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# Road traffic accidents in children: the 'what', 'how' and 'why'

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**INTRODUCTION** Road traffic accidents (RTAs) in Singapore involving children were evaluated, with particular focus on the epidemiology, surrounding circumstances and outcomes of these accidents. Key factors associated with worse prognosis were identified. We proposed some measures that may be implemented to reduce the frequency and severity of such accidents.

**METHODS** This was a retrospective study of RTAs involving children aged 0–16 years who presented to the Children's Emergency at KK Women's and Children's Hospital, Singapore, from January 2011 to June 2014. Data was obtained from the National Trauma Registry and analysed in tiers based on the Injury Severity Score (ISS).

**RESULTS** A total of 1,243 accidents were reviewed. RTA victims included motor vehicle passengers (60.4%), pedestrians (28.5%), cyclists (9.9%) and motorcycle pillion riders (1.2%). The disposition of emergency department (ED) patients was consistent with RTA severity. For serious RTAs, pedestrians accounted for 63.6% and 57.7% of Tier 1 (ISS > 15) and Tier 2 (ISS 9–15) presentations, respectively. Overall use of restraints was worryingly low (36.7%). Not restraining increased the risk of serious RTAs by 8.4 times. Young age, high ISS and low Glasgow Coma Scale score predicted a longer duration of intensive care unit stay.

**CONCLUSION** The importance of restraints for motor vehicle passengers or helmets for motorcycle pillion riders and cyclists in reducing morbidity requires emphasis. Suggestions for future prevention and intervention include road safety education, regulation of protective restraints, use of speed enforcement devices and creation of transport policies that minimise kerbside parking.

*Keywords: children, restraints, road traffic accidents, Singapore*

## INTRODUCTION

Injuries continue to be a leading cause of death and disability in children. Trauma has been reported as an important cause of childhood injuries in developed countries.(1) In the United States (US), over 1.5 million childhood trauma cases occur annually, resulting in approximately 600,000 hospitalisations and 15,000–20,000 paediatric deaths each year.(2) In China, trauma was consistently found to be among the top three causes of childhood death during the period of 2004–2011.(3)

Children present to our emergency department (ED) almost daily after having been involved in road traffic accidents (RTAs). However, to the best of our knowledge, there has not been a recent major analysis of these accidents and the consequent injuries. From 2011 to 2014, the motor vehicle population in Singapore increased from 956,704 to 972,037, while the number of casualties saw a disparate decrease from 11,065 to 9,834.(4) About 16% of the Singapore population of more than five million comprises children aged below 15 years.(5) No statistics are available on how many of these accidents involved children, or other indicators such as severity of accidents, their outcome and associated factors.

In the present study, we evaluated RTAs involving children in Singapore. The focus of our analysis was the epidemiology of these accidents, the circumstances surrounding them and their outcomes. Through this analysis, we identified some key factors associated with worse prognosis for children involved in RTAs. Using these results and what is known from studies in other countries, we proposed some measures that may be implemented to reduce the frequency of these accidents and decrease the severity of the injuries sustained when they do occur.

## METHODS

This was a retrospective study of RTAs involving children who presented to the Children's Emergency at KK Women's and Children's Hospital (KKH), Singapore, from January 2011 to June 2014. All children aged 0–16 years who presented to KKH for medical attention after being involved in an RTA were included in our study. The study population also comprised patients who initially presented to the EDs of other hospitals and were transferred to KKH for continued care. Data was obtained from the National Trauma Registry and analysed in tiers based on the Injury Severity Score (ISS). Information that is usually entered into the National Trauma Registry is shown in Table I.

RTAs were divided into three tiers based on severity, as determined by the ISS, with Tier 1 (ISS > 15) being the most severe and Tier 3 (ISS < 9) being the least severe. Tier 1 and Tier 2 (ISS 9–15) RTAs were considered to be serious RTAs, while Tier 3 RTAs were non-serious RTAs. Patients were analysed to identify factors that were significantly different across these tiers and could potentially explain the severity of an RTA.

The information obtained was compiled using Microsoft Excel 2010 (Microsoft Corp, Redmond, WA, USA). Data

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**Table I. Data fields in the National Trauma Registry.**

| Data type | Information collected |
|---|---|
| Demographic data | Patient identification, name |
| | Resident status |
| | Date of birth |
| | Age (yr, mth) |
| | Gender |
| | Country of citizenship |
| | Ethnic group |
| Injury epidemiology | Type of injury (blunt or penetrating) |
| | Mechanism of injury |
| | Road traffic accident |
| | *Injured person type* |
| | *Type of vehicle* |
| | *Was a collision involved?* |
| | *Type of object collided with* |
| | *Type of impact (e.g. head-on, side-on, rear end, roll over)* |
| | *Injured restrained?* |
| | *Type of restraint used* |
| | *Site of road traffic accident* |
| | Place of occurrence |
| Pre-hospital details | Mode of arrival to ED |
| | Standby case |
| | Injury date and time |
| | Transferred in? (yes/no) |
| | Referring hospital/facility |
| Clinical data | ED 1st parameter |
| | *Pulse (beats/min), respiratory rate (breaths/min)* |
| | *SBP (mmHg), DBP (mmHg)* |
| | *$O_2$ saturation (%)* |
| | *Glasgow Coma Scale score* |
| | Paediatric Trauma Score |
| Acute care | Arrival date and time |
| | Trauma team activated |
| | Airway established |
| | Disposition of ED patient |
| | Complications during acute care (yes/no, description) |
| | Length of hospital stay (ICU, high dependency ward, total) in days |
| | Fluid/blood given (amount, location) |
| | Surgeries performed and description |
| | CT or angiography done and description |
| | Discharge status (alive/dead) |
| Injuries | Injuries on admission |
| | Final injuries list |
| | General injury data (RTS, PS, ISS) |

CT: computed tomography; DBP: diastolic blood pressure; ED: emergency department; ICU: intensive care unit; ISS: Injury Severity Score; PS: probability of survival; RTS: Revised Trauma Score; SBP: systolic blood pressure

entered was counter-checked using the Online Paediatric Emergency Care system version 5.5.10 (Eutech Cybernetics Pte Ltd, Singapore), which is the software used at KKH Children's Emergency to document every patient encounter. Errors were corrected and missing data was obtained to improve the accuracy and comprehensibility of our results. The characteristics of patients were presented in percentages and frequencies.

All statistical analyses were carried out using SAS version 9.4 (SAS Institute, Cary, NC, USA). Logistic regression analysis was conducted on Tier 1 and 2 RTAs jointly, given the similarity of Tier 1 and 2 accidents by mechanism of injury ($\chi^2$ = 1.8249, df = 3; p = 0.6095), to determine factors that could be associated with a child being at higher risk for a serious RTA, and the odds ratios for significant factors were computed. With a focus on severe RTAs, further analysis was also done to determine key factors for adverse clinical outcome. A p-value < 0.05 was considered to be statistically significant.

## RESULTS

The demographics, clinical characteristics, acute care management and hospitalisation outcome of RTA victims are shown in Table II. A similar analysis of the RTA victims based on their mode of transportation is presented in Table III.

A total of 1,243 patients presented to the ED following RTAs during the study period. There were 22 (1.8%), 26 (2.1%) and 1,195 (96.1%) patients in Tier 1, Tier 2 and Tier 3, respectively. The mean age of RTA victims was 8.0 ± 4.5 years, with a slight male preponderance (57.1%). The ethnic composition of the patients was Chinese (57.2%), Malay (23.7%), Indian (10.1%) and others (9.1%). The majority (75.0%) were Singaporean. RTA victims were mostly motor vehicle passengers (60.4%), followed by pedestrians (28.5%), cyclists (9.9%) and motorcycle pillion riders (1.2%). Most RTAs involved a collision with a car, pickup truck or van (80.7%). The use of restraints/protective headgear (36.7%) was worryingly low across all tiers, and was the lowest in Tier 1 (0%) and the highest in Tier 3 (37.3%) accidents. The majority of RTA victims who were in any type of vehicle did not use restraints/protective headgear.

Contrary to our expectations, an analysis of factors that were significantly different across the various tiers and could possibly explain RTA severity found that the object or vehicle that victims collided with did not affect RTA severity. Although pedestrians only accounted for 28.5% of overall RTA injuries that presented to our ED, they made up a significant proportion of Tier 1 (63.6%) and Tier 2 (57.7%) presentations. This indicated a trend toward worse presentation and injury profile among pedestrians involved in RTAs.

Mean time spent at the ED was 126.0 ± 82.4 minutes. The disposition of ED patients was consistent with RTA severity. The proportion of Tier 1, 2 and 3 patients who were admitted to the intensive care unit (ICU) was 86.4%, 38.5% and 0.3%, respectively. The proportion of Tier 1, 2 and 3 patients admitted to the high dependency ward was 4.5%, 30.8% and 1.4%, respectively. 2 (0.2%) patients who were classified as Tier 1 RTA died at the Children's Emergency. Further analysis also showed that patients in Tier 1 had a significantly longer mean duration of ICU stay than those in Tier 2 (7.5 ± 6.2 days vs. 2.1 ± 3.4 days; p = 0.0014).

**Table II. Demographics and clinical characteristics of road traffic accident (RTA) victims.**

| Variable | No. (%)/mean ± standard deviation | | | | p-value |
|---|---|---|---|---|---|
| | Overall (n = 1,243) | Tier 1 (n = 22) | Tier 2 (n = 26) | Tier 3 (n = 1,195) | |
| **Age (yr)** | 8.0 ± 4.5 | 8.0 ± 4.2 | 10.4 ± 3.3 | 8.0 ± 4.5 | 0.0209 |
| **Gender** | | | | | 0.2210 |
| Male | 710 (57.1) | 16 (72.7) | 17 (65.4) | 677 (56.7) | |
| Female | 533 (42.9) | 6 (27.3) | 9 (34.6) | 518 (43.3) | |
| **Ethnicity** | | | | | 0.1931 |
| Chinese | 711 (57.2) | 12 (54.5) | 16 (61.5) | 683 (57.2) | |
| Malay | 294 (23.7) | 3 (13.6) | 3 (11.5) | 288 (24.1) | |
| Indian | 125 (10.1) | 2 (9.1) | 3 (11.5) | 120 (10.0) | |
| Other | 113 (9.1) | 5 (22.7) | 4 (15.4) | 104 (8.7) | |
| **Country of citizenship** | | | | | 0.0597 |
| Singapore | 932 (75.0) | 17 (77.3) | 16 (61.5) | 899 (75.2) | |
| India | 42 (3.4) | 0 (0) | 1 (3.8) | 41 (3.4) | |
| Malaysia | 29 (2.3) | 1 (4.5) | 0 (0) | 28 (2.3) | |
| Indonesia | 13 (1.0) | 0 (0) | 2 (7.7) | 11 (0.9) | |
| Other | 227 (18.3) | 4 (18.2) | 7 (26.9) | 216 (18.1) | |
| **Details and assessment of RTA** | | | | | |
| Injured person profile | | | | | < 0.0001 |
| *Cyclist* | 123 (9.9) | 4 (18.2) | 4 (15.4) | 115 (9.6) | |
| *Motor vehicle passenger* | 750 (60.4) | 4 (18.2) | 5 (19.2) | 741 (62.1) | |
| *Motorcycle pillion rider* | 15 (1.2) | 0 (0) | 2 (7.7) | 13 (1.1) | |
| *Pedestrian* | 354 (28.5) | 14 (63.6) | 15 (57.7) | 325 (27.2) | |
| Restrained/wore protective headgear | | | | | 0.0153 |
| *Yes* | 325 (36.7) | 0 (0) | 1 (9.1) | 324 (37.3) | |
| *No* | 560 (63.3) | 6 (100.0) | 10 (90.9) | 544 (62.7) | |
| Type of object collided with | | | | | 0.2458 |
| *2-/3-wheeler motor vehicle* | 66 (6.4) | 4 (18.2) | 1 (3.8) | 61 (6.2) | |
| *Car, pickup truck or van* | 829 (80.7) | 14 (63.6) | 21 (80.8) | 794 (81.1) | |
| *Fixed/stationary object* | 49 (4.8) | 2 (9.1) | 0 (0) | 47 (4.8) | |
| *Heavy transport vehicle/bus* | 57 (5.6) | 1 (4.5) | 3 (11.5) | 53 (5.4) | |
| *Other* | 26 (2.5) | 1 (4.5) | 1 (3.8) | 24 (2.5) | |
| ISS | – | 27.2 ± 8.3 | 10.6 ± 1.7 | – | < 0.0001 |
| Revised Trauma Score | – | 5.3 ± 2.5 | 7.7 ± 0.3 | – | < 0.0001 |
| Probability of survival | – | 72.9 ± 30.6 | 99.2 ± 0.3 | – | 0.0001 |
| Glasgow Coma Scale score | – | 8.7 ± 4.9 | 14.6 ± 0.9 | – | < 0.0001 |
| **Acute care management** | | | | | |
| Time spent at ED (min) | 126.0 ± 82.4 | 78.5 ± 63.2 | 81.7 ± 50.5 | 127.4 ± 82.7 | 0.0034 |
| Trauma team activated | 26 (2.1) | 15 (68.2) | 7 (26.9) | 4 (0.3) | < 0.0001 |
| Airway established | 32 (2.6) | 10 (45.5) | 5 (19.2) | 17 (1.4) | < 0.0001 |
| Disposition of ED patient | | | | | < 0.0001 |
| *ICU* | 32 (2.6) | 19 (86.4) | 10 (38.5) | 3 (0.3) | |
| *HD ward* | 26 (2.1) | 1 (4.5) | 8 (30.8) | 17 (1.4) | |
| *General ward* | 308 (25.1) | 0 (0) | 8 (30.8) | 300 (25.4) | |
| *Discharge from ED* | 843 (68.6) | 0 (0) | 0 (0) | 843 (71.4) | |
| *Discharge at own risk* | 18 (1.5) | 0 (0) | 0 (0) | 18 (1.5) | |
| *Morgue* | 2 (0.2) | 2 (9.1) | 0 (0) | 0 (0) | |
| **Hospitalisation outcome** | | | | | |
| Duration of stay in ICU (day) | – | 7.5 ± 6.2 | 2.1 ± 3.4 | – | 0.0014 |
| Duration of stay in HD ward (day) | – | 3.1 ± 2.0 | 1.7 ± 2.7 | – | 0.0826 |
| Total duration of hospitalisation (day) | | 23.3 ± 14.9 | 9.6 ± 10.0 | – | 0.0006 |
| Mortality | 2 (0.2) | 2 (9.1) | 0 (0) | 0 (0) | |

Percentage values are computed after excluding missing data points within the sample. Injury Severity Score (ISS) was classified as Tier 1 (ISS > 15), Tier 2 (ISS 9–15) and Tier 3 (ISS < 9). ED: emergency department; HD: high dependency; ICU: intensive care unit

**Table III. Demographics and severity of injury of road traffic accident (RTA) victims according to mode of transportation.**

| Variable | No. (%)/mean ± standard deviation | | | | p-value |
|---|---|---|---|---|---|
| | Cyclist (n = 123) | Motor vehicle passenger (n = 750) | Motorcycle pillion rider (n = 15) | Pedestrian (n = 354) | |
| **Age (yr)** | 10.8 ± 4.1 | 6.7 ± 4.3 | 11.6 ± 3.3 | 9.8 ± 4.2 | < 0.0001 |
| **Gender** | | | | | < 0.0001 |
| Male | 102 (82.9) | 391 (52.1) | 10 (66.7) | 206 (58.2) | |
| Female | 21 (17.1) | 359 (47.9) | 5 (33.3) | 148 (41.8) | |
| **Ethnicity** | | | | | < 0.0001 |
| Chinese | 52 (42.3) | 459 (61.2) | 5 (33.3) | 194 (54.8) | |
| Malay | 39 (31.7) | 170 (22.7) | 8 (53.3) | 77 (21.8) | |
| Indian | 22 (17.9) | 58 (7.7) | 1 (6.7) | 44 (12.4) | |
| Other | 10 (8.1) | 63 (8.4) | 1 (6.7) | 39 (11.0) | |
| **Country of citizenship** | | | | | 0.0005 |
| Singapore | 95 (77.2) | 574 (76.5) | 11 (73.3) | 251 (70.9) | |
| India | 10 (8.1) | 12 (1.6) | 0 (0) | 20 (5.6) | |
| Malaysia | 2 (1.6) | 15 (2.0) | 1 (6.7) | 11 (3.1) | |
| Indonesia | 2 (1.6) | 8 (1.1) | 1 (6.7) | 2 (0.6) | |
| Other | 14 (11.4) | 141 (18.8) | 2 (13.3) | 70 (19.8) | |
| **Details and assessment of RTA** | | | | | < 0.0001 |
| Tier 1 | 4 (3.3) | 4 (0.5) | 0 (0) | 14 (4.0) | |
| Tier 2 | 4 (3.3) | 5 (0.7) | 2 (13.3) | 15 (4.2) | |
| Tier 3 | 115 (93.5) | 741 (98.8) | 13 (86.7) | 325 (91.8) | |
| Type of object collided with* | | | | | < 0.0001 |
| *2-/3-wheeler motor vehicle* | 5 (5.6) | 26 (4.0) | 1 (8.3) | 34 (12.5) | |
| *Car, pickup truck or van* | 70 (77.8) | 536 (82.2) | 7 (58.3) | 216 (79.4) | |
| *Fixed/stationary object* | 0 (0) | 47 (7.2) | 1 (8.3) | 1 (0.4) | |
| *Heavy transport vehicle/bus* | 2 (2.2) | 42 (6.4) | 1 (8.3) | 12 (4.4) | |
| *Other* | 13 (14.4) | 1 (0.2) | 2 (16.7) | 9 (3.3) | |

*Percentage values are computed after excluding missing data points within the sample.

Logistic regression analysis of factors that were associated with a child being at higher risk for a serious RTA showed that compared to an RTA victim in a motor vehicle, a cyclist was 5.8 times ($p = 0.0012$) more likely to be involved in a Tier 1 or 2 RTA (Table IV). Similarly, a motorcycle pillion rider was 22.1 times ($p = 0.0007$) and a pedestrian 55.0 times ($p = 0.0002$) more likely to be involved in a serious RTA. The use of restraints/protective headgear showed positive benefits; conversely, being unrestrained/unprotected increased the risk of a serious RTA by 8.4 times ($p = 0.0457$).

Further linear regression analysis of key factors for adverse clinical outcome in severe RTAs, using the duration of ICU stay as a surrogate measure, showed that young age ($p = 0.0478$), high ISS ($p = 0.0011$) and low Glasgow Coma Scale (GCS) score ($p = 0.0488$) predicted longer duration of ICU stay, with $R^2$ of 65.9% (Table V).

Although restraints and helmets are known to reduce morbidity, we found insufficient use of restraints by motor vehicle passengers and of helmets by motorcyclist pillion riders and cyclists. Over 50% of RTA victims who were in any vehicle did not use restraints/helmets, and cyclists were the least protected group (94.3% without helmet). The profile of restraints/protective headgear used by the RTA victims is presented in Table VI.

**Table IV. Association between road traffic accident (RTA) severity and profile of victim.**

| Variable | OR (95% CI) | p-value |
|---|---|---|
| **Unrestrained/unprotected** | 8.4 (1.0–68.2) | 0.0457 |
| **Vehicle of RTA victim** | | |
| Motor vehicle | 1 (Reference) | Reference |
| Bicycle | 5.8 (2.0–16.6) | 0.0012 |
| Motorcycle | 22.1 (3.7–130.7) | 0.0007 |
| Pedestrian | 55.0 (6.9–437.6) | 0.0002 |

Severe and non-severe RTAs were compared. CI: confidence interval; OR: odds ratio

## DISCUSSION

This study supports earlier studies showing that RTAs are a significant health problem in the paediatric population. To the best of our knowledge, there have been no studies in Singapore to date that have focused on paediatric RTAs. An epidemiological study from the United Arab Emirates showed a higher mean age of 13.2 years and more similar characteristics in terms of the type of RTA victims, with the majority being motor vehicle passengers.[6] Similar to several local and international studies, including those on adult populations, the proportion of boys was higher than that of girls in our study.[7-13]

**Table V. Impact of victim characteristics on duration of intensive care unit stay in severe road traffic accidents.**

| Variable | Beta | SE | p-value |
|---|---|---|---|
| Age | −0.32 | 0.15 | 0.0478 |
| ISS | 0.27 | 0.08 | 0.0011 |
| GCS | −0.42 | 0.21 | 0.0488 |

$R^2$ = 65.9%. GCS: Glasgow Coma Scale score; ISS: Injury Severity Score; SE: standard error

**Table VI. Profile of restraints/protective headgear used among road traffic accident victims.**

| Variable | No. (%) |
|---|---|
| **Motor vehicle passenger (n = 750)** | |
| Car seat belt | 213 (28.4) |
| Booster seat | 34 (4.5) |
| Baby car seat* | 26 (3.5) |
| None | 477 (63.6) |
| **Motorcycle pillion rider (n = 15)** | |
| Helmet | 7 (46.7) |
| None | 8 (53.3) |
| **Cyclist (n = 123)** | |
| Helmet | 7 (5.7) |
| None | 116 (94.3) |

*Baby car seat included both baby convertible and infant capsule.

In terms of RTA victims with severe injuries, international studies have also found that pedestrians in the paediatric population account for a majority of severe injuries sustained.[8,10] Such a finding has also been confirmed in local studies.[14,15] A study in Montreal, Canada, has similarly shown that among victims who sustained severe injuries, 69% were pedestrians.[10] In that study, however, the proportion of pedestrian victims was 57%, as opposed to the 28.5% in our study. Likewise, in northern Manhattan in the US, the percentage of pedestrian victims (64.9%) was higher than motor vehicle occupants (14.9%).[16]

The safety benefits of restraint use and rear seating of children have been demonstrated in multiple studies, with higher GCS score at presentation, and significant reductions in the Abbreviated Injury Scale score, ISS, duration of hospital stay and operations required for those involved in traffic accidents.[17-23] Up to 27% of serious injuries were found to be preventable if all children used appropriate restraints in a motor vehicle.[17] As opposed to the dismal overall 36.7% of our patients who were appropriately restrained/protected, a much higher compliance rate for restraints was reported in a US study,[16] with only 3% of patients reported to not having been using restraints. This is without doubt a significant area for improvement in our local population.

In our study, pedestrian victims were shown to be a highly vulnerable group; hence, recognising the factors that may contribute to pedestrian injuries is of paramount importance. Common contributing factors seen in other studies include occurrence during weekdays or daylight hours, children from families of low socioeconomic status, low paternal education, traffic exposure during journey to school, lack of supervision during outside play and duration of outside play.[24-27]

Child pedestrians are uniquely vulnerable due to their immature level of physical, sensory and cognitive development, leading to potential errors in judgement, decision-making and impulse control.[8,26,28] Given their small physical size, drivers' view of them is easily obstructed. In one review published by the Child Death Review Unit (CDRU), British Columbia, Canada, driver visibility of 54.5% of injured pedestrians was reduced by multiple factors, such as darkness, roadside objects (e.g. parked cars) and vehicle configuration.[28] The large surface-area-to-body ratio among children and their relatively large head also predispose them to more severe injury.

Risky behaviour, or lack of inhibitory control, is one of the strongest predictors of child pedestrian injuries and fatalities.[14,27] Examples of common risky pedestrian behaviour in children are crossing or darting into oncoming traffic, and walking or playing on the roadway. Although pedestrian education and skill-building programmes have demonstrated improvements in safety attitudes and awareness, these interventions have not had a measurable effect on child injury rates.[28] Given the developmental vulnerability involved and limited effectiveness of child pedestrian education as an isolated strategy, adult supervision is critical for ensuring that young children navigate traffic safely.

As this was a retrospective study, there were limitations in obtaining specific data for all patients. Unlike overseas studies that have the benefit of analysing a standard and highly comprehensive set of data from insurance companies,[16] our available data was comparatively limited, as illustrated in Table I. For future studies, additional data that could be collected include the location and timing of accidents, so as to concentrate the necessary resources required to implement changes that could help to reduce the incidence of RTAs. A joint project with accident reporting centres in Singapore that collect a more extensive set of data could further augment our understanding of local RTA characteristics. Other factors that were not studied, which may have influenced the number of fatalities or the difference in ISS scores, include ambulance response times, pre-hospital care provided and the presence of adult supervision during the time of injury.

Another limitation of this study was that it took place at a single centre: the triage and disposition of paediatric patients who present to other hospitals after RTAs may differ. As KKH is the largest children's hospital in Singapore, most patients who are stable after having been involved in an RTA would have presented to our department. A potential blind spot comprised children involved in RTAs who were taken to other hospitals, and died there or were deemed too ill for transfer, or were well on arrival and discharged directly from those respective EDs.

Based on our findings and the currently available literature, there are strong grounds to recommend that preventive measures aimed at reducing serious RTAs in children should adopt a multipronged approach. We suggest involving all stakeholders in this effort.

For children, road safety education should be encouraged, for them to learn and follow practices for remaining safe on the roads. Children involved in RTAs are largely in the 6–10 years age group. Even though previous studies have not shown a significant decrease in injury rates with the implementation of pedestrian education and skill-building programmes,[28] we feel that inculcating safety knowledge and translating such knowledge into active practice is still necessary. Constant reinforcement of road safety principles and rules to children – done in tandem at home and school, both in theory and practice – would result in more effective primary prevention. Specific areas for education are road safety as pedestrians or cyclists, the necessity of wearing helmets for cyclists and the need to buckle seatbelts for motor vehicle passengers. Other additional safety measures are ensuring that children wear bright or light-coloured clothing to increase their visibility to drivers, ensuring that they have reflective light strips on some clothes and backpacks, and fitting their bicycles with front and rear lights.

We recommend that such education be started as early as kindergarten level (age five years) and remain a permanent fixture in the curriculum of both public and private schools. Currently in Singapore, most primary schools organise a trip to the Road Safety Community Park, where students are taught basic road safety rules and put this knowledge to use in a session during which they can be pedestrians, cyclists or drivers, and they have to make it through a road circuit without violating any of the rules. We hope that such visits continue to be incorporated into the primary school curriculum.

Parents and guardians can help on several fronts, including the provision of adequate supervision. The CDRU in British Columbia is the only agency that systematically collects data on adult supervision in fatal childhood injuries. Results of its review showed that only 33% of children under ten years of age were under active supervision (i.e. within sight and reach) of an adult at the time of the fatal incident.[28] Presence of adult supervision during play has been found to be strongly associated with reduction in child pedestrian RTAs.[25] These findings strongly support the need to raise awareness about child pedestrian injuries and improve supervision practices among parents and caregivers.

Vehicle drivers could potentially play pivotal roles in ensuring road safety by, for instance, maintaining up-to-date knowledge on size-appropriate restraints for children and enforcing their compulsory use. Residents in Singapore applying for a driving licence are required to take at least a basic theory test involving local traffic rules and regulations. We suggest that knowledge of height-appropriate restraints for children in vehicles be emphasised. Currently in Singapore, all children of height below 1.35 m are required to be secured with a child seat appropriate for their height and weight, or a booster seat to supplement the seat belt, whereas those over 1.35 m are required to wear a seat belt. It is also mandatory for all school buses to have three-point seat belts, and all passengers are required to wear the appropriate child restraints or seat belts.[29] Vehicle drivers could also ensure that children are placed in the rear seats. For more than a decade, studies have demonstrated the synergistic benefit of placing children in the rear seat, coupled with appropriate restraint use.[17,20,21,30,31] This is a practice that we opine can be easily promoted and has an extremely low barrier to implementation.

Law enforcement agencies may potentially play a more active role in ensuring the implementation of road safety practices. The use of protective restraints could be mandated, as this is currently not strictly enforced in Singapore. While many drivers are aware of the rules, a significant proportion of drivers do not adhere to them. Stricter enforcement of these rules, possibly through roadblocks and random checks, would help to improve compliance.

Speed enforcement detection devices at crucial areas, particularly school zones and areas of high foot traffic, could be put in place. Cochrane reviews done over the past decade have shown that speed cameras are a worthwhile intervention in the prevention of road traffic injuries and deaths.[32,33] Another effective intervention is the introduction of red-light cameras for reducing total casualty crashes.[34] Around school zones and areas of high foot traffic, which other studies have identified as locations where children are at higher risk of traffic accidents, the combined implementation of speed cameras and red light cameras is likely to be beneficial.

We also propose the creation of transport policies that minimise kerbside parking, particularly during periods when children are at higher risk, such as during daylight hours on weekdays, and in areas of high traffic movement. Roberts et al[24] suggested that high density of kerbside parking on the streets increases the risk of child pedestrian injury, as these parked vehicles may obstruct oncoming drivers' view of children as they cross the road. Kerbside parking is not uncommon in Singapore, especially during peak hours, when parents drop off or pick up their children from school. This is an area where the Land Transport Authority, the lead agency in Singapore dealing with road safety, may be able to play a significant role.

In conclusion, our study has found that child pedestrians are at the highest risk of being involved in serious RTAs, although a majority of local RTA victims are motor vehicle passengers. We also highlighted the dismal rate of use of appropriate restraints/protective headgear for children while on the road. These are areas in which there is great potential for improvement. We have proposed some measures that we hope will be implemented, with the ultimate aim of protecting our children from preventable injuries.

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