underwent a CT head scan (at the physician's discretion). In cases of polytrauma, we confirmed that the low GCS was due to head trauma, as evidenced by a positive CT consisting: intracranial bleed, cerebral oedema, diffuse axonal injury or skull fracture. In the case of death, the post mortem must have proven an intracranial injury for the patient to be included.

Variables: The primary mechanism of injury was collected for all patients, including the following: Fall, road traffic injury, sports injury and assault (specifically, we differentiated child abuse cases by caregivers from other forms of assault that occurred in schools or by strangers). For falls, the height of the fall was documented. In the case of road traffic injuries, the injured person type (pedestrian, cyclist, motor vehicle passenger, motorbike user) and the use of restraints (helmets, child car seats or seat belts) were collected. The object involved in the trauma and the location of occurrence (home, school, public road, sports area or playground) was also recorded. We followed the International Classification of External Causes of Injury (ICECI) classification [10] and established common data points across the PATOS centres. The patient's presenting GCS and physical examination findings were documented.

Main outcome measures: The primary outcome measures were: Death, need for endotracheal intubation or neurosurgical intervention.[11] We also reviewed the hospital and ED length of stay.

Analysis: Categorical data were presented as frequencies and percentages. Continuous data were presented using means (with standard deviation) or medians (with interquartile ranges, IQR), depending on normality of distribution. We presented children 2 years and older, versus children < 2 years separately. The latter group is important because younger children are preverbal, developing ambulatory skills and are predisposed to different mechanisms of injury.[12] Measures of association between the outcomes and categorical variables were analysed using Chi Square test or Fisher's Exact test, while that of continuous variables were analysed using either student t-test or Mann Whitney U depending on normality. For predictors with multiple categories, the Kruskal-Wallis test was used. Statistical significance was established at $p < 0.05$. A univariable logistic regression was performed to establish the association between the mechanism of injury and severe outcomes. In the multivariable logistic regression, we adjusted for age, gender, intent (unintentional, intentional or unknown), mechanism of injury (fall, road traffic injury, struck by person or object, or others) and GNI group. For the regression, we presented each point estimate with its 95% confidence interval (CI). Data were analysed using IBM SPSS Statistics Version 19.0. SPSS Inc, Chicago.

RESULTS

A total of 1438 children met the inclusion criteria (Figure 2). 953 children (66.3%) were male and the median age was 5.0 years (IQR 1.0-10.0). 1000 children (69.5%) were from high-income, 208 (14.5%) were from upper middle-income and 230 (16.0%) were from lower middle-income countries. (The number of patients analysed from each centre is described in Supplementary Table 1. The annual paediatric trauma attendance and number of trauma cases requiring hospitalisation in each centre are elaborated in Supplementary Table 2.) We did not have missing data for the primary mechanism of injury.

There was no statistically significant difference in the intent of injury between children younger than 2 years old and those 2 years and above (p=0.268). Falls were the most common mechanism across all ages (957, or 66.6%). Specifically among 415 children less than 2 years old, most of the head injuries were a result of falls (344,or 82.9%) that occurred in the home (299, or 72.0%) (Table 1). The median height of the fall in these young children was 0.7metres (IQR 0.5 – 1.0).

Children 2 years old and above with head injuries were more likely to be involved in a road traffic injury (264, 25.8%), compared to children younger than 2 years old (46, 11.1%). Among all 310 children involved in road traffic injuries, 96 (31.0%) were pedestrian injuries (Table 1). Among vehicle occupants, motorcycle users and pedal cyclists (n=214), only 29 children (13.6%) were restrained (referring to child car seats, seat belts or helmets), 48 (22.4%) were not restrained and 137 children (64.0%) did not have documentation on the use of restraints. Among vehicle occupant injuries, 29/80 (36.3%) involved airbag activations during the collision.

Table 2 shows the physical examination findings and outcomes for children in our study. Head-injured children 2 years and older were more likely to have a CT head performed compared to younger children (p<0.001). Among children 2 years and above, 301 (29.4%) had a positive CT head, as compared to 134 (32.3%) among those < 2 years (p=0.284). Eight-five patients (5.9%) were documented to have polytrauma, among whom intra-thoracic and long bone fractures were the most common (each 27 patients, or 1.9%). 279 children (19.4%) required admission to higher acuity care units (intensive care or high dependency) after stabilisation in the ED. Among 115 children who underwent neurosurgery, 75 (65.2%) had a craniotomy, 55 (47.8%) had their intracranial bleeds evacuated and 17 (14.8%) underwent elevation of depressed skull fractures. Among the 55 children who died, the median days of death post injury was 3 days (IQR 1.0-7.0). 19 children (34.5%) who died were documented to have polytrauma, mainly intra-thoracic injuries (7 patients, 12.7%).

Specifically among the 15 children subject to child abuse, 5 (33.3%) required intubation, 4 (26.7%) received neurosurgical intervention and 2 children (13.3%) died. The median age of the abused child was 7 years (IQR 0.0-14.0).

Table 3 describes the primary mechanism of injury when stratified by GNI. Falls comprised a larger proportion of head injuries seen in the EDs of high-income countries (745, or 74.5%) compared to upper (90, 43.3%) and lower (122, 53.0%) middle-income countries. Conversely, road traffic injuries were responsible for a larger proportion of head injuries that presented to lower (94, 40.9%) and upper (107, 51.4%) middle-income countries, compared to high-income countries (109, 10.9%). Severe and secondary outcomes stratified by GNI are shown in Table 3. A greater proportion of children had the composite of severe outcomes in lower and upper middle-income countries compared to high-income countries (28.4% and 58.2%, vs 3.6%, $p<0.0001$). This effect was seen for each of the individual severe outcomes of endotracheal intubation, neurosurgical intervention and death (Table 3). When stratified by mechanism of injury, the length of hospital stay was significantly longer for children who were involved in road traffic injuries (median 3.0 days, IQR 1.0 – 7.0) compared to falls (median 1.0 day, IQR 1.0 – 2.0) ($p<0.001$).

Road traffic injuries were significantly associated with the severe outcomes of death, endotracheal intubation or need for neurosurgery (Table 4). This remained statistically significant (adjusted odds ratio, aOR 2.183, 95%CI 1.448 – 3.293) after adjusting for age, gender, intent of injury and GNI. Intentional injuries were no longer statistically significant after adjustment (aOR 2.470, 95%CI 0.839 – 7.272). In our study, centres in lower (aOR 8.769, 95%CI 5.520 – 13.929) and upper (aOR 28.579, 95%CI 17.986 – 45.412) middle-income countries were more likely to receive and care for children who subsequently had severe outcomes, compared to those from high-income countries.

DISCUSSION

After infancy, childhood injuries remain high on the list of killers in various parts of Asia.[13] WHO recommends strengthening the role of the health sector in evidence-based advocacy and service provision for victims of such trauma.[14] This collaboration among participating PATOS centres enabled clinical childhood injury data across different centres in Asia to be analysed.

In our study, falls were the most common mechanism of injury, particularly among children < 2 years old. Road traffic injuries, while less common than falls, were more likely to occur in children 2 years and older, and were significantly associated with severe outcomes. Children with head injuries who presented to the EDs of lower and upper middle-income countries were more likely to be involved in road traffic injuries and to suffer severe outcomes, compared to those in high-income countries.

Our findings on falls reinforce that of a national study from the United Kingdom.[15] Falls among preverbal children occur mainly in the home, involving ground surfaces and furniture. Although most falls occur from a low height, they still result in physical injuries and urgent care attendances. This suggests the need to relook at home safety and caregiver awareness.

The association between road traffic injuries and severe outcomes emphasizes that road safety remains a pressing public health concern in Asia. Road traffic legislation on the use of child restraints (child car seats and helmets) is variable among different countries in Asia.[16] Even in countries with clear legislation on the use of child restraints, compliance has been found to be lacking.[17] There was an extremely low rate of documented restraint use in this study. This highlights both the need for better injury surveillance and documentation, as well as improved adherence to safe road practices and enforcement of road traffic laws.[18-19] Specific concerns among motorcycle road users in Asia include the low rate of helmet use among children,[20] overloading of motorcycles,[21] and high risk behaviour among adolescents while racing.[22-23]

When stratified by GNI, a larger proportion of paediatric head injuries were attributed to falls in the PATOS centres from high-income countries. We postulate that this may be due to differences in health care delivery – with lower acuity injuries from falls more likely to present to the EDs of high-income compared to middle-income countries. The larger proportion of injuries attributed to road traffic collisions in middle-income countries could also be due to the absence of enforced legislation for safe road practices.

There were more deaths and severe in-hospital outcomes among lower and upper middle-income countries, despite a smaller total number of injuries. This effect persisted after adjusting for mechanism of injury. We postulate that severity of injury, pre-hospital care and accessibility to trauma centres with paediatric capabilities contribute to this effect.[24] We did not collect data on interventional strategies for traumatic brain injuries in this study.

CT scan rates here are high compared to other studies.[12] This was likely due to differences in case ascertainment, because we excluded mild cases that had symptom resolution. In our study, 258 children (17.9%) had a GCS of 13 and below. There was a positive CT rate of 30.3% and a positive event rate (death, intubation or neurosurgery) of 15.4%. Importantly, differences in healthcare settings were likely to contribute to the variability in CT rates, including individual hospital protocols and the availability of facilities to observe head injured children.

Our findings on child abuse build on previous reports that such injuries are associated with death and long term neurological compromise.[25-26] Early clinical recognition is paramount for holistic care of the child,[27] and such cases must be readily identified by emergency medicine providers acting as advocates for this vulnerable population. The median age of 7 years differs from another study where infants predominated among victims of child abuse.[28] In our study, we recognise that child abuse cases were very few in number. These are likely to be under-diagnosed and under-reported in Asia. Important differences between centres include varying definitions for child abuse, the presence (or absence) of a multidisciplinary team for onward referral, and variable child protection measures formally stipulated by state law. Moving forward, we recognize the need to gain common ground, including the multi-disciplinary assessment required for accurate case definitions.[29]

We recognise the following limitations of this study. We have compiled data across different populations with varying healthcare delivery systems. In this retrospective review, details surrounding the use of restraints were missing in some countries that do not have routine surveillance data. The impact of different countries' road traffic laws on the rate and types of injuries were not explored here. We recognise that hospital-based studies are limited and should extend to more systematic surveillance in each country that can translate to practical safety measures.[30] We were not able to report detailed neurological assessments for both in-hospital and out-of-hospital outcomes because availability of these data varied between centres. The above highlight the dire need for improved documentation that can inform policies and injury prevention strategies in Asia.

To our knowledge, this is the first attempt to collate paediatric head injury surveillance data from different centres in Asia. Road traffic injuries continue to account for death and severe injuries, especially in middle-income countries. Importantly, this paves the way for further prospective surveillance studies to be performed among the PATOS centres.

Table 1. Intent and mechanism of injury among all head injured children

Intent and primary mechanism of injury			
	Children 2 years old and above N=1023	Children < 2 years old N=415	p value
Intent of Injury, n (%)			
Unintentional	980 (95.8)	397 (95.7)	0.268
Assault – Child Abuse	9 (0.9)	6 (1.4)	
Assault – Others	13 (1.3)	1 (0.2)	
Intentional Self-Harm	1 (0.1)	0 (0.0)	
Unknown	20 (2.0)	11 (2.7)	
Primary Mechanism of Injury, n (%)			
Fall	613 (59.9)	344 (82.9)	<0.001
Road Traffic Injury	264 (25.8)	46 (11.1)	
Struck by Object or Person	102 (10.0)	15 (3.6)	
Sports Injury	25 (2.4)	0 (0.0)	
Gun Shot	2 (0.2)	0 (0.0)	
Others	13 (1.3)	10 (2.4)	
Among Road Traffic Injuries: Type of Road User, n (%)			
Total	264 (100.0)	46 (100.0)	<0.001
Pedestrian	86 (32.6)	10 (21.7)	
Motorcyclist	75 (28.4)	7 (15.2)	
Vehicle Occupant	54 (20.5)	26 (56.5)	
Pedal Cyclist	45 (17.0)	3 (6.5)	
Unknown	4 (1.5)	0 (0)	
Object involved in Injury, n (%)			
Ground Surface	294 (28.7)	87 (21.0)	<0.001
Land Transport/Means of Land Transport	210 (20.5)	39 (9.4)	
Furniture	94 (9.2)	128 (30.8)	
Building Component or Fitting	135 (13.2)	60 (14.5)	
Animal, Plant or Person	111 (10.9)	34 (8.2)	
Equipment for Sports or Recreational Activity	67 (6.5)	1 (0.2)	
Infant or Child Care Product	17 (1.7)	34 (8.2)	
Location of Injury, n (%)			
Home	351 (34.3)	299 (72.0)	<0.001
Street, Highway or Road	276 (27.0)	43 (10.4)	
School	169 (16.5)	10 (2.4)	
Public Playground or Amusement Park	61 (6.0)	8 (1.9)	
Sports or Athletics Areas	50 (4.9)	1 (0.2)	

Table 2. Physical examination and outcome measures

	Children 2 years old and above N=1023	Children < 2 years old N = 415	p value
Presenting GCS, n (%)			
GCS 14-15	837 (81.8)	342 (82.4)	0.077
GCS 8-13	91 (8.9)	24 (5.8)	
GCS < 8	95 (9.3)	48 (11.6)	
Physical Examination Findings, n (%)			
Contusion or Hematoma	353 (34.5)	172 (41.4)	
Abrasion	214 (20.9)	89 (21.4)	0.011
Palpable Skull Fracture	75 (7.3)	33 (8.0)	
Laceration	93 (9.1)	15 (3.6)	
CT Brain Performed, n (%)	660 (64.5)	187 (45.1)	<0.001
Endotracheal Intubation, n (%)	114 (11.1)	55 (13.3)	0.278
Blood Products Required, n (%)	60 (5.9)	18 (4.3)	0.583
ED LOS[#] (in hours), median (IQR)	2.1 (1.2-5.0)	2.7 (2.0-4.2)	0.026
ED Disposition, n (%)			<0.001
ICU/HD[^] Admissions	191 (18.7)	88 (21.2)	
Transfer to Operating Theatre	33 (3.2)	2 (0.5)	
Transfer to Other Medical Centres	18 (1.8)	8 (1.9)	
Neurosurgical Intervention, n (%)	84 (8.2)	31 (7.5)	0.594
Death, n (%)	30 (2.9)	25 (6.0)	0.012
Hospital LOS[#] (in days) for Admitted Patients, median (IQR)	1.0 (1.0-4.0)	1.0 (1.0-2.0)	<0.001

[#]LOS – Length of Stay
[^]ICU/HD – Intensive Care Unit/High Dependency

Table 3. Mechanism of injury, computed tomography use, severe and secondary outcomes by Gross National Income (GNI)

	Lower Middle-Income, n (%)	Upper Middle-Income, n (%)	High-Income, n (%)	Total, n (%)	p value
Primary Mechanism of injury					
Total	230	208	1000	1438	
Fall	122 (53.0)	90 (43.3)	745 (74.5)	957 (66.6)	<0.001
Traffic Injury	94 (40.9)	107 (51.4)	109 (10.9)	310 (21.6)	
Struck by Person or Object	5 (2.2)	8 (3.8)	104 (10.4)	117 (8.1)	
Sports Injury	2 (0.9)	1 (0.5)	22 (2.2)	25 (1.7)	
Stab or Cut	0 (0.0)	0 (0.0)	4 (0.4)	4 (0.3)	
Gun Shot	2 (0.9)	0 (0.0)	0 (0.0)	2 (0.1)	
Others[#]	5 (2.2)	2 (1.0)	16 (1.6)	23 (1.6)	
Computed Tomography Use					
CT Use	214 (93.0)	208 (100.0)	426 (42.6)	848 (59.0)	<0.001
Severe Outcomes					
Endotracheal Intubation	49 (21.4)	97 (46.6)	23 (2.3)	169 (11.8)	<0.001
Neurosurgical Intervention	20 (10.4)	71 (34.1)	24 (2.4)	115 (8.2)	<0.001
Death	13 (5.7)	35 (16.8)	7 (0.7)	55 (3.8)	<0.001
Secondary Outcome					
Admitted to Hospital	187 (81.3)	188 (90.4)	788 (78.8)	1163 (80.9)	<0.001
Hospital Length of Stay, median (IQR)	3.0 (2.0 – 6.0)	5.0 (2.0 – 13.0)	1.0 (1.0 – 2.0)	1.0 (1.0 – 3.0)	<0.001

[#] 'Others' mechanism comprised primarily of cases where the mechanism of injuries could not be obtained or categorized from retrospective chart review.

Table 4. Logistic regression for death, intubation or neurosurgical intervention

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age	0.988 (0.960- 1.017)	0.968 (0.932 – 1.007)
Male Gender	1.612 (1.165 – 2.231)	1.233 (0.832 – 1.828)
Mechanism of Injury		
Fall	Referent	Referent
Road Traffic Injury	4.903 (3.574 – 6.726)	2.183 (1.448 – 3.293)
Struck by Person or Object	0.857 (0.433 – 1.695)	1.135 (0.484 – 2.661)
Others	2.084 (1.016 – 4.277)	2.946 (1.200 – 7.227)
Intent		
Unintentional	Referent	Referent
Intentional	2.956 (1.355 – 6.446)	2.470 (0.839 – 7.272)
Unknown	0.802 (0.278 -2.311)	1.252 (0.365 – 4.291)
Gross National Income		
High-Income	Referent	Referent
Upper Middle-Income	37.240 (24.178 – 57.360)	28.579 (17.986 – 45.412)
Lower Middle-Income	10.612 (6.838 – 16.471)	8.769 (5.520 – 13.929)

Figure 1. Map of participating Pan Asian Trauma Outcomes Study (PATOS) centres

Figure 2. Flow diagram of patients included for analysis

Contribution: CSL, URK, IS, and MEHO made substantial contributions to the conception and design of the work. CSL, URK, IS, SJS, WQ, SFJ, HTAQ, and CSY contributed in the data acquisition. CSL, URK, IS, CSY and MEHO contributed in the analysis and interpretation of the data. All authors revised it critically for important intellectual content and approved of the final version to be published.

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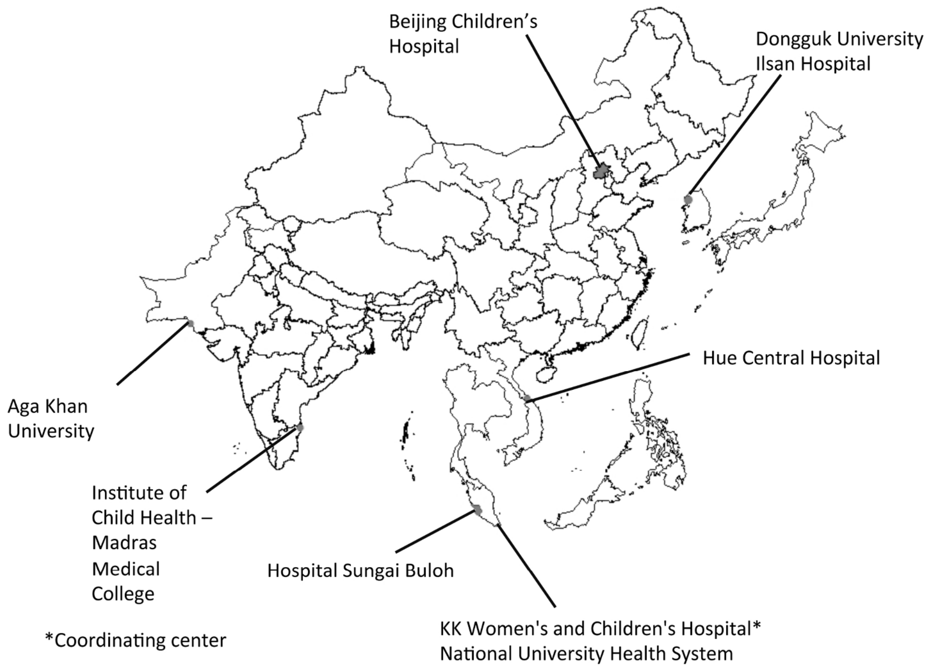

Figure 1. Map of participating Pan Asian Trauma Outcomes Study (PATOS) centres

198x139mm (300 x 300 DPI)

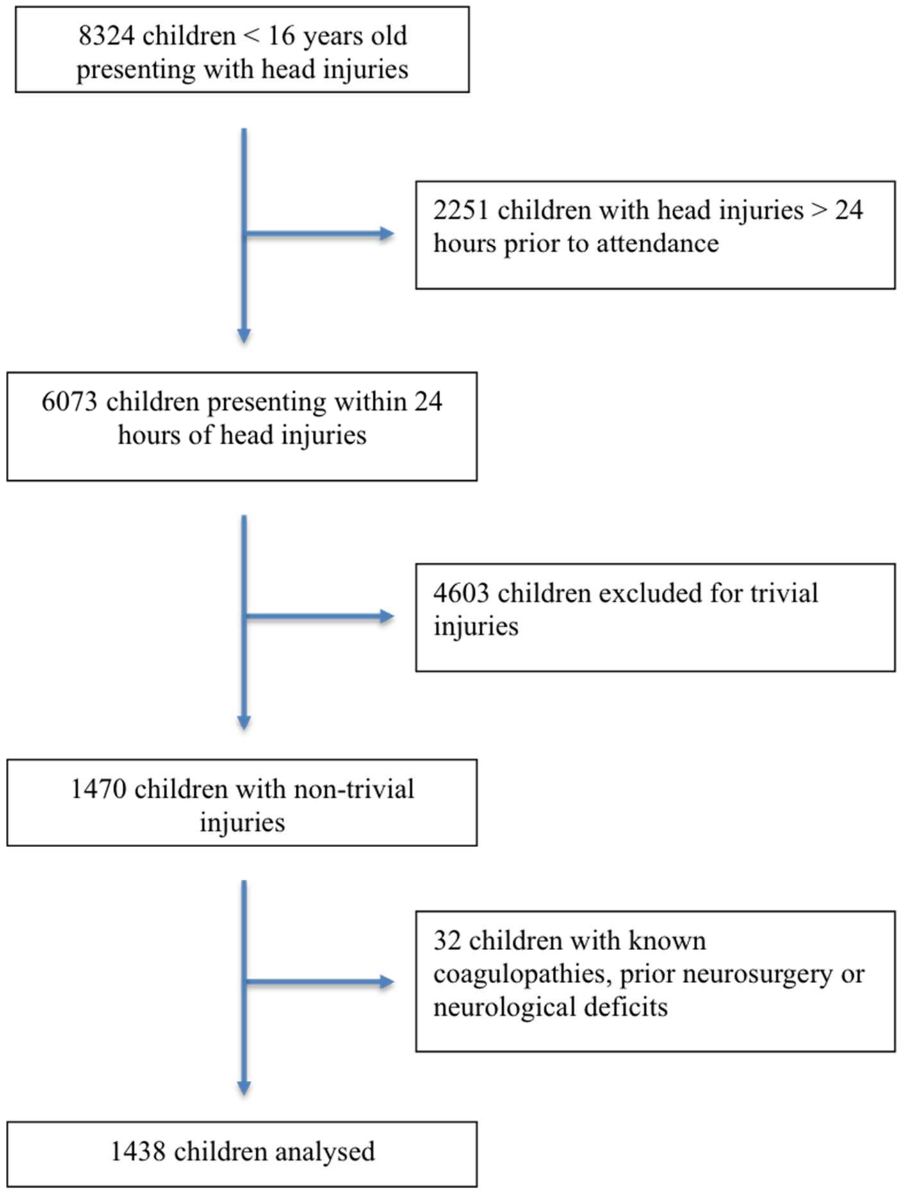

Figure 2. Flow diagram of patients included for analysis

131x177mm (300 x 300 DPI)

Supplementary Table 1. Number of patients analysed from each participating PATOS Centre

Lower Middle Income	n (%)	**Upper Middle Income**	n (%)	**High Income**	n (%)
Aga Khan University (Pakistan)	101 (7.0)	Beijing Children's Hospital (China)	137 (9.5)	Dongguk University Ilsan Hospital (South Korea)	185 (12.9)
Hue Central Hospital (Vietnam)	84 (5.8)	Hospital Sungai Buloh (Malaysia)	71 (4.9)	KK Women's and Children's Hospital (Singapore)	628 (43.7)
Institute of Child Health – Madras Medical College (India)	45 (3.1)			National University Health System (Singapore)	187 (13.0)
Total	230 (16.0)	Total	208 (14.5)	Total	1000 (69.5)

PATOS – Pan Asian Trauma Outcomes Study

Countries are categorised by Gross National Income (GNI) [9]

Supplementary Table 2. Individual hospital characteristics

	Annual Paediatric* Trauma Attendance	Annual Paediatric* Trauma Hospitalisations
Lower Middle Income		
Aga Khan University# (Pakistan)	509	411
Hue Central Hospital# (Vietnam)	2161	483
Institute of Child Health – Madras Medical College# (India)	1204	45
Upper Middle Income		
Beijing Children's Hospital (China)	10000	1500
Hospital Sungai Buloh (Malaysia)	2892	345
High Income		
Dongguk University Ilsan Hospital (South Korea)	4489	86
KK Women's and Children's Hospital (Singapore)	28222	2197
National University Health System (Singapore)	6501	708

*This is defined as < 16 years old
#Obtained from manual chart review

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 6-7
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	6-7
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	8
Objectives	3	State specific objectives, including any prespecified hypotheses	8
Methods			
Study design	4	Present key elements of study design early in the paper	9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	9-10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	9-10
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	10-11
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	10-11
Bias	9	Describe any efforts to address potential sources of bias	10-11
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	11
		(*b*) Describe any methods used to examine subgroups and interactions	11
		(*c*) Explain how missing data were addressed	12

		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	11

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	(Epidemiology study, all who fit inclusion criteria, Page 9-10)
		(c) Consider use of a flow diagram	Figure 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12-13,19-20
		(b) Indicate number of participants with missing data for each variable of interest	12
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	13-14
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	14, 22
		(*b*) Report category boundaries when continuous variables were categorized	12-13.19-20
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-14,19-21
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18

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	25

*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.

BMJ Open

A Retrospective Review of Paediatric Head Injuries in Asia – A Pan Asian Trauma Outcomes Study (PATOS) Collaboration

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SCHOLARONE™ Manuscripts

A Retrospective Review of Paediatric Head Injuries in Asia – A Pan Asian Trauma Outcomes Study (PATOS) Collaboration

Title Page

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ABSTRACT

Objective We aim to examine the mechanisms of head-injured children presenting to participating centres in the Pan Asian Trauma Outcomes Study (PATOS) and to evaluate the association between mechanism of injury and severe outcomes.

Design and Setting We performed a retrospective review of medical records among emergency departments (EDs) of eight PATOS centres, from September 2014 – August 2015.

Participants We included children < 16 years old who presented within 24 hours of head injury and were admitted for observation or required a computed tomography (CT) of the brain from the ED. We excluded children with known coagulopathies, neurological co-morbidities or prior neurosurgery. We reviewed the mechanism, intent, location and object involved in each injury, and the patients' physical findings on presentation.

Outcomes Primary outcomes were death, endotracheal intubation or neurosurgical intervention. Secondary outcomes included hospital and ED length of stay.

Results 1438 children were analysed. 953 children (66.3%) were male and the median age was 5.0 years (IQR 1.0-10.0). Falls predominated especially among children younger than 2 years (82.9%), while road traffic injuries were more likely to occur among children 2 years and above compared to younger children (25.8% vs 11.1%). Centres from upper and lower middle-income countries were more likely to receive head injured children from road traffic collisions compared to those from high-income countries (51.4% and 40.9%, vs 10.9%, p<0.0001) and attended to a greater proportion of children with severe outcomes (58.2% and 28.4%, vs 3.6%, p<0.0001). After adjusting for age, gender, intent of injury and gross national income, traffic injuries (adjusted OR 2.183, 95%CI 1.448-3.293) were associated with severe outcomes, as compared to falls.

Conclusions Among children with head injuries, traffic injuries are independently associated with death, endotracheal intubation and neurosurgery**.** This collaboration among Asian centres holds potential for future prospective childhood injury surveillance.

Keywords: traumatic brain injury; child; non-accidental Injury; neurosurgery

Article Summary

Strengths

- In this pioneer collaboration, mechanisms of head injury and patient outcomes were compared between diverse centres in Asia.
- Data were obtained through a common electronic platform using a standardised form.

Limitations

- Heterogeneity in trauma documentation exists among different centres.
- We presented hospital-based clinical data because national data of this nature are not available in many countries in Asia, where trauma databases are being established.

INTRODUCTION

Childhood injury remains a regrettable source of premature death and disability worldwide. Despite the progress made in injury prevention, the scale of paediatric trauma remains significant.[1] According to WHO autopsy reports, up to a quarter of deaths from external causes occurred in children younger than 15 years old.[2] These were dominated by transport-related injuries in many parts of Asia and Africa,[2] where fatalities and injuries from road traffic collisions are increasing.[3]

Paediatric head injuries are critically important because of the high mortality risk.[4] Among survivors, the potential for lifelong neurological devastation could mean years of lost productivity, compromised quality of life and dependence on others for activities of daily living.[5] Severe traumatic brain injury slows down processing speed and adaptive functioning in the long term.[6,7] These irreversible effects are keenly felt by the child, the family and society at large.

A significant proportion of severe paediatric head injuries occur in Asia, yet surveillance in this region remains inadequate. In this multicentre study, we aim to: (1) Examine the injury epidemiology of children presenting with head injuries to participating centres in the Pan Asian Trauma Outcomes Study (PATOS), specifically comparing children younger than 2 years to children 2 years and older, and (2) Study the association between the mechanism of injury and severe outcomes as defined by death, the need for endotracheal intubation and neurosurgical intervention.

MATERIALS AND METHODS

Design and Setting This was a retrospective chart review performed in participating centres of PATOS between September 2014 to August 2015. PATOS is an Asian clinical research network with a multicentre trauma registry.[8] Centres participated in this study on a voluntary basis and are from the following countries: Singapore, Pakistan, India, South Korea, China, Malaysia and Vietnam. (Figure 1) Countries were grouped into lower middle, upper middle and high-income economies by per capital gross national income (GNI) based on the World Bank classification.[9] The data collection was performed in a uniform fashion using a standardised electronic data form with the variables explored a priori for common understanding.

Ethics approval was obtained for each centre, with the coordinating centre obtaining approval from the Singapore Singhealth Centralised Institutional Review Board (CIRB, E).

Patients We included children < 16 years old who presented within 24 hours of head injury and were admitted for observation or required a computed tomography (CT) of the brain from the emergency department (ED). Patients with known coagulopathies, prior neurosurgery, neurological deficits or developmental delay were excluded. The presence of neurological deficits or developmental delay was determined by the attending ED physician. We chose to exclude the above patients because of increased complexity in neurological assessment and different thresholds for investigations and hospitalisation. We also excluded trivial injuries in children whose symptoms had resolved while in the ED and who did not clinically warrant further monitoring or investigations. Patients with a low Glasgow Coma Scale (GCS) score (13 and below) or with persistence of symptoms including headache or vomiting underwent a CT head scan (at the physician's discretion). In cases of polytrauma, we confirmed that the low GCS was due to head trauma, as evidenced by a positive CT consisting: intracranial bleed, cerebral oedema, diffuse axonal injury or skull fracture. In the case of death, the post mortem must have proven an intracranial injury for the patient to be included.

Variables: We followed the International Classification of External Causes of Injury (ICECI) classification [10] and established common data points across the PATOS centres. The primary mechanism of injury was collected for all patients, including the following: Fall, road traffic injury, struck by object or person, sports injury, gunshot or others. For falls, the height of the fall was documented. In the case of road traffic injuries, the injured person type (pedestrian, cyclist, motor vehicle passenger, motorbike user) and the use of preventative measures (helmets, child car seats or seat belts) were collected. The intent of injury describes if the child was involved in an unintentional injury, intentional self-harm, assault or if the intent was unknown. Specifically for assault, we differentiated child abuse cases by caregivers from other forms of assault that occurred in schools or by strangers. The object involved in the trauma (including ground surface, furniture or land transport) and the location of occurrence (home, school, public road, sports area or playground) was also recorded. The patient's presenting GCS and physical examination findings were documented.

Main outcome measures: The primary outcome measures were: Death, need for endotracheal intubation or neurosurgical intervention.[11] We also reviewed the hospital and ED length of stay.

Analysis: Categorical data were presented as frequencies and percentages. Continuous data were presented using means (with standard deviation) or medians (with interquartile ranges, IQR), depending on normality of distribution. We analysed children < 2 years versus children 2 years and older separately, recognising that younger children are preverbal, have evolving ambulatory skills and are predisposed to different mechanisms of injury.[12] Measures of association between the outcomes and categorical variables were analysed using Chi Square test or Fisher's Exact test, while that of continuous variables were analysed using either Student t-test or Mann Whitney U, depending on normality. For predictors with multiple categories, the Kruskal-Wallis test was used. Statistical significance was established at $p < 0.05$. A univariable logistic regression was performed to establish the association between the mechanism of injury and severe outcomes. In the multivariable logistic regression, we adjusted for age, gender, intent (unintentional, intentional or unknown), mechanism of injury (fall, road traffic injury, struck by person or object, or others) and GNI group. For the regression, we presented each point estimate with its 95% confidence interval (CI). Data were analysed using IBM SPSS Statistics Version 19.0. SPSS Inc, Chicago.

RESULTS

A total of 1438 children met the inclusion criteria (Figure 2). 953 children (66.3%) were male and the median age was 5.0 years (IQR 1.0-10.0). 1000 children (69.5%) were from high-income, 208 (14.5%) were from upper middle-income and 230 (16.0%) were from lower middle-income countries. (The number of patients analysed from each centre is described in Supplementary Table 1. The annual paediatric trauma attendance and number of trauma cases requiring hospitalisation in each centre are elaborated in Supplementary Table 2.) We did not have missing data for the primary mechanism of injury.

Falls were the most common mechanism of injury across all ages (957, or 66.6%). Specifically among 415 children less than 2 years old, most of the head injuries were a result of falls (344,or 82.9%) that occurred in the home (299, or 72.0%) The median height of the fall in these young children was 0.7metres (IQR 0.5 – 1.0). (Table 1). Among all 310 children involved in road traffic injuries, 96 (31.0%) were pedestrian injuries. Among vehicle occupants, motorcycle users and pedal cyclists (n=214), only 29 children (13.6%) were restrained (referring to child car seats, seat belts or helmets), 48 (22.4%) were not restrained and 137 children (64.0%) did not have documentation on the use of established preventative measures. Among vehicle occupant injuries, 29/80 (36.3%) involved airbag activations during the collision.

Children 2 years old and above with head injuries were more likely to be involved in a road traffic injury (264, 25.8%), compared to children younger than 2 years old (46, 11.1%). There was no statistically significant difference in the intent of injury between children younger than 2 years old and those 2 years and above (p=0.268). Table 2 shows the physical examination findings and outcomes for children in our study. Head-injured children 2 years and older were more likely to have a CT head performed compared to younger children (p<0.001). Among children 2 years and above, 301 (29.4%) had a positive CT head, as compared to 134 (32.3%) among those less than 2 years (p=0.284).

Eighty-five patients (5.9%) were documented to have polytrauma, among whom intra-thoracic and long bone fractures were the most common (each 27 patients, or 1.9%). 279 children (19.4%) required admission to higher acuity care units (intensive care or high dependency) after stabilisation in the ED. Among 115 children who underwent neurosurgery, 75 (65.2%) had a craniotomy, 55 (47.8%) had their intracranial bleeds evacuated and 17 (14.8%) underwent elevation of depressed skull fractures. Thirty children (2.9%) 2 years and older died, compared to 25 (6.0%) who were younger than 2 years old (p=0.012). The median days of death post injury was 3 days (IQR 1.0-7.0). 19 children (34.5%) who died were documented to have polytrauma, mainly intra-thoracic injuries (7 patients, 12.7%). Specifically among the 15 children subject to child abuse, 5 (33.3%) required intubation, 4 (26.7%) received neurosurgical intervention and 2 children (13.3%) died. The median age of the abused child was 7 years (IQR 0.0-14.0).

Table 3 describes the primary mechanism of injury when stratified by GNI. Falls comprised a larger proportion of head injuries seen in the EDs of high-income countries (745, or 74.5%) compared to upper (90, 43.3%) and lower (122, 53.0%) middle-income countries. Conversely, road traffic injuries were responsible for a larger proportion of head injuries that presented to lower (94, 40.9%) and upper (107, 51.4%) middle-income countries, compared to high-income countries (109, 10.9%). Severe and secondary outcomes stratified by GNI are shown in Table 3. A greater proportion of children had the composite of severe outcomes in lower and upper middle-income countries compared to high-income countries (28.4% and 58.2%, vs 3.6%, p<0.0001). This effect was seen for each of the individual severe outcomes of endotracheal intubation, neurosurgical intervention and death (Table 3). When stratified by mechanism of injury, the length of hospital stay was significantly longer for children who were involved in road traffic injuries (median 3.0 days, IQR 1.0 – 7.0) compared to falls (median 1.0 day, IQR 1.0 – 2.0) (p<0.001).

Road traffic injuries were significantly associated with the severe outcomes of death, endotracheal intubation or need for neurosurgery (Table 4). This remained statistically significant (adjusted odds ratio, aOR 2.183, 95%CI 1.448 – 3.293) after adjusting for age, gender, intent of injury and GNI. Intentional injuries were no longer statistically significant after adjustment (aOR 2.470, 95%CI 0.839 – 7.272). In our study, centres in lower (aOR 8.769, 95%CI 5.520 – 13.929) and upper (aOR 28.579, 95%CI 17.986 –

45.412) middle-income countries were more likely to receive and care for children who subsequently had severe outcomes, compared to those from high-income countries.

DISCUSSION

After infancy, childhood injuries remain high on the list of killers in various parts of Asia.[13] WHO recommends strengthening the role of the health sector in evidence-based advocacy and service provision for victims of such trauma.[14] This collaboration among participating PATOS centres enabled clinical childhood injury data across different centres in Asia to be analysed.

In our study, falls were the most common mechanism of injury, particularly among children < 2 years old. Road traffic injuries, while less common than falls, were more likely to occur among children 2 years and older, and were significantly associated with severe outcomes. Children with head injuries who presented to the EDs of lower and upper middle-income countries were more likely to be involved in road traffic injuries and to suffer severe outcomes, compared to those in high-income countries.

Our findings on falls reinforce that of a national study from the United Kingdom.[15] Falls among preverbal children occur mainly in the home, involving ground surfaces and furniture. Although most falls occur from a low height, they still result in physical injuries and urgent care attendances. This suggests the need to relook at home safety and caregiver awareness.

The association between road traffic injuries and severe outcomes emphasizes that road safety remains a pressing public health concern in Asia. Road traffic legislation on the use of child restraints (child car seats and helmets) is variable among different countries in Asia.[16] Even in countries with clear legislation on the use of child restraints, compliance has been found to be lacking.[17] There was an extremely low rate of documented restraint use in this study. This highlights both the need for better injury surveillance and documentation, as well as improved adherence to safe road practices and enforcement of road traffic laws.[18-19] Specific concerns among motorcycle road users in Asia include the low rate of helmet use among children,[20] overloading of motorcycles,[21] and high risk behaviour among adolescents while racing.[22-23]

When stratified by GNI, a larger proportion of paediatric head injuries were attributed to falls in the PATOS centres from high-income countries. We postulate that this may be due to differences in health care delivery – with lower acuity injuries from falls more likely to present to the EDs of high-income compared to middle-income countries. This is suggested by the different hospitalisation rate between centres when stratified by GNI (Supplementary Table 2). The larger proportion of injuries attributed to road traffic collisions in middle-income countries could also be due to the absence of enforced legislation for safe road practices.

There were more deaths and severe in-hospital outcomes among lower and upper middle-income countries, despite a smaller total number of injuries. This effect persisted after adjusting for mechanism of injury. We postulate that severity of injury, pre-hospital care and accessibility to trauma centres with paediatric capabilities contribute to this effect.[24] We did not collect data on interventional strategies for traumatic brain injuries in this study.

CT scan rates here are high compared to other studies.[12] This was likely due to differences in case ascertainment, because we excluded mild cases that had symptom resolution. In our study, 258 children (17.9%) had a GCS of 13 and below. There was a positive CT rate of 30.3% and a positive event rate (death, intubation or neurosurgery) of 15.4%. Importantly, differences in healthcare settings were likely to contribute to the variability in CT rates, including individual hospital protocols and the availability of facilities to observe head injured children.

Our findings on child abuse build on previous reports that such injuries are associated with death and long term neurological compromise.[25-26] Early clinical recognition is paramount for holistic care of the child,[27] and such cases must be readily identified by emergency medicine providers acting as advocates for this vulnerable population. The median age of 7 years differs from another study where infants predominated among victims of child abuse.[28] In our study, we recognise that child abuse cases were very few in number. These are likely to be under-diagnosed and under-reported in Asia. Important differences between centres include varying definitions for child abuse, the presence (or absence) of a multidisciplinary team for onward referral, and variable child protection measures formally stipulated by state law. Moving forward, we recognize the need to gain common ground, including the multi-disciplinary assessment required for accurate case definitions.[29]

We recognise the following limitations of this study. We have compiled data across different populations with varying healthcare delivery systems. In this retrospective review, details surrounding the use of restraints were missing in some countries that do not have routine surveillance data. The impact of different countries' road traffic laws on the rate and types of injuries were not explored here. We recognise that hospital-based studies are limited and should extend to more systematic surveillance in each country that can translate to practical safety measures.[30] We were not able to report detailed neurological assessments for both in-hospital and out-of-hospital outcomes because availability of these data varied between centres. The above highlight the dire need for improved documentation that can inform policies and injury prevention strategies in Asia. Specifically, individual factors including injury severity scores and systemic factors including pre-hospital systems, accessibility to trauma care and interventional strategies for paediatric head injuries must be better documented.

To our knowledge, this is the first attempt to collate paediatric head injury surveillance data from different centres in Asia. Road traffic injuries continue to account for death and severe injuries, especially in middle-income countries. Importantly, this paves the way for further prospective surveillance studies to be performed among the PATOS centres.

Table 1. Intent and mechanism of injury among all head injured children

	Children < 2 years old N=415	Children 2 years old and above N=1023	p value
Intent of Injury, n (%)			
Unintentional	397 (95.7)	980 (95.8)	
Assault – Child Abuse	6 (1.4)	9 (0.9)	
Assault – Others	1 (0.2)	13 (1.3)	0.268
Intentional Self-Harm	0 (0.0)	1 (0.1)	
Unknown	11 (2.7)	20 (2.0)	
Primary Mechanism of Injury, n (%)			
Fall	344 (82.9)	613 (59.9)	
Road Traffic Injury	46 (11.1)	264 (25.8)	
Struck by Object or Person	15 (3.6)	102 (10.0)	<0.001
Sports Injury	0 (0.0)	25 (2.4)	
Gun Shot	0 (0.0)	2 (0.2)	
Others	10 (2.4)	13 (1.3)	
Among Road Traffic Injuries: Type of Road User, n (%)			
Total	46 (100.0)	264 (100.0)	
Pedestrian	10 (21.7)	86 (32.6)	
Motorcyclist	7 (15.2)	75 (28.4)	<0.001
Vehicle Occupant	26 (56.5)	54 (20.5)	
Pedal Cyclist	3 (6.5)	45 (17.0)	
Unknown	0 (0)	4 (1.5)	
Object involved in Injury, n (%)			
Ground Surface	87 (21.0)	294 (28.7)	
Land Transport/Means of Land	39 (9.4)	210 (20.5)	
Transport	128 (30.8)	94 (9.2)	
Furniture	60 (14.5)	135 (13.2)	<0.001
Building Component or Fitting	34 (8.2)	111 (10.9)	
Animal, Plant or Person	1 (0.2)	67 (6.5)	
Equipment for Sports or	34 (8.2)	17 (1.7)	
Recreational Activity			
Infant or Child Care Product			
Location of Injury, n (%)			
Home	299 (72.0)	351 (34.3)	
Street, Highway or Road	43 (10.4)	276 (27.0)	
School	10 (2.4)	169 (16.5)	<0.001
Public Playground or Amusement	8 (1.9)	61 (6.0)	
Park	1 (0.2)	50 (4.9)	
Sports or Athletics Areas			

Table 2. Physical examination and outcome measures

	Children < 2 years old N = 415	Children 2 years old and above N=1023	p value
Presenting GCS, n (%)			
GCS 14-15	342 (82.4)	837 (81.8)	0.077
GCS 8-13	24 (5.8)	91 (8.9)	
GCS < 8	48 (11.6)	95 (9.3)	
Physical Examination			
Findings, n (%)	172 (41.4)	353 (34.5)	
Contusion or Hematoma	89 (21.4)	214 (20.9)	0.011
Abrasion	33 (8.0)	75 (7.3)	
Palpable Skull Fracture	15 (3.6)	93 (9.1)	
Laceration			
CT Brain Performed, n (%)	187 (45.1)	660 (64.5)	<0.001
Endotracheal Intubation, n (%)	55 (13.3)	114 (11.1)	0.278
Blood Products Required, n (%)	18 (4.3)	60 (5.9)	0.583
ED LOS[#] (in hours), median (IQR)	2.7 (2.0-4.2)	2.1 (1.2-5.0)	0.026
ED Disposition, n (%)			<0.001
ICU/HD[^] Admissions	88 (21.2)	191 (18.7)	
Transfer to Operating Theatre	2 (0.5)	33 (3.2)	
Transfer to Other Medical Centres	8 (1.9)	18 (1.8)	
Neurosurgical Intervention, n (%)	31 (7.5)	84 (8.2)	0.594
Death, n (%)	25 (6.0)	30 (2.9)	0.012
Hospital LOS[#] (in days) for Admitted Patients, median (IQR)	1.0 (1.0-2.0)	1.0 (1.0-4.0)	<0.001

[#]LOS – Length of Stay
[^]ICU/HD – Intensive Care Unit/High Dependency

Table 3. Mechanism of injury, computed tomography use, severe and secondary outcomes by Gross National Income (GNI)

Primary Mechanism of injury					
	Lower Middle-Income, n (%)	Upper Middle-Income, n (%)	High-Income, n (%)	Total, n (%)	p value
Total	230	208	1000	1438	
Fall	122 (53.0)	90 (43.3)	745 (74.5)	957 (66.6)	<0.001
Traffic Injury	94 (40.9)	107 (51.4)	109 (10.9)	310 (21.6)	
Struck by Person or Object	5 (2.2)	8 (3.8)	104 (10.4)	117 (8.1)	
Sports Injury	2 (0.9)	1 (0.5)	22 (2.2)	25 (1.7)	
Stab or Cut	0 (0.0)	0 (0.0)	4 (0.4)	4 (0.3)	
Gun Shot	2 (0.9)	0 (0.0)	0 (0.0)	2 (0.1)	
Others#	5 (2.2)	2 (1.0)	16 (1.6)	23 (1.6)	
Computed Tomography Use					
CT Use	214 (93.0)	208 (100.0)	426 (42.6)	848 (59.0)	<0.001
Severe Outcomes					
Endotracheal Intubation	49 (21.4)	97 (46.6)	23 (2.3)	169 (11.8)	<0.001
Neurosurgical Intervention	20 (10.4)	71 (34.1)	24 (2.4)	115 (8.2)	<0.001
Death	13 (5.7)	35 (16.8)	7 (0.7)	55 (3.8)	<0.001
Secondary Outcome					
Admitted to Hospital	187 (81.3)	188 (90.4)	788 (78.8)	1163 (80.9)	<0.001
Hospital Length of Stay, median (IQR)	3.0 (2.0 – 6.0)	5.0 (2.0 – 13.0)	1.0 (1.0 – 2.0)	1.0 (1.0 – 3.0)	<0.001

‘Others’ mechanism comprised primarily of cases where the mechanism of injuries could not be obtained or categorized from retrospective chart review.

Table 4. Logistic regression for death, intubation or neurosurgical intervention

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Age	0.988 (0.960- 1.017)	0.968 (0.932 – 1.007)
Male Gender	1.612 (1.165 – 2.231)	1.233 (0.832 – 1.828)
Mechanism of Injury		
Fall	Referent	Referent
Road Traffic Injury	4.903 (3.574 – 6.726)	2.183 (1.448 – 3.293)
Struck by Person or Object	0.857 (0.433 – 1.695)	1.135 (0.484 – 2.661)
Others	2.084 (1.016 – 4.277)	2.946 (1.200 – 7.227)
Intent		
Unintentional	Referent	Referent
Intentional	2.956 (1.355 – 6.446)	2.470 (0.839 – 7.272)
Unknown	0.802 (0.278 -2.311)	1.252 (0.365 – 4.291)
Gross National Income		
High-Income	Referent	Referent
Upper Middle-Income	37.240 (24.178 – 57.360)	28.579 (17.986 – 45.412)
Lower Middle-Income	10.612 (6.838 – 16.471)	8.769 (5.520 – 13.929)

Figure 1. Map of participating Pan Asian Trauma Outcomes Study (PATOS) centres

Figure 2. Flow diagram of patients included for analysis

Contribution: CSL, URK, IS, and MEHO made substantial contributions to the conception and design of the work. CSL, URK, IS, SJS, WQ, SFJ, HTAQ, and CSY contributed in the data acquisition. CSL, URK, IS, CSY and MEHO contributed in the analysis and interpretation of the data. All authors revised it critically for important intellectual content and approved of the final version to be published.

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Competing interests: The authors have no conflict of interest to declare.

Data sharing statement: There is no additional unpublished data from this study available currently.

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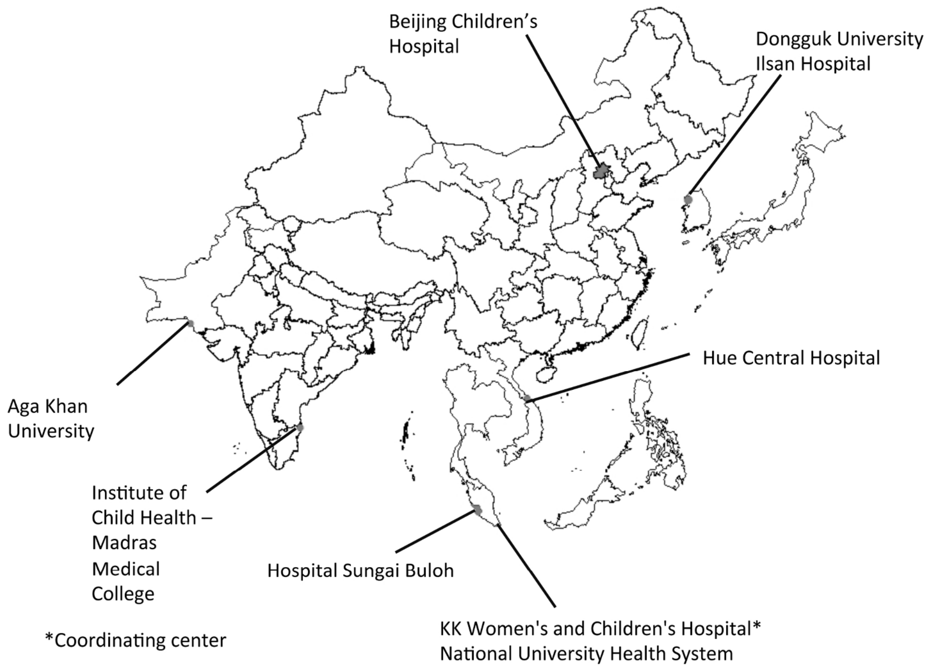

Figure 1. Map of participating Pan Asian Trauma Outcomes Study (PATOS) centres

198x139mm (300 x 300 DPI)

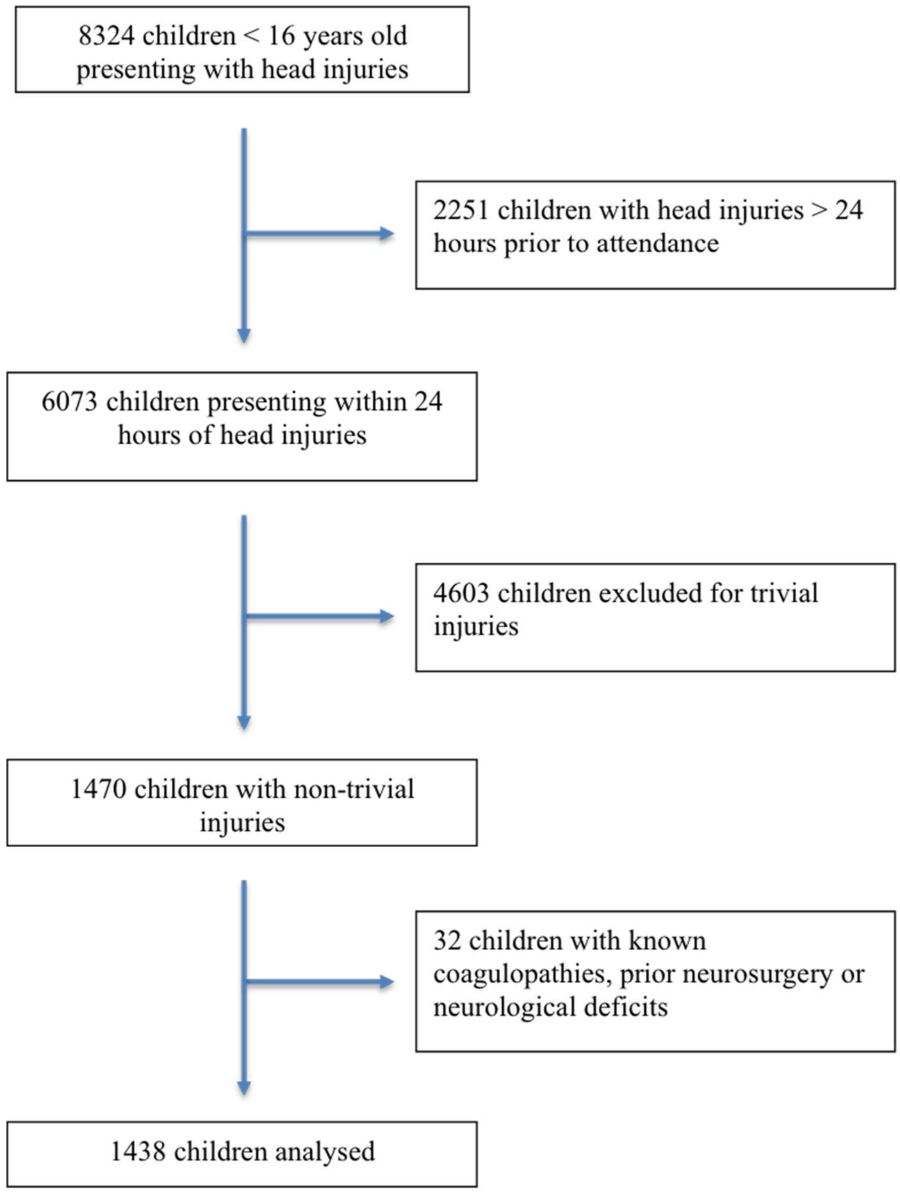

Figure 2. Flow diagram of patients included for analysis

131x177mm (300 x 300 DPI)

Supplementary Table 1. Number of patients analysed from each participating PATOS Centre

Lower Middle Income	n (%)	**Upper Middle Income**	n (%)	**High Income**	n (%)
Aga Khan University (Pakistan)	101 (7.0)	Beijing Children's Hospital (China)	137 (9.5)	Dongguk University Ilsan Hospital (South Korea)	185 (12.9)
Hue Central Hospital (Vietnam)	84 (5.8)	Hospital Sungai Buloh (Malaysia)	71 (4.9)	KK Women's and Children's Hospital (Singapore)	628 (43.7)
Institute of Child Health – Madras Medical College (India)	45 (3.1)			National University Health System (Singapore)	187 (13.0)
Total	230 (16.0)	Total	208 (14.5)	Total	1000 (69.5)

PATOS – Pan Asian Trauma Outcomes Study

Countries are categorised by Gross National Income (GNI) [9]

Supplementary Table 2. Individual hospital characteristics

	Annual Paediatric* Trauma Attendance	Annual Paediatric* Trauma Hospitalisations
Lower Middle Income		
Aga Khan University# (Pakistan)	509	411
Hue Central Hospital# (Vietnam)	2161	483
Institute of Child Health – Madras Medical College# (India)	1204	45
Upper Middle Income		
Beijing Children's Hospital (China)	10000	1500
Hospital Sungai Buloh (Malaysia)	2892	345
High Income		
Dongguk University Ilsan Hospital (South Korea)	4489	86
KK Women's and Children's Hospital (Singapore)	28222	2197
National University Health System (Singapore)	6501	708

*This is defined as < 16 years old
#Obtained from manual chart review

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 6-7
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	6-7
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	8
Objectives	3	State specific objectives, including any prespecified hypotheses	8
Methods			
Study design	4	Present key elements of study design early in the paper	9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	9-10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	9-10
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	10-11
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	10-11
Bias	9	Describe any efforts to address potential sources of bias	10-11
Study size	10	Explain how the study size was arrived at	NA
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	11
		(*b*) Describe any methods used to examine subgroups and interactions	11
		(*c*) Explain how missing data were addressed	12

		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	-
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	(Epidemiology study, all who fit inclusion criteria, Page 9-10)
		(c) Consider use of a flow diagram	Figure 2
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12-13, 20-21
		(b) Indicate number of participants with missing data for each variable of interest	12
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	13-14
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	14, 23
		(*b*) Report category boundaries when continuous variables were categorized	12-13, 20-21
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-14, 20-22
Discussion			
Key results	18	Summarise key results with reference to study objectives	16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19

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	26

*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.