Original Article

The Buffering analysis to identify common geographical factors within the vicinity of severe injury related to motor vehicle crash in Malaysia

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BACKGROUND: The main objective was to identify common geographical buildup within the 100-meter buffer of severely injured based on injury severity score (ISS) among the motor vehicle crash (MVC) victims in Malaysia.

METHODS: This was a prospective cohort study from July 2011 until June 2013 and involved all MVC patients attending emergency departments (ED) of two tertiary centers in a district in Malaysia. A set of digital maps was obtained from the Town Planning Unit of the district Municipal Office (local district map). Vector spaces were spanned over these maps using GIS software (ARCGIS 10.1 licensed to the study center), and data from the identified severe injured cases based on ISS of 16 or more were added. Buffer analysis was performed and included all events occurring within a 100-meter perimeter around a reference point.

RESULTS: A total of 439 cases were recruited over the ten-month data collection period. Fifty two (11%) of the cases were categorized as severe based on ISS scoring of 16 and more. Further buffer analysis looking at the buildup areas within the vicinity of the severely injured locations showed that most of the severe injuries occurred at locations on municipal roads (15, 29%), straight roads (16, 30%) and within villages buildup (suburban) areas (18, 35%).

CONCLUSION: This study has successfully achieved its objective in identifying common geographical factors and buildup areas within the vicinity of severely injured road traffic cases.

KEY WORDS: Motor vehicle crash; Emergency department; Injury severity score

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INTRODUCTION

Identifying risk factors for seriously injured victims is crucial in implementing the primary prevention especially in regards to geographical buildup factors common to the accident sites involving critically injured road users.^[1] In the past, too much of prevention is focused on general minimally injured population, which can cost millions and increase economic burden on developing countries.

Few studies had indicated that pattern of road traffic injury (RTI) is significantly influenced by geographical lay out and its surrounding buildup.^[2,3] Therefore the investigator planned to conduct a research with a primary objective to identify hotspot areas and geographical buildup within the vicinity of severely injured victims of road traffic accidents. The severely injured population was chosen because it involved more of productive young road users

who are crucial for socioeconomic status of the country. Such identification would promote a more focused primary prevention for those regions that are facing with ever-increasing financial crisis. It will create a much safer environment for vulnerable road users and hence reduces the socioeconomic burden of the country.

METHODS

This was a prospective cohort study from July 2011 until June 2013. It involved all MVC patients attending the emergency departments (ED) of two tertiary centers in a district in Malaysia. The Kota Bharu district on the East Coast of Peninsular of Malaysia was chosen because it was known for high prevalence of road traffic injuries. The study sample included all patients with road-related injuries within the study district who attended the two EDs. Consent was taken from each patient or relative 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 size of road traffic accident victims was 415 based on a study done by Abdul Razak in Karachi Pakistan.^[4]

For this study, the investigator extracted age, gender, accident mechanisms and causes, and vehicle types from the police & hospital management and outcome. A set of digital maps (road and borough layers) was obtained from the Town Planning Unit of the district Municipal Office (local district map). Vector spaces were spanned over these maps using GIS software (ARCGIS 10.1 licensed to the study center), and data from the identified trauma cases were added. Spatial analysis and overlay tools were used to identify local clusters of events. Buffer analysis was performed and included all events occurring within a 100-meter perimeter around a reference point (Figure 1). The investigators asked the prehospital care providers and patients or relatives to specifically identify and draw the map location of the RTI. The researcher attended each of the location of incidence and obtained x and y GIS coordinate in degree, minute and second in WGS 84 format by using a hand held GPS unit brand Garmin model GPS 72H with Serial number 1T7071348 (Manufactured in Taiwan by Garmin Corporation in 2010) which was accurate to 5 meters of the location. The land use and type of buildings within the 100-meter buffer region for each accident point were identified from both the "land use" digital map layer provided and also from the free open software Google earth view version 7.1.2.2041 operating system Microsoft Windows

(5.1.2600.3) (Figure 2). Digital photos were also taken and kept in file. The investigators performed specific geospatial analysis on severely injured victims based on injury severity score (ISS) of 16 and more.

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 and no clinical outcome data available. This was the very first buffer analysis study carried out in the country in relation to clinical severity as outcome. The author also could not find any article published related to 100-meter buffer analysis for severe cases (based on ISS) related to RTI.

Figure 1. The 100-meter buffer for each accident point.

Figure 2. The Google Earth analysis of geographical build up for each MVC point.

Table 1. Cases with missing data, which were excluded from the epidemiological analysis

Reasons	Number excluded out of total cases, n (%)
Various degree of data lacking	27 (6.1)
All data missing (general demography, prehospital, clinical & geographical data)	17 (3.8)
Parts of data missing	10 (2.3)
Coordinate missing or location outwith border of maintenance by the Kota Bharu District Council (MPKB)	66 (15)

Table 2. The distribution of the initial vital signs on arrival in ED and injury score based on final diagnoses

Injury severity	Range (min, max)	Mean (SD)	Variance	Skewness (SE)
Systolic BP on arrival	150 (80, 230)	130.06 (18.31)	335.50	1.15
Respiratory rate on arrival	30 (6, 36)	17.84 (3.83)	14.67	1.151
Glasgow Coma Scale on arrival	15 (3, 18)	14.55 (1.75)	3.06	-4.73
Revised Trauma Score	4.91 (2.93, 7.84)	7.70 (0.57)	0.33	-5.46
Injury Severity Score	74 (1, 75)	8.79 (10.49)	110.13	3.54
Number of body systems injured	4 (0, 4)	1.19 (0.62)	0.38	1.21
Number of body parts injured	11 (0, 11)	1.65 (1.07)	1.15	2.33

Figure 3. The mapping of the coordinate locations for RTI cases.**Table 3.** The common geographical buildup within the 100-meter buffer area of the RTI locations based on the coordinates obtained

Geographical variables	n	Percent
Road lay out		
Straight	289	68.6
Curve	12	2.9
4-way junction	26	6.2
T-junction	84	20.0
On the bridge	8	1.9
Others	2	0.5
Presence of shoplots		
No shoplots	220	52.1
Shoplots	202	47.9
Presence of school building		
No schools in the vicinity	381	90.5
Schools in the vicinity	40	9.5
MVC occurred at traffic light junction		
Yes	34	8.0
No	389	92.0
Distant from the nearest junction		
More than 100 meters	242	57.6
Less than 100 meters	178	42.4

RESULTS

A total of 439 cases were recruited over the ten-month data collection period from August 2012 till May 2013. The variables collected were divided into general demography, prehospital, clinical and geographical data. However there were 27 cases with missing data, which were excluded from the epidemiological analysis (Table 1). The mean age (SD) of the RTI victims was 26.04 years (SD 15.26). The range of age was between 2 to 81 years of age. Age (in years) groupings for the RTI victims were less than 13 (4.4%), 13 to 19 (35%), 20 to 40 (41.4%) and older than 40 (18.4%). There were 302 (71.7%) males. Motorcyclists (351, 80.0%) were the most common type of victim involved, which comprised

of 87% (305) male riders followed by car occupants (55, 12.5%). A total of 49 (11.2%) of the cases resulted from spontaneous skid and falls without any two vehicle impact. Table 2 shows the distribution of the initial vital signs on arrival in ED and injury scoring based on final diagnoses.

The majority of the RTI occurred on the municipal roads (310, 73.3%) within the district of interest. The mapping of the coordinate locations for all the RTI cases within the study period was plotted as shown in Figure 3 based on the borough and road network layers. Table 3 shows the common geographical buildup within the 100-meter buffer area of the RTI locations based on the coordinates obtained. Fifty-two (11%) of the cases were

categorized as severe based on ISS scoring of 16 or more. Interestingly, the majority of the severely injured victims sustained the RTI on roads with maximum speed limit of 60 km/hour (38, 73%) whereas only ten (19%) cases of the severely injured victims occurred on the roads with maximum speed limit of 90 km/hour. Further buffer analysis looking at the buildup areas within the vicinity of the severely injured locations showed that most of the severe injuries occurred at locations on municipal roads (15, 29%), straight roads (16, 30%) and within villages (suburban) areas (18, 35%). Both adult and pediatric age group victims showed similar geographical distribution. However most of the children (less than 18 years) sustained the RTI within the vicinity of primary schools and on straight roads.

DISCUSSION

RTI is the eighth leading cause of death internationally, and the leading cause of death for young people aged 15–29. Current trend suggests that by 2030 road traffic deaths will become the fifth leading cause of death unless urgent action is taken. According to the Ministry of Health Malaysia's data in 2013, accident due to motor vehicle crash (MVC) was ranked as the fourth most common cause of hospital admissions and fifth cause of death in the country.^[5–7]

The study has shown similar trend in the prehospital and clinical parameters of the RTI victims to the nationwide and international data in particular data originating from the developing countries.^[8,9] The victims commonly involved the young age group (40% at between 20 to 40 years of age), the age at which the general population is very productive socioeconomically. Sadly, a significant number of the victims were among the school-aged population ranging from primary schools to the late adolescent (28%). There were significantly more male MVC victims compared to the female. Young age and male are both common denominators in MVC cases worldwide. These two factors are strongly related to psychosocial contributions towards involving in challenging and risky behaviors on the road. Furthermore, the cultural pattern within the study locations showed more men ride motorcycles compared to women. Women tend to be pillion riders to their spouses. A study by Malaysia Institute Research For Road Safety (MIROS) in 2006 indicated that women and elderly population tend to ride less motorcycles compared to men and the young age group respectively.^[10] The risky behavior such as speeding, showing off stunt actions, illicit

drug influence and driving without safety equipment commonly result in disastrous outcomes on the road.^[11,12]

A similar trend of young age and male preponderance was found in Singapore data on road fatalities from year 2000 to 2004. 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.^[13–15] Malaysian Institute of Research on Road Safety (MIROS) reported that over the 10-year period (2000–2010), an estimated 1.2%–1.5% of the registered motorcycles in Malaysia were involved in accidents. In 2010 alone, out of the 120 156 motorcycle accidents, there were 3 614 driver and 422 pillion rider fatalities. This gives the fatality index (i.e. number of fatalities per road accidents) of 0.03 and 0.003 for riders and pillions respectively.^[16]

The investigators also noted that ISS among the victims in suburban area was significantly higher than those in the urban area. Many factors contributed to this significant clinical finding such as speeding that is more common in the suburban area due to less traffic density and straighter roads with fewer intersections. In addition there were many motorcyclists who show high-risk behavior on the roads within this area such as young age, no driving license, not wearing safety helmet and illegal racing. Poor enforcement by the police and road safety officer also contributed to the high-risk behaviors as mentioned above.^[17,18] Most of the literatures mentioned about well-established factors that determine the clinical outcome such as^[19,20]: 1) inadequate in-vehicle crash protection; 2) inadequate roadside protection; 3) the non-use of protective devices in vehicles; 4) the non-use of protective crash helmets; 5) excessive and inappropriate speed; 6) the presence of alcohol.

In this study, majority of the RTI cases of all categories (ISS>16, polytrauma, disabled, operated cases) occurred on the road with maximum speed limit of 60 km/hour. This road network is mainly located in the suburban area. Much less severe categories of injured victims occurred on the road with maximum speed limit of 35 km/hour. Collectively, more severe categories of MVC cases occurred on roads with higher maximum speed limits (60 & 90 km/hour) compared to those that occurred on the road with speed limit of 35 km/hour. Even though the investigators were unsure of the actual vehicle speed at the time of every impact, it can be concluded that the road users tend to drive faster on any

roads with higher speed limits and hence increase the risk of MVC.^[21,22] Unfortunately in this study, the attempt to obtain reliable data on speed of vehicles at the onset of accident was difficult and unreliable partly due to the road users unwillingness to disclose the speed.

Nowadays many highway and road safety agencies have been using GIS system for analyzing road related accidents.^[23] The process in identifying the environmental factors that contribute to any MVC is crucial and may serve as a corrective measure to prevent similar incident in future. When using the system, the user can merge the MVC cases and road infrastructure data and also match the MVC cases with locations buildup. There is a need to obtain accurate information on the circumstances of every collision, especially with regard to location in order to get a general relation of severity of road related injuries with the environment buildup. In this study, the investigators have carried out detail analysis of the environment buildup at each of the MVC location by using proximity analysis buffer technique from ARCGIS software. This study found that the cases with severe ISS (more than 16) matched with cases mostly at the location similar to polytrauma cases. The two common locations were at major intersections of Borough Kenali and 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. The fact that these roads are normally congested and contain high vehicular density, the risk factors such as vulnerable road users and human attitude have contributed to significant adverse outcome. There were cases in this 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. Similar geographical pattern was seen in the USA where forty percent of all traffic fatalities occur in urban areas, the percentage increases to 63 percent in an area that also included the rural area within 2.5 miles of the urban boundary. The percentage increased to 73 percent 5.0 miles out, 81 percent 7.5 miles out, and 86 percent 10 miles out.^[24]

The underage motorcyclists and speeding tend to be seen in the suburban and village areas. The enforcement is lacking and the relative low density of vehicles on the road attract drivers to speed. Many of these vulnerable road users did not wear protective helmets based on the report obtained from the ambulance paramedics attending the victims, history from patients and

witnesses. Furthermore the distance from the tertiary hospitals resulted in the delay in ambulance arrival and hence delayed ED treatment. A study done by Abdul Manan in 2012 on road fatalities among motorcyclist in Malaysia has shown that 60% of the fatalities occurred on the roads in non-busy areas such as suburban and rural locations. They also found that the majority were young riders (89%), 16 to 20 years old (22.5%), and 90% of the motorcycles were privately owned.^[25] Interestingly the east coast region in Malaysia, with a lower motorcycle population and less built-up density, has the highest fatality rate per 10 000 motorcycles. Meanwhile, the Federal Territories, which have the highest population density, record the lowest rate in motorcycle fatality per 10 000 registered motorcycles.^[26] Commonly we see that the occurrence of polytrauma cases at the site connecting two major towns. The road which is straight, wide, and traverses through village housing is commonly used by heavy vehicles such as lorries and trucks with the presence of vulnerable road users such as pedestrian, children and motorcyclists among the villagers. The common maximum speed limit within this area is 60 km/hour, which is high enough to cause significant clinical injuries or death upon impact on other vehicle or human body. Less vehicle density and straight road have always contributed to the urge for drivers to speed at this area and hence increase the risk of MVC. Another significant factor that contributed to severe impact on road users is the quality of road barriers and guardrail. A study carried out at other locations in the country has found that the impact on vehicles and the occupants was partly affected by the type of guardrail installed alongside the roads.^[27]

Overall this study has successfully achieved its objectives in identifying geographical factors that are commonly found at locations of severely injured victims related to MVC. The identifications of these factors can be utilized further by agencies and government authority interested in focusing implementation of primary prevention against severe injuries related to road traffic. By focusing on this group of road victims, more financial and manpower resources can be utilized effectively to curtail severe MVC cases and hence prevent unnecessary use of money in providing long term management of critically injured road users. The potential for GIS in RTI research is very promising and great because it has capability in linking display data with health and injury data. Road traffic injuries can be envisaged in relationship to the health care provision, environmental factors and description to sociocultural aspects of the population involved. 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 outcomes 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 RTI research such as: determination of network of ambulance transportation for trauma cases; pediatric pedestrian injuries specifically targeting the school children; cyclist injuries; death related RTI; injury specific analysis which is common in Malaysia i.e traumatic brain injury, orthopedic injury, maxillofacial injury, abdominal injury; Geriatric injury on the road; heavy vehicle and public transportation related MVC and injuries.

Limitations of the study

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. The 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 limiting factor of this study was the involvement of motorcyclists in the majority of MVC cases. Investigators were hoping the analysis would have covered for 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 involvements 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 objective of the study to look at the hotspot analysis and clinical outcome rather than the mechanism of injury. In addition, the investigators were unable to determine the exact cause of MVC (i.e. illicit drug taking or mechanical cause) due to unreliable sources of information from the witnesses.

In conclusion, this study has successfully achieved its objective in identifying common geographical factors and buildup areas within the vicinity of severely injured road traffic cases. Investigators are hoping that this data can be utilized further for the implementation of focused primary prevention to curtail severe injuries on the road and hence reduce the economic burden of RTI in developing country. A bigger scale of geospatial buffer analysis in future will provide a more general conclusive data for nationwide use.

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