Geospatial and clinical analyses on pediatric related road traffic injury in Malaysia

Nik Hisamuddin Rahman¹, Ruslan Rainis², Syed Hatim Noor³, Sharifah Mastura Syed Mohamad⁴

¹ Department of Emergency Medicine, School of Medical Sciences, USM, Kota Bharu 16150, Malaysia
² School of Humanity, USM, Penang, Malaysia
³ Unit of Biostatistics, School of Medical Sciences, USM, Kota Bharu 16150, Malaysia
⁴ Unit of Health Informatics, School of Health Sciences, USM, Kota Bharu 16150, Malaysia

Corresponding Author: Nik Hisamuddin Rahman, Email: nhliza@hotmail.com

BACKGROUND: The main aim of this study is to utilize the geographical information system (GIS) software and perform the spatial analysis in relation to clinical data for road traffic injury (RTI) pediatric cases attending the emergency department.

METHODS: The study sample included pediatric patients (age less than 18 years) with road-related injuries within a district in Malaysia who attended emergency departments of two tertiary hospitals within the district. In addition to injury, pre-hospital care and outcome data, the coordinate of the locations were obtained by the ambulance paramedics by using portable handheld GPS unit brand Garmin® model GPS 72 H. The data was transferred into the excel format which in turn underwent GIS analysis by using ARCGIS® (by ESRI) software version 10.1 licensed to the study institution.

RESULTS: A total of 102 (24.8%) of all motor vehicle crash (MVC) victims involved the pediatric age group (age 18 years and below). The mean (SD) age of the pediatric victims was 14.30 years (SD 3.830). Male comprised of 68 (66.7%) of the cases. Motorcyclists [88 (88.0%)] were the most common type of victims involved. Interestingly, the majority of the severely injured victims [75 (73%)] sustained the RTI on roads with maximum speed limit of 60 km/hour. The mean (SD) length of hospital stay was 7.83 days (5.59).

CONCLUSION: The pediatric related road traffic injury in Malaysia causes significant health and social burden in the country. This study showed both important clinical and geographical factors that need to be taken into consideration for future preventive action.

KEY WORDS: Pediatric; Injury; Road safety; Geospatial; Geographical information system

INTRODUCTION

Road traffic injury (RTI) is a very common cause of admission to the hospital worldwide, in particular in developing countries.¹ The most productive and vulnerable group of the population is the mostly affected by injury. Loss of days of work, schooling and earning as a result of the injuries contribute to further socioeconomic deprivation in the society. Much of the data and work previously focused on general epidemiology and clinical outcome and yet little information is gathered on geospatial risk factors especially among the vulnerable group of road users such as children. The main aim of this study is to utilize the geographical information system (GIS) software and perform the spatial and multiple logistic regression analyses in relation to clinical data for road traffic injury (RTI) pediatric cases attending the emergency department. Specifically we would perform the buffer analysis to determine common geographical buildup in the vicinity of RTI affecting children in Malaysia.
METHODS

This study was a prospective cohort cross sectional study from July 2011 until June 2013. The study sample included pediatric patients (age less than 18 years) with road-related injuries within a district in Malaysia who attended emergency departments of two tertiary hospitals within the district. The Kota Bharu district in the east coast of Peninsular of Malaysia was chosen due to its high motorvehicle crash incidents based on the Royal Malaysian Police report. Consent was obtained from each patient or legal guardians by using standard consent form approved by ethical committee of the main study center. By using a two proportion sampling; alpha value of 0.05, power of study 80% and 20% drop out, the required sample of road traffic accident victims were 101 cases.\(^2\)

The exclusion criteria included missing or unable to detect the exact location and coordinate (latitude and longitude) of RTI, injury treated in hospitals other than the two study hospitals, injury caused by other events i.e domestic violence or assault, adults patients (age 18 years and above) and no/lack of clinical outcome data available. The clinical variables were documented prospectively and retrospectively based on the ED clerking sheet and medical record. In addition to injury, pre-hospital care and outcome data, the coordinate of the locations were obtained by the ambulance paramedics by using portable handheld GPS unit brand Garmin\(^\circledR\) model GPS 72 H with Serial number 1T7071348 (Manufactured in Taiwan by Garmin\(^\circledR\) Corporation in 2010) which was accurate to 5 meters of the location. The final injury severity score (ISS) was recorded retrospectively prior to discharge from the hospitals. The disability outcome was considered either at discharge from the ED and/or from the ward. Disability at discharge was defined as a physical or mental condition that limits a person's movements, senses, or activities as a consequence of RTI. The data was transferred into the excel format which in turn underwent GIS analysis by using ARCGIS\(^\circledR\) (by ESRI) software version 10.1 licensed to the study institution. The GIS analysis included general borough and road network RTI layer mapping and Buffer analysis (within 100 meters) of accident locations (Figure 1). The variables for geographical build up area within the vicinity of each RTI cases were also obtained by direct visualization (photo) and by using Google Earth\(^\text{TM}\) free software version 7.1.2.2041 operating system Microsoft Windows\(^\circledR\) (5.1.2600.3) with maximum texture size set at 4096×4096 and image date taken on the 19\(^\text{th}\) August 2013 (Figure 2). The data was geospatially analyzed by using buffer and inverse distance weighting to obtain the geographical build up factors and density of motor vehicle crash (MVC) involving children respectively. The combination of geographical and other clinical data (ISS, GCS, age, number of body parts injured, operative procedure, helmet wearing, pre-hospital and injury data) were analyzed by using multiple logistic regression analysis to predict the hospital admission and the occurrence of disability at discharge. Variable selections were based on any variable with \(P\)-value less than 0.25 and clinical importance for further analysis.

![Figure 1. The 100-meter buffer for each accident point.](image1)

![Figure 2. The Google Earth analysis of geographical build up for each MVC point.](image2)
RESULTS

A total of 102 (24.8%) of all MVC victims involved the pediatric age group (age 18 years and below). The mean (SD) age of the pediatric victims was 14.30 years (SD 3.830). Male comprised of 68 (66.7%) of the cases. Sixty-nine (67.7%) of the victims were involved in the MVC during non-school period i.e. late afternoon and evening. Motorcyclists [88 (88.0%)] were the most common type of victims involved. Thirty-seven (47.0%) of the motorcyclists admitted wearing the safety helmets either from the history taking or from the witness. The ED triage distribution in the ED for all the MVC victims was as shown in (Figure 3). Thirty-five (34.3%) victims were admitted to the wards. The majority of the cases [65 (64%)] were discharged directly from the ED. Whereas those who were admitted include orthopedic [21 (62%)], neurosurgery [7 (21%)], maxillofacial [3 (9%)] and other surgical related disciplines cases. The mean (SD) length of hospital stay was 7.83 days (5.59). Majority of the patients [59 (57.8%)] were discharged well whereas 43 (42.2%) were disabled upon discharged from the ED respectively.

The majority of the MVC [310 (73.3%)] occurred on the municipal roads within the District of Kota Bharu which was under the maintenance of the Municipal Office of Kota Bharu (MPKB). The distribution was almost equally distributed in both urban and suburban areas of the district. Other geographical data variable was as shown in Table 1. Sixty-six (64.7%) of cases occurred on straight road. Figures 4 & 5 show general geospatial distribution (inverse distance weighting) of MVC and motorcycle related injury respectively involving children within the study district. Interestingly, the majority of the severely injured victims [75 (73%)] sustained the RTI on roads with maximum speed limit of 60 km/hour, whereas only 5 (4%) cases of the severely injured victims occurred on the roads with maximum speed limit of 90 km/hour. The highest

<table>
<thead>
<tr>
<th>Type of location (valid)</th>
<th>n (%)</th>
<th>Valid percent</th>
<th>Cumulative percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburban</td>
<td>50 (48.0)</td>
<td>48.5</td>
<td>48.5</td>
</tr>
<tr>
<td>Urban</td>
<td>52 (51.0)</td>
<td>51.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>102 (99.0)</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Build up surrounding(valid)</th>
<th>n (%)</th>
<th>Valid percent</th>
<th>Cumulative percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop lots</td>
<td>31 (30.4)</td>
<td>30.4</td>
<td>30.4</td>
</tr>
<tr>
<td>Residential houses</td>
<td>25 (24.5)</td>
<td>24.5</td>
<td>54.9</td>
</tr>
<tr>
<td>Schools</td>
<td>18 (17.6)</td>
<td>17.6</td>
<td>72.5</td>
</tr>
<tr>
<td>Offices</td>
<td>4 (3.9)</td>
<td>3.9</td>
<td>76.5</td>
</tr>
<tr>
<td>Villages</td>
<td>3 (2.9)</td>
<td>2.9</td>
<td>79.4</td>
</tr>
<tr>
<td>Markets</td>
<td>1 (1.0)</td>
<td>1.0</td>
<td>80.4</td>
</tr>
<tr>
<td>Cafes restaurants</td>
<td>4 (3.9)</td>
<td>3.9</td>
<td>84.3</td>
</tr>
<tr>
<td>Plantation</td>
<td>1 (1.0)</td>
<td>1.0</td>
<td>85.3</td>
</tr>
<tr>
<td>Others</td>
<td>6 (5.9)</td>
<td>5.9</td>
<td>91.2</td>
</tr>
<tr>
<td>Mixed building</td>
<td>9 (8.8)</td>
<td>8.8</td>
<td>99.9</td>
</tr>
<tr>
<td>Total</td>
<td>102 (100.0)</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Initial triage coding in the ED for pediatric victims.

Table 1. Geographical demography of MVC involving pediatric group

Figure 4. Map of motor vehicle crash involving pediatric age group based on inverse distance weighting analysis.
density of MVC among the children occurred within the borough known as Kenali.

Pediatric age group (less than 19 years of age) had 52.1% lesser odds compared to the adults to have disability at discharge from hospital (95%CI 0.258–0.889, P value <0.001) when adjusted for ISS and operative procedure. A child with an increase in ISS by one had a 37% higher odds to have disability at hospital discharge (95%CI 1.253–1.499, P value <0.001) when adjusted for age group and operative procedure. An injured person with an increase in ISS by one had a 50% higher the odds to be admitted to hospital (95%CI 1.359–1.650, P value <0.001) when adjusted for gender and multi-intervention. Males were 3.1 times more likely to be admitted to hospitals following MVC (95%CI 1.345–7.138, P value =0.008) when adjusted for injury severity score (ISS) and multi-intervention. The ROC analysis indicated that the AUC was 0.883 (Figure 6).

DISCUSSION

Malaysia is a middle-income country and is typical of countries that have seen a decline in infectious disease but an increase in death and disability from injuries over the past few decades. Health fact published by Ministry of Health, Malaysia showed that accidents were fourth out of 10 principal causes of hospitalization in Ministry of Health hospital which accounts for 8.03% of total admission in 2012. Road traffic deaths and injuries today place an enormous strain on our country’s health care system and national economy.

In our nation, there has never been a day without reported cases of trauma in the newspapers. Sadly, the majority of the victims involved the most vulnerable groups of road users namely motorcyclists and young children or adolescents as what was found in our study. Strikingly, the majority of victims of MVC in this study were among the drivers of motorcycles involved in crashes but yet only half of them admitted of having valid driver licenses. Driving without driving license implies that the road users were not competent enough to handle the vehicles and obeying the rules on the road and hence put them at higher risk to sustain MVC. The mean age of 14 years suggested that the secondary school children significantly involved in the MVC in Kota Bharu district. As for the general MVC population, males predominate the injured group. The majority of pediatric injured victims were involved in motorcycle related crash. The psychosocial factor of young males contribute significantly to the high risk of sustaining injuries on the road. Young adolescents are more likely to undergo high risk behavior on the road such as riding motorcycle without driving license, speeding,
not wearing safety helmet, illegal racing and riding with illicit drug influence. Peer pressure and showing off to peers when riding motorcycle were part of the contributive factors to injuries. In addition, many of the young victims admitted to not wearing or improperly wearing safety helmet.\[1\]

As in other middle and low-income countries, the most common type of vehicle involved was two wheelers (motorcycles) and cars (80% and 12% respectively). Numerous other similar findings were published on the risk factors of a two-wheeler involvement in the MVC resulting either in severe injuries or deaths worldwide.\[7–9\] Although the fatality index for both motorcycle riders and pillions were small, it was significant enough to cause huge losses to the economic output of the country. This was because the majority of motorcyclists consisted of adolescents and young adults, the future contributors to our socio-economic development. In 2009, 50% of the riders who died on the road were 29 years old and below while the mean age of the pillions that died were 28, and 50% of them were 21 years old and below.\[10\] In another analysis on motorcycles crashes in Malaysia, Abdul Manan and Varhelyi reported that 22.5% of the fatalities in their study involved riders aged 16–20 years.\[11\] This age figure of motorcycle users was similarly reflected in this study. This is due to low cost maintenance and fuel saving strategy of the road users. In addition, the main reason of using the motorcycle is due to affordability of motorcycles and high cost of cars in the country.

From the general observation by the investigator, poor parental guidance and monitoring against the use of vehicles among their children is a common finding in Kota Bharu district especially in the suburban area. Commonly the children ride motorcycle for social reasons such as fun riding with friends and attending local markets. There was a uniform distribution of the MVC occurrence among the children throughout the day with peak occurrence in the evening. Almost half of the injuries related to MVC among children occurred during the evening. Obvious reasons to this finding include the upsurge of motorcycle ride among the youngsters after the schooling period. The poor vision due to dark environment also contributed to high risk of injuries on the road.\[12\] From the researcher point of view, the young riders tend to involve in high-risk activities on the road in the evening such as illegal racing and riding in stunt position. On top of that, the law enforcement on the road is lacking in the evening time especially in the suburban areas. Another common occurrence and wrong riding practice in Malaysia and Kota Bharu specifically among the adult riders was to carry more than one pillion young riders with them on the motorcycle. The negligence of parents and adults has always resulted in injuries among the young pillions. The overloaded motorcycle easily causes the imbalance of the vehicle especially when the main rider is hit by another vehicle or if they apply the break in a sudden action resulting in loss of control the vehicle and hence injuries among the young unprotected pillions. Most of the injured young pillion riders do not wear safety helmets and this has indeed increased the incidence of serious TBI.

The spatial analysis in this study utilized the software ArcGIS version 10.0 that was licensed to the Universiti Sains Malaysia (USM). ArcGIS is a geography information system (GIS) for working with maps and geographic information. ArcGIS software is developed and distributed by Environmental System Research Institute.\[13\] This software was essential for creating, editing and analyzing spatial and attribute data. The spatial pattern and distribution of all motorcycle related cases followed the same pattern as the whole MVC cases since more than 80 percent of the cases were among two wheelers. The distribution showed that most of the MVC related to the motorcycles were focused on the main municipal roads on the central and southern parts of the town, which is at the border of urban and suburban development. These areas were densely populated and contains major road network with high density of road users. The roads within these areas were the main feeder road network connecting the suburban and the urban areas. Borough Kenali within this area was shown to have a very high incidence of MVC and similarly the vulnerable group of road users especially the underage and two wheelers were affected most.

The investigators observed that the underage riders and road user commonly focused their activities during the weekend at the local markets. They rode motorcycles with peers and without the adult supervision in addition to non-adherence to safety helmet wearing, making them vulnerable to involve in MVC. This study also found that the MVC occurrence at any intersections was more common during peak hours. This finding was similar for both intersections at urban and suburban areas. Obviously at peak hours most road users would be rushing to workplace or schools. This was comparable with a study in Thailand where the peak of all motorcycle crashes was found between 6:00 pm and 9:00 pm.\[14\] However, in a study by Yau\[15\] in Hong Kong commented
that a higher risk of severe injury was observed for accidents that happened at 8:00 pm to 11:59 midnight (OR 6.562, 95% CI 1.794–24.002) and from 08:00 am to 11:59 am (OR 4.220, 95% CI 1.051–16.941). Valent et al.\(^7\) also reported the OR of death rather for driving at early morning hours and evening were 13.44 (95% CI 2.54–71.05) and 6.67 (95% CI 1.49–29.95) respectively. The reasons for the high risk of accidents and fatalities among the motorcycle riders in overseas could be related to the greater use of alcohol during that time.

The geospatial analysis in this study has showed that most of the MVC related child injuries on the road occurred on a busy road network in either the urban or the suburban areas. These were normally focus areas for the children doing their activities such as going to school, shopping and attending local markets. Motorcycle is the easiest mode of transportation available in the region that is affordable by most households. This study found that the cases with severe ISS (more than 16) coincide with cases mostly at the location similar to the polytrauma cases. The two common locations were at the major intersections of Borough Kenali and Mukim Binjai. These two areas are well known to have high vehicle density and vulnerable road users including motorcyclists, pediatric pedestrian and school children. The maximum speed limit within these areas is 60 km/hour. There were cases in our study that involved underage motorcyclists (both pillion and main riders) who sustained injuries after illegal motorcycle racing on the road in particular long stretch straight road with maximum speed limit of 90 km/hour. This area is mainly in the suburban area. There is a high potential for these riders to ride the bike above the maximum speed limit set for the road. Even though there are so many factors contributing to the outcome of any MVC incidence, the investigator could not ignore the fact that geographical factors such as road layout (straight vs. curve), urban vs. suburban areas, presence of intersection and traffic lights play a significant role in the severity of MVC. It is no doubt that an application of injury epidemiology is to identify geographical areas and relate them to population groups that are at high risk of injury or death. Identification of high-risk group based on the GIS allows the selection of appropriate interventions to reduce or eliminate specific risk factors.

Overall, this study has attempted to combine all the available variables collected at the ED on MVC cases. A combination of general demography, pre-hospital data, injury data, clinical outcome and geographical data were recorded systematically both manually and electronically. This study attempted to analyze and develop the multiple logistic regression analysis by creating the best-fit model analysis for most of the variables mentioned above. Finally, only clinical variables (ISS, operative, multi interventions and age) were found to be strongly predictive for both of the outcomes. All the geographical variables were found to be excluded by the statistical model. However, it does not mean that these factors are irrelevant in contributing towards the injury outcome, but perhaps the factors can be considered as confounders and effect modifiers. Even though none of these factors was statistically significant in predicting the chosen outcomes, it has been proven that individually, the factors were a common finding for certain clinical outcome and victims such as polytrauma, disability, severely injured, pediatric and motorcyclists. The use of geospatial analysis on RTI related outcome can either be carried out on a general scope or specific to certain outcomes.

A systematic RTI data collection system in Auckland utilized the GIS model in mapping the serious injuries related to RTI. It has shown that high numbers of serious and fatal cases occurred in rural areas of Auckland.\(^8\) A study carried out by Farooqui et al.\(^9\) looked into the pattern of RTI in rural area of a state in India. He found that forty-seven percent (47%) of cases were from accidents occurring on secondary systems i.e. state highways and major district highways, followed by 27 (27.6%) on rural and village roads. Most injuries [122 (32.4%)] were found on the head, neck and face, followed by the upper extremities [79 (21%)] and the lower extremities [74 (19.7%)]. The striking and alarming findings include delayed ambulance responses and poor initial pre-hospital care management on RTI victims in this area.

This study was also subjected to a few limitations. The fundamentals of this study required the exact location of the MVC occurrence for the hotspot analysis. A majority of the latitude and longitude readings were taken by the paramedics who attended the cases with five to ten-meter accuracy; however, there was a small proportion of the self-attended cases which we had to rely on the graphical drawing of the exact location by the victims or relatives and retrieval of the coordinates was done retrospectively by the researcher. The confirmation of these locations was made by asking the witness at the site and by locating the traces of the MVC such as broken glasses and vehicle parts at the sites. One of the striking findings that was also a source of limitation was the involvement of motorcyclists in the majority of

www.wjem.org
MVC cases. We were hoping the analysis would have covered all types of the road users but unfortunately it was skewed mainly for two-wheeler users. This is unavoidable as the same pattern of MVC involvement throughout developing countries especially within the urban and suburban areas has been reported in journals and government websites. However this would not alter the ultimate objectives of the study as one of the main objectives was to look at the geospatial analysis and clinical outcome rather than the mechanism of injury.

Therefore, we would like to suggest few improvements in conducting similar research effort in future:

i. The GIS analysis on road safety should be made much wider, not only in the urban area but also the rural area so that we can see the total spectrum of the injury problem. A comparison can be made with rural area and this will provide a much better preventive strategies to the authority in future.

ii. An integrated data source will be a much better way to conduct such study. It will be ideal if police and health data can be integrated into one system and this can be utilized further for road safety research. Injury outcome analysis can be improved if pre-hospital, hospital data and injury data are organized into one system. The database system must have geographical component as well to support the Haddon Matrix concept in injury prevention. However this data combination must have common and standardize definition which can be comprehended and made available by many agencies for the purpose of research and audit.

iii. It would be ideal in future, for our setting, if GIS technique can be utilized in specific area of road traffic injury (RTI) research such as: 1) determination of network of ambulance transportation for trauma cases; 2) pediatric pedestrian injuries specifically targeting the school children; 3) cyclist injuries; 4) death related RTI; 5) injury specific analysis which is common in Malaysia i.e traumatic brain injury, orthopedic injury, maxillofacial injury, abdominal injury.

In conclusion, this study has proven that the occurrences of pediatric related road traffic injury has caused significant burden and social issues in the country. The utility of geospatial analysis and traditional clinical data collection have significantly contributed to a better understanding of the issue in our society. This study has successfully derived a combination of geographical, pre hospital and clinical data; and the use of GIS analysis in addition to the multiple logistic regression analysis has created a more robust and reliable study outcome. We hoped that this current data can be an impetus for prevention strategies in providing safer road for our children.

ACKNOWLEDGMENT

The authors thank the emergency departments staff of USM and HRPZ (2) who have assisted in the data collection and the USM research management office who has awarded the RU (I) research grant for this research project.

Funding: None.
Ethical approval: The study was approved by the institutional ethics review board.
Conflicts of interest: The authors declare no conflict of interest during the preparation, conduct and submission of the manuscript.
Contributors: Rahman NH conceived the study, collected the data and prepared the manuscript. Rains R conceived the study. Noor SH provided statistical advice on study design and analyzed the data. All authors contributed substantially to its revision. Mohamad SM takes responsibility for the paper as a whole.

REFERENCES


www.wjem.org

Received December 16, 2015
Accepted after revision June 3, 2016