Spine Injuries among Fatal Victims of Vehicular Accidents in Kuala Lumpur, Malaysia

Zarir Hafiz Zulkipli[1], Siti Atiqah Mohd Faudzi[1], Norlen Mohamed[1]

Abstract Spine injury is one of the critical injuries due to vehicular accidents as injuries to the spine often cause morbidity and sometimes death especially if at upper cervical spine. This study aims to determine and compare the patterns of spinal injury in passenger car occupants, motorcyclists and pedestrians involved in road accidents. The study was undertaken on 670 victims of road traffic accidents who died due to all types of injuries and who were autopsied at Kuala Lumpur Hospital, Malaysia over a period of 4 years between January 2006 and December 2009. Of the 670 motor vehicle occupant fatalities included in the study, 176 (26.3%) cases presented with spine injuries. Most of the victims were motorcyclists (N=102, 62.2%) followed by passenger car occupants (N=43, 26.2%) and pedestrians (N=19, 11.6%). Of spinal injuries, the cervical region is the most common in all road accident victims. A higher proportion of MAIS 4 – 6 spine injuries were found for passenger car occupants compared to motorcyclists and pedestrians. Although 164 road accident victims presented with spine injuries, only 9 were attributed as the primary cause of death. Taking into account spine injuries contributing to fatal outcome, there were altogether 8.4% (56 out of 670) victims. The fatalities due to the spine injury are indeed very low and the occurrences of high severity spine injuries are usually concomitant with high severity injury in other body regions. The high severity of head and thorax injuries concomitant with spine injuries suggested that improved protection against injuries of these vital body regions could reduce spine injury severity as well.

Keywords fatalities, road accident, spinal injuries

I. INTRODUCTION

Yearly, over 6000 people are killed and thousands more are injured in Malaysia from road traffic accidents. Statistics reveal that the number of fatalities has increased by 11% within 5 years (6,200 in 2005; 6,872 in 2010) [1]. Consistent with other studies in the literature the predominant cause of death is attributed to head and thorax injuries for all types of road users [2]–[5].

Although equally devastating injuries, spine injuries are often reported as being rare and an uncommon cause of death among road traffic accident victims [6]–[7]. That these injuries are not commonly seen may be due to the fact that they are really rare. Yet, their rarity most probably is due to the presence of substantial multiple injuries or more pronounced lethal injuries such as head injuries which satisfy the pathologist as to the cause of death without the need to carry out further detailed examination. Furthermore, soft tissue injuries such as vertebral arteries are relatively inaccessible and therefore render their examination at post-mortem difficult. Thus they are frequently ignored or overlooked [8]–[9]. This study aims to determine and compare the patterns of spinal injury in passenger car occupants, motorcyclists and pedestrians involved in road accidents.

Zarir Hafiz Zulkipli. Author is Research Officer in the Vehicle Safety and Biomechanics Centre at Malaysian Institute at Road Safety Research (MIROS) in Malaysia. (Tel.: +603 8924 9200; Fax: +603 8736 8685; *E-mail address:* zarirhafiz@miros.gov.my.
Siti Atiqah Mohd Faudzi. Author is Research Officer in the Vehicle Safety and Biomechanics Centre of Malaysian Institute at Road Safety Research (MIROS) in Malaysia. Norlen Mohamed, MD. Author is Head of Unit of Crash Injury Sciences and Preventions Unit in the Vehicle Safety and Biomechanics Centre at Malaysian Institute of Road Safety Research (MIROS) in Malaysia.

II. METHODS

This was a retrospective cross-sectional study, which included all road traffic deaths presenting to the Department of Forensic Medicine, Kuala Lumpur Hospital (HKL) from 2006 to 2009. The protocol for the study was approved by MIROS' Research Committee and Research and Ethics Committee, National Institute of Health, Ministry of Health Malaysia.

Data collected from the post-mortem files included post-mortem report number, police report number, personal identification number, age, gender, ethnic group, time of crash, date of crash, type of crash, type of road user, type of vehicle, type of case, type of substance use, concentration of substance use and injury details. Based on the personal identification number and police report number, the records from the post-mortem files were matched with the police-based accident data. Information on time of crash, date of crash, type of crash, type of road user and type of vehicle were cross-checked with the police-based data. With regard to crash information, the police-based accident data were used if there was any discrepancy among the sources of data.

A total of 710 fatal road traffic deaths were registered at the Department of Forensic Medicine, HKL during the study period of 2006 to 2009. Out of this number, 40 cases were excluded for analysis as the post-mortem report details had not been finalised by the attending forensic doctors. The data left then were filtered to find cases with spine injuries. In this study spine injuries were defined as injuries which included soft tissues of the neck, soft tissue of the vertebral column and fracture of the bony structure of the neck and the vertebral column.

The injuries from the post mortem reports were coded using AIS 2005 [10]. Each injury description was assigned a unique 6-digit numerical code, describing the body region injured, type of anatomical structures involved, nature of injury and a severity score, ranging from AIS 1 (minor), AIS 2 (moderate), AIS 3(serious), AIS 4 (severe), AIS 5 (critical) to AIS 6 (beyond treatment). Injury codes AIS 4, 5 or 6 were deemed possibly responsible for death.

Data were analyzed according to the type of crash victim, namely motorcyclist, passenger car occupant or pedestrian. Demographics and some crash characteristics for these road accident victims were included. Characteristic injuries of motorcyclists, passenger car occupants and pedestrians were compared.

III. RESULTS

Of the 670 motor vehicle occupant fatalities included in the study, 176 (26.3%) cases presented with spine injuries. However, only 164 cases were used for the analysis as 12 cases were discarded due to insufficient information which included three cases of heavy vehicle occupants and two bicyclists.

Males comprised 86.6% and females 13.4% of the total victims with spine injury. The most commonly injured age group for both males and females was between 21 and 30 years (42.1%), and the least common was the 0-10 year age group (1.1%). The mean age of all 164 injured was 33.4 years (SD±15.5; range 2-93; median 29; mode 22 and 24). The mean age of males was similar (33.0 years, age range 2 years to 93 years) while the mean age of females was 36.6 years (age range 15 years to 73 years). See Fig. 1.

The time of day was divided into four periods of 6-hour intervals using 24-hour notation (00:01-07:00, 07:01-12:00, 12:01-18:00, and 18:01-00:00). Results show most of the accidents had taken place during late night and early morning hours (00:01–07:00) with 43.8% (Fig. 2). During this time period a high proportion of the victims were found to have been driving under the influence compared to other time periods.

Among the motorcyclists, the status of helmet wearing was known for only 25 out of 102 of which 23 were found to be wearing a helmet while two were not. Among passenger car occupants, the status of seat belt use was known for only 19 out of 43 of which 12 were recorded to be using a seat belt while seven were not.

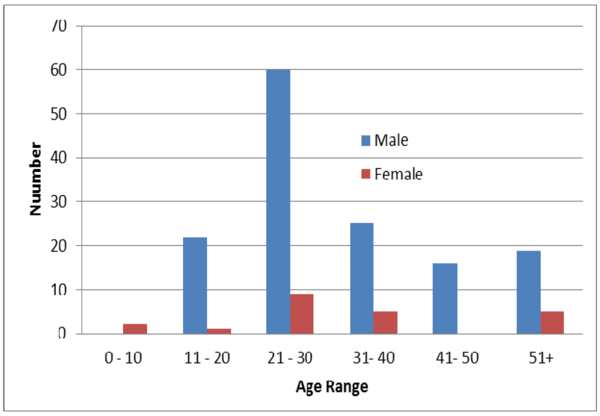

Fig. 1. Age and gender distribution

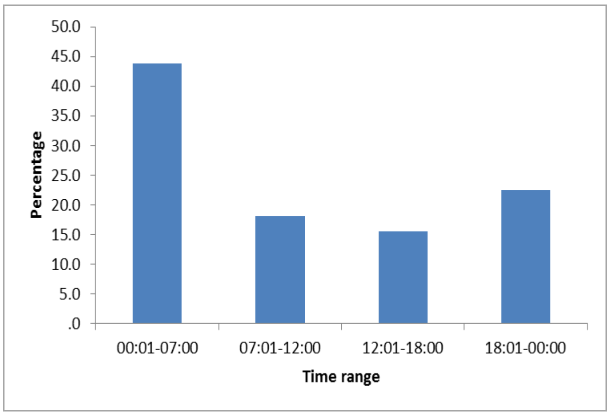

Fig. 2. The distribution of accident occurrence according to time.

Most of the victims were motorcyclists (N=102, 62.2%) followed by passenger car occupants (N=43, 26.2%) and pedestrians (N=19, 11.6%) which is shown in Table I. In general, the pattern of spine injury among motorcyclists, car occupants and pedestrians was almost similar with the highest number of the injuries occurring to the cervical followed by the thoracic and the least to the lumbar region. Nonetheless, pillion riders sustained most spine injuries in the thoracic region. The highest proportion of cervical injuries was observed in pedestrians (73.7%), the highest proportion of thoracic injuries in motorcyclists (28.4%) and the highest proportion of lumbar injuries in passenger car occupants (7.0%). Injuries involving multiple spine regions were found to be in slightly higher proportion for passenger car occupants than motorcyclists and pedestrians. There were different patterns observed between motorcycle riders and pillion riders as well as between car drivers and front and rear occupants. However, due to the small number for motorcycle pillion riders and passenger car occupants, the findings should be read cautiously.

As helmet use was known for only a small number of motorcyclists, it was not possible to determine the effect of helmet use in spine injury outcomes. For passenger car occupants, a higher proportion of cervical injuries was observed among unbelted car occupants (5 out of 7) compared to belted occupants (6 out 12). Again, these small numbers should be interpreted cautiously.

TABLE I
DISTRIBUTION OF SPINE INJURIES ACCORDING TO SPINE REGION FOR EACH ROAD ACCIDENT VICTIMS' GROUP

Spine Region	Motorcyclist			Passenger Car Occupant				Pedestrian
	Rider	Pillion	Total	Driver	Front passenger	Rear passenger	Total	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Cervical	58(63.0)	3 (30.0)	61 (59.8)	17 (54.8)	2 (33.3)	5 (83.3)	24 (55.8)	14 (73.7)
Thoracic	23 (25.0)	6 (60.0)	29 (28.4)	8 (28.4)	2 (33.3)	1 (16.7)	11 (25.6)	3 (15.8)
Lumbar	2 (2.2)	1 (10.0)	3 (2.9)	3 (9.7)	-	-	3 (7.0)	1 (5.3)
Multiple	9 (9.8)	-	9 (8.8)	3 (9.7)	2 (33.3)	-	5 (11.6)	1 (5.3)

Distribution of maximum injury severity (MAIS) according to body region among motorcyclists, passenger car occupants and pedestrians is demonstrated in Table II. For spine injuries there were considerable differences between the unprotected (motorcyclist and pedestrian) and protected (passenger car occupant) groups: MAIS 1 to 2 (67.6%, 68.4% vs 46.5%) and MAIS 4 to 6 (23.5%, 31.6% vs 44.1%). MAIS 3 spine injuries were found only in motorcyclists and passenger car occupants and the proportions were almost the same within the two groups (8.8% vs 9.3%).

The distribution of head injuries was almost similar between each group with MAIS 4 injuries the most prevalent. The highest proportion of MAIS 4 head injuries was seen in the pedestrians (47.4%). Face injuries were the least prevalent injuries found among the victims with only 14.0% for passenger car occupants, 4.9% for motorcyclists and 5.3% for pedestrians. For all groups, thorax injuries with MAIS 3 – 4 were the most prevalent. In contrast, for abdomen and upper extremity most of the injuries were MAIS 1 – 2. Interestingly, more severe lower extremity injuries were found to occur among passenger car occupants (25.6%) compared to motorcyclists (12.7%) and pedestrians (10.5%).

TABLE II
INJURIES SEVERITY SUSTAINED BY ROAD ACCIDENT VICTIM ACCORDING TO BODY REGIONS

Body region	Motorcyclist		Passenger Car Occupant		Pedestrian	
	N	%	N	%	N	%
Head[a]						
MAIS 1 – 2	6	5.9	4	9.3	1	5.3
MAIS 3	29	28.4	10	23.3	5	26.3
MAIS 4	36	35.3	17	39.5	9	47.4
MAIS 5	10	9.8	5	11.6	3	15.8
MAIS 6	12	11.8	2	4.7	-	-
Face[a]						
MAIS 1 – 2	5	4.9	6	14.0	1	5.3
MAIS 3	-	-	-	-	-	-
MAIS 4	-	-	-	-	-	-
MAIS 5	-	-	-	-	-	-
MAIS 6	-	-	-	-	-	-
Thorax[a]						
MAIS 1 – 2	1	1.0	1	2.3	1	5.3
MAIS 3	48	47.1	17	39.5	9	47.4
MAIS 4	31	30.4	16	37.2	6	31.6
MAIS 5	11	10.8	3	7.0	3	15.8
MAIS 6	3	2.9	3	7.0	-	-
Spine[a]						
MAIS 1 – 2	69	67.6	20	46.5	13	68.4
MAIS 3	9	8.8	4	9.3	-	-
MAIS 4	-	-	1	2.3	-	-
MAIS 5	16	15.7	13	30.2	4	21.1
MAIS 6	8	7.8	5	11.6	2	10.5
Abdomen[a]						
MAIS 1-2	33	32.4	7	16.3	10	52.6
MAIS 3	9	8.8	7	16.3	3	15.8
MAIS 4	14	13.7	6	14.0	2	10.5
MAIS 5	2	2.0	4	9.3	1	5.3
MAIS 6	2	2.0	1	2.3	-	-
Upper Extremity[a]						
MAIS 1 – 2	21	20.6	10	23.3	6	31.6
MAIS 3	-	-	-	-	-	-
MAIS 4	-	-	-	-	-	-
MAIS 5	-	-	-	-	-	-
MAIS 6	-	-	-	-	-	-
Lower Extremity[a]						
MAIS 1 – 2	7	6.9	2	4.7	3	15.8
MAIS 3	13	12.7	11	25.6	2	10.5
MAIS 4	-	-	-	-	-	-
MAIS 5	-	-	-	-	-	-
MAIS 6	-	-	-	-	-	-

Table III shows severity of spine injuries cross tabulated with severity of other body region injuries. In motorcyclists and passenger car occupants, spine injuries at all levels of MAIS had a high proportion of head injuries with MAIS 4 – 6. Even with MAIS 1 – 2 spine injuries, a high proportion of head injuries with MAIS 4 – 6 was observed. Pedestrians show a high proportion of spine injuries with MAIS 4 – 6 corresponding to high head injuries with similar MAIS levels, but due to a small sample, the result may be inconclusive.

In MAIS 3 – 6 spine injuries more than half of the concomitant thorax injuries were seen to be MAIS 4 – 6 for both motorcyclists and passenger car occupants. However, in minor to moderate spine injuries (MAIS 1 – 2) concomitant thorax injuries were mostly MAIS 3 especially for motorcyclists. Typical thorax injuries observed were haemothorax and lung contusion.

No apparent pattern was observed to indicate severe spine injuries accompanied by concomitant severe abdomen injuries. Similarly, MAIS for upper and lower extremity injuries also do not show an obvious pattern corresponding to MAIS spine injuries except for passenger car occupants in which severe spine injuries (MAIS 4 – 6) involve a higher proportion of serious lower extremity injuries (MAIS 3).

TABLE III
CROS S TABULATION OF SPINE INJURIES SEVERITY WITH OTHER BODY REGION INJURIES SEVERITY FOR EACH ROAD ACCIDENT VICTIMS' GROUP

Body region	Motorcyclist			Passenger Car Occupant			Pedestrian		
	Spine								
	MAIS 1 – 2	MAIS 3	MAIS 4 – 6	MAIS 1 – 2	MAIS 3	MAIS 4 – 6	MAIS 1 – 2	MAIS 3	MAIS 4 – 6
	N=69 (%)	N=9 (%)	N=24 (%)	N=20 (%)	N=4 (%)	N=19 (%)	N=13 (%)	N=0 (%)	N=6 (%)
Head									
MAIS 1 – 2	5 (7.2)	1 (11.1)	-	2 (10.0)	1 (25.0)	1 (5.3)	1 (7.7)	-	-
MAIS 3	15 (21.7)	3 (33.3)	11(45.8)	4 (20.0)	1 (25.0)	5 (26.3)	4 (30.8)	-	1 (16.7)
MAIS 4 – 6	43 (62.3)	4 (44.4)	11(45.8)	13 (65.0)	2 (50.0)	9 (47.4)	7 (53.8)	-	5 (83.3)
Thorax									
MAIS 1 – 2	-	-	1 (4.2)	-	-	1 (5.3)	1 (7.7)	-	-
MAIS 3	40 (58.0)	1 (11.1)	7 (29.2)	10 (50.0)	1 (25.0)	6 (31.6)	6 (46.2)	-	3 (50.0)
MAIS 4 – 6	25 (36.2)	5 (55.6)	15 (62.5)	9 (45.0)	3 (75.0)	10 (52.6)	6 (46.2)	-	3 (50.0)
Abdomen									
MAIS 1 – 2	22 (31.9)	3 (33.3)	8 (33.3)	4 (20.0)	-	3 (15.8)	8 (61.5)	-	2 (33.3)
MAIS 3	6 (8.7)	-	3 (12.5)	5 (20.0)	-	2 (10.5)	2 (15.4)	-	1 (16.7)
MAIS 4 – 6	12 (17.4)	1 (11.9)	5 (20.8)	3 (15.0)	3 (75.0)	5 (26.3)	2 (15.4)	-	1 (16.7)
Upper extremity									
MAIS 1 – 2	13 (18.8)	2 (22.2)	6 (25.0)	4 (20.0)	1 (25.0)	5 (26.3)	3 (23.1)	-	3 (50.0)
MAIS 3	-	-	-	-	-	-	-	-	-
MAIS 4 – 6	-	-	-	-	-	-	-	-	-
Lower extremity									
MAIS 1 – 2	13 (18.8)	1 (11.1)	2 (8.3)	-	-	2 (10.5)	2 (15.4)	-	1 (16.7)
MAIS 3	9 (13.0)	2 (22.2)	2 (8.3)	4 (20.0)	1 (25.0)	6 (31.6)	2 (15.4)	-	-
MAIS 4 – 6	-	-	-	-	-	-	-	-	-

To identify the most common severe injuries involved among the victims, motorcyclists, passenger car occupants and pedestrians with MAIS 4 – 6 spine injuries were filtered and grouped in Table IV. In general, common injuries involved were fractures or dislocations with lacerations or transections of the spinal cord. Most of these injuries occurred to the cervical spine region with more than 50% occurring to pedestrians. Compared to passenger car occupants and pedestrians, motorcyclists suffered a higher number of injuries to the upper cervical spine (C1 – C3).

As shown earlier, spine injuries with MAIS 4 – 6 usually demonstrated corresponding thorax injuries with a similar level of MAIS. While common severe spine injuries were listed in Table IV, typical severe injuries (MAIS 4 – 6) for the thorax were haemothorax, subendocardial hemorrhage and severe laceration to the aorta, heart and lung. The thoracic spine was the most commonly associated spine region affected by these severe thorax injuries.

TABLE IV
COMMON SEVERE SPINE INJURY (AIS 4 – 6)

Spine injuries in MAIS 4 – 6	Motorcyclist		Passenger Car Occupant		Pedestrian	
	N	%	N	%	N	%
	24	100	19	100	6	100
Upper spinal cord and junction medulla oblongata laceration	1	4.2	1	5.3	-	-
C1 – C3 fracture/dislocation with spinal cord laceration/transection	9	37.5	4	21.1	2	33.3
C4 – C7 fracture/dislocation with spinal cord laceration/transection	2	8.3	5	26.3	3	50.0
Carotid artery severe lacerated	-	-	1	5.3	-	-
T1 – T12 fracture/dislocation with lacerated/ transected spinal cord	12	50.0	7	36.8	1	16.7
L1 fracture with transected spinal cord	-	-	1	5.3	-	-

Table V shows the causes of death recorded from the post mortem. Out of 164 road accident victims 140 (85.4%) were pronounced dead before arrival at the hospital while only 24 (14.6%) victims died in the emergency department or ward. For 9 victims (5.5%), the cause of death was attributed to spine injury alone while there were 27 (16.5%) victims reported to have spine injury in combination with only one other body region. In victims where multiple injuries were reported as the cause of death, 21 (12.8%) were found to have spine injury with MAIS 4 – 6 with motorcyclists being the lowest proportion relative to passenger car occupants and pedestrians.

A higher proportion of car passenger occupants compared to motorcyclists died due either to spine injury alone or to spine and thorax injuries. On the other hand, a higher proportion of motorcyclists died compared to car passenger occupants due to head and spine injuries.

TABLE V
CAUSES OF DEATH OF THE ROAD ACCIDENT VICTIM

Cause of death	Motorcyclist		Passenger Car Occupant		Pedestrian	
	N	%	N	%	N	%
	102	100	43	100	19	100
Abdominal injuries	1	1.0	1	2.3	-	-
Thorax and abdominal injuries	2	2.0	4	9.3	2	10.5
Thorax injuries	5	4.9	1	2.3	-	-
Head and chest injuries	11	10.8	3	7.0	2	10.5
Head and pelvic injuries	-	-	-	-	1	5.3
Head injuries	20	19.6	3	7.0	3	15.8
Spine injuries	4	3.9	5	11.6	-	-
Head and spine injuries	12	11.8	3	7.0	1	5.3
Thorax and spine injuries	5	4.9	5	11.6	-	-
Abdominal and spine injuries	1	1.0	-	-	-	-
Multiple injuries						
MAIS 1 – 3 spine injuries	31	30.4	11	25.6	6	31.6
MAIS 4 – 6 spine injuries	10	9.8	7	16.3	4	21.1

IV. DISCUSSION

The predominant male to female ratio (6.5:1) in the present study concurs with other studies [11]–[12]. This shows the male dominance in the traffic scene. In our study, the age group of 21–30 years was the most commonly injured as this group comprised a high number of motorcyclists [13]. Furthermore, high accident occurrence during late night and early morning hours reflects that the accidents that occurred during this period tend to be more severe and are associated with a higher number of fatalities [14].

The 26% incidence of spine injuries reported in this series is relatively higher compared to previous studies of injured patients [6], [15] or those involved in lethal crashes [16]–[17]. The reason for the high number of spine injuries may be due to the inclusion of the neck injuries as part of spine injuries. In this study neck soft tissue such as muscle, carotid artery, vertebral artery, jugular vein and internal organ such as larynx were considered as spine injuries. Conversely, most of the previous studies usually only took into account the vertebral column, spinal cord, nerve root and spine ligament as spine injuries. This is possibly because these neck injuries were indeed rare in nonfatal victims or difficult to access in fatal victims.

In previous studies of nonfatal victims, the thoracic spine was the most commonly injured region in the motorcyclist, the cervical spine in the passenger car occupant and the lumbar spine in the pedestrian [11],[18]. However, in the present study the most frequently injured spine region for all the road accident victims was the cervical spine. The predominance of cervical spine injury in motorcyclists and pedestrians in the study were most likely due to occurrence of head injuries in virtually every victim for each group. Studies have shown that head injuries usually yield concurrent neck injuries in motorcyclists [12], [19]. It is postulated that these cervical spine injuries result from the transfer of energy from direct axial loading to the head [20]. Moreover, the energy transfer can occur from a hypermotion in which the relatively slender neck is strained by disconjugate motion between the larger masses of the head and torso [8]. These mechanisms offered an explanation for the occurrence of cervical spine injuries in victims who had no direct contact trauma to the neck. The high proportion of MAIS 1 – 2 cervical spine injuries with concomitant MAIS 4 – 6 head injuries in motorcyclists and pedestrians in the current study may reflect such occurrence. While it has been suggested that a helmet protects the cervical spine by preventing hyperflexion [21] – [22], we were unable to substantiate the same from this study due to insufficient information on helmet usage.

In addition, the differences in the patterns of injuries for motorcyclists between the current findings and earlier studies may be attributed to regional differences [23]. Previous studies were from developed countries such as in Europe and the USA in which most of the motorcycles are big and high-powered, and therefore could move very fast [24]. Thus, accidents often involve high-energy transfer. This may not be reflective of developing countries such as Malaysia because most of the motorcycles are small, low-powered and usually used for commuting in the cities. The accidents usually involved less in energy transfer due to low speed. This factor may determine the injury outcomes because of the spine biomechanics. Unlike the cervical spine, the thoracic spine, especially the mid-section, is always associated with high-energy injury because great force is required to injure the thoracic spine which is well-protected by the rigid rib cage [25].

While unprotected motorcyclists and pedestrians are exposed to multiple impacts and various loadings to their body, restrained car occupants are typically subjected to a single impact resulting from a rapid deceleration effect [18]. As the seat belt only restrains the passenger car occupant's body, the unrestrained head and neck are still susceptible to injury [26]. This is evidenced in the current study by the high proportion of head and cervical spine injuries among the car occupants. However, in comparison to the unbelted car occupants incidences of cervical fractures were much lower in belted car occupants [27] – [28]. Likewise, our findings show a higher proportion of cervical spine injury among the unbelted car occupants compared to the belted occupants. Nevertheless, due to limited sample size comparison of belted and unbelted car occupants in relation to spine injuries severity was inconclusive. Reference [11] associates the low levels of thoracic spinal injury in passenger car occupants due to the protection of the thoracolumbar spine afforded by seats and seat belts.

Although the proportion of cervical spine injury was relatively higher in motorcyclists and pedestrians, a higher proportion of MAIS 4 – 6 spine injuries was found for passenger car occupants. Consistently, thorax and abdomen MAIS 4 – 6 injuries were also in higher proportion for passenger car occupants than for motorcyclists and pedestrians. The finding agrees with previous studies in which passenger car occupants have a higher tendency to suffer thorax and abdominal injuries as compared to motorcyclists and pedestrians [11]. Furthermore, the presence of a higher proportion of lower extremity injuries, especially femur fracture, and facial injuries to passenger car occupants suggested that the car occupant may have suffered massive crush from extensive intrusion in frontal crashes. Moreover, reference [17] highlighted that pelvic fractures and facial injuries which are associated with a skull injury were observed exclusively among unbelted subjects.

A high number of the road accident victims died immediately before reaching hospital. This concurs with previous studies [29]–[31]. Low fatality due to spine injuries has been reported previously. Reference [32] reported 131 road accident fatalities but only found 8 (6.1%) victims who died due to spine injuries. The present study mirrors this low fatality due to spine injuries with only 1.3% (9 out of 670) of the victims in which the cause of death was primarily spine injury alone. After taking into account the spine injuries contributing to fatal outcome, these were altogether 8.4% (56 out of 670) of the victims. A higher proportion of car passenger occupants died due to spine injury compared to motorcyclists and pedestrians because of the high occurrence of thorax and spine injuries in passenger car occupants. As stated earlier, the presence of MAIS 4-6 thorax injury in passenger car occupants seems to indicate the presence of a similar level of MAIS in spine injuries as well. However, the presence of MAIS 4 – 6 head injuries does not necessarily indicate identical level of MAIS for spine injuries as a higher proportion of head injuries was seen to exist across all MAIS levels for spine injuries. The findings mirror a previous study which shows that for the AIS 4+ injuries, the three most frequent locations were the thorax alone (30% of subjects), the head alone (23%) and a combination of the two (18%) [17]. However, the study did not highlight the associated severity of spine injury for comparison.

High spinal cord injuries were observed to occur less frequently in car drivers [17]. Comparably, this study demonstrated that upper spinal cord injury (C1 – C3) occurrence was the lowest in passenger car occupants and the highest among the motorcyclists. References [2], [23] considered that high cervical injuries are frequently combined with head injuries. This supports the current finding that shows a higher proportion of head injuries (MAIS 3 – 6) occur to motorcyclists and pedestrians. The higher proportion found in motorcyclists and pedestrians may be due to the unprotected nature of these road user groups in a crash. In a crash the head can be subjected to multiple impacts which can result in severe injuries.

The limitations of the study include its retrospective design and relatively small size. The small sample size of passenger car occupants and pedestrians hinders a meaningful investigation through statistical analysis to be done. Furthermore, since the presence of spine injury was an inclusion criterion for the current study, more general observations on the risk of spine injury in the presence of other body regions cannot be elucidated. Also, the study lacks information about the circumstances of the road crash, i.e. side impact collision, head-on or rear end. The information about passive safety of the victims such as helmet wearing and seat belt use was also scarce. Though police reports were used to complement the post mortem reports, detailed information about safety systems was incomplete and therefore left out of this analysis. This type of information is important in order to fully understand the factors influencing the specific body parts and regions injured. Furthermore, the information on safety devices could help in determining the effectiveness of them in protecting the victims as well as their effect on injury severity.

V. CONCLUSIONS

Fatalities due to spine injury are indeed very low and the occurrences of high severity spine injuries are usually concomitant with high severity injury in other body regions. Cervical spine injuries are the most common in all road accident victims. The upper cervical cord region is more frequently injured than are other spine regions in motorcyclists and pedestrians or in passenger car occupants. Commonly associated injuries were head and spine injuries with more than 90% of the victims presenting with these injuries. Yet, the presence of severe head injuries does not directly correlate with severe spine injuries in which the severity of head injuries can be as high as MAIS 4 – 6 but the concomitant spine injuries can still be as low as MAIS 1 – 2. On the other hand, the presence of thorax injuries with MAIS 4 – 6 seems to indicate the presence of a similar level of MAIS in spine injuries in passenger car occupants and motorcyclists. Common severe injuries for thorax were haemothorax, subendocardial hemorrhage and severe laceration to the aorta, heart and lung. The high severity of head and thorax injuries concomitant with spine injuries suggests that improved protection against injuries of these vital body regions could reduce the severity of spine injuries as well.

VI. ACKNOWLEDGEMENT

Our deep appreciation goes to the Department of Forensic Medicine, Kuala Lumpur Hospital for providing the data and facilitating the data collection process. Special thanks to the Research and Ethics Committee, Malaysian Institute of Road Safety Research and Research and Ethic Committee, National Institute of Health, Ministry of Health, Malaysia for approving the design and conduct of this study. This work was supported by Malaysian Institute of Road Safety Research.

VII. REFERENCES

[1] Hashim HH, Sarani R, Sharifah Allyana SMR, Mohamed N, Jamilah MM, Mohd Sadullah AF, Patterns of Anatomical Injury Severity to Different Types of Road Users in Road Crashes. *Proceedings of 3rd International Conference on Road Safety and Simulation,* Indianapolis, USA, 2011.

[2] Green RN, German A, Nowak ES, Dalmotas D, Stewart DE, Fatal injuries to restrained passenger car occupants in Canada: crash modes and kinematics of injury, *Accident Analysis and Prevention*, 26(2), 207–214, 1994.

[3] Santamarina-Rubio E, Perez K, Ricart I, Arroyo A, Borell CJC, Injury profiles of road traffic deaths, *Accident Analysis and Prevention*, 39(1), 1–5, 2007.

[4] Carson HJ, Cook BA, Massive internal injury in the absence of significant external injury after collisions of passenger vehicles with much larger vehicles, *Journal of Forensic and Legal Medicine,* 15(4), 219–222, 2008.

[5] Pang TY, Radin Umar RS, Azhar AA, Harwant S, Shahrom AW, Halim AHM, Zahari N, Shafie MO, Fatal injuries in Malaysian motorcyclists. *International Medical Research Journal,* 3(2), 115-119, 1999.

[6] Ankarath S, Giannoudis PV, Barlow I, Bellamy MC, Matthews SJ, Smith RM, Injury patterns associated with mortality following motorcycle crashes, *Injury*, 33(6), 473–477, 2003.

[7] Braddock M, Schwartz R, Lapidus G, Banco L , Jacobs L , A population-based study of motorcycle injuries and costs, *Annals of Emergency Medicine,* 21(3), 273–278, 1992.

[8] Kasantikul V, Ouellet JV, Smith TA, Head and neck injuries in fatal 618 motorcycle collisions as determined by detailed autopsy, *Traffic Injury Prevention*, 4(3), 255–262, 2002.

[9] Pang TY, Radin Umar RS, Azhar AA, Ahmad MM, Nasir MT, Harwant S, Accident characteristics of injured motorcyclists in Malaysia, *Medical Journal Malaysia*, 55(1), 45–50, 2000.

[10] AAAM, The Abbreviated Injury Scale 2005, Update 2008, AAAM, Des Plaines, IL, 2008.

[11] Robertson A, Branfoot T, Barlow IF, Giannoudis PV, Spinal injury patterns resulting from car and motorcycle accidents, *Spine,* 27(24), 2825-2830, 2002.

[12] Ooi SS, Wong SV, Radin Umar RS, Azhar AA, Megat Ahmad, MMH, Cervical spine injuries sustained by motorcyclists in road crashes in Malaysia, *International Journal of Crashworthiness,* 10(3), 295–303, 2005.

[13] Sharifah Allyana SMR, Zarir HZ, Abdul Rahmat AM, Siti Atiqah MF, Noor FP, Wong SV, Jamilah MJ, Recent trend of fatal motorcycle crashes in Malaysia, *Proceedings of the 8th International Forum of Automotive Traffic Safety (INFATS)*, Wuhu, China, 2010.

[14] Fadhli Y, Zarir HZ, Sharifah Allyana SMR, Norlen M, Wong SV, Road collisions involving express buses travelling during wee hours (12.00am – 6.00am), *MER 04/2009*, Kuala Lumpur: Malaysian Institute of Road Safety Research, 2009.

[15] Zargar M, Khaji, Karbakhsh M, Pattern of motorcycle-related injuries in Tehran, 1999 to 2000: a study in 6 hospitals, *East Mediterranean Health Journal*, 12(1-2), 81–87, 2006.

[16] Sinha AK, Boot DA, Gorman DF, Teanby DN, Severe motorcycle injury in Mersey region and North Wales, *Injury,* 26(8), 543–545, 1995.

[17] Ndiaye A, Chambost M, Chiron M, The fatal injuries of car drivers, *Forensic Science International*, *184*(1-3), 21-7, 2009.

[18]Vives MJ, Kishan S, Asghar J, Peng B, Reiter MF, Milo S, Livingston D, Spinal injuries in pedestrians struck by motor vehicles, *Journal of Spinal Disorders and Techniques*, 21(4), 281–7, 2008.

[19]Krantz KP, Head and neck injuries to motorcycle and moped riders, with special regard to the effect of protective helmets, *Injury*, 16(4), 253-258, 1985.

[20]Nightingale RW, McElhaney JH, Richardson WJ, Myers BS, Dynamic responses of the head and cervical spine to axial impact loading, *Journal of Biomechanics*, 29(3), 307-318, 1996.

[21]Orsay EM, Muelleman RL, Peterson TD, et al. Motorcycle helmets and spinal injuries: dispelling the myth, *Annals of Emergency Medicine,* 23(4), 802–6, 1994.

[22]Walker KA, Motor-racing, *Practitioner,* 215, 178–87, 1975.

[23]Pedram H, Reza ZM, Reza RM, Vaccaro AR, Vafa RM, Spinal fractures resulting from traumatic injuries. *Chinese Journal of Traumatology* (English Edition), 13(1), 3–9, 2010.

[24]Teoh ER, Campbell M, Role of motorcycle type in fatal motorcycle crashes, *Journal of Safety Research,* 41(6), 507–512, 2010.

[25]Bohlman HH, Treatment of fractures and dislocations of the thoracic and lumbar spinal, *Journal of Bone and Joint Surgery*, 67(1), 165–169, 1985.

[26]Mackay GM, Hill JR, The limitations of current seatbelts in Europe—some population considerations, *Journal of Trauma,* 38(4), 533–7, 1995.

[27]Huelke DF, O'Day J, Mendelsohn RA. Cervical injuries suffered in automotive crashes, *Journal of Neurosurgery*, 54(3), 316–322, 1981.

[28]Richter M, Otte D, Pohlemann T, Krettek C, Blauth M. Whiplash-type neck distortion in restrained car drivers: frequency, causes and long-term results, *European Spine Journal,* 9(2), 109–117, 2000

[29]Ryan M, Stelle J, Chiu H, Ragg M, Injury patterns and preventability in prehospital motor vehicle crash fatalities in Victoria, *Emergency Medicine Australasia*, 16(4), 274–279, 2004.

[30]Wyatt JP, O'Donnell J, Beard D, Busuttil A, Injury analyses of fatal motorcycle collisions in south-east Scotland, *Forensic Science International,* 104(2), 127–132, 1999.

[31]McCoy GF, Johnstone RA, Nelson IW, Duthie RB, A review of fatal road accidents in Oxfordshire over a 2–year period, *Injury*, *20*(2), 65–8, 1989.

[32]Mackay GM, Cheng L, Smith M, Parkin S, Restrained front seat car occupant fatalities—the nature and circumstances of their injuries, *Accident Analysis and Prevention,* 24(3), 307–315, 1992.