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Research Paper: Injury Patterns and Causes of Death Among Occupants of Three-wheelers Succumbed to Their Injuries From Road Traffic Accidents in Sri Lanka

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ABSTRACT

Background: In Sri Lanka and South Asian countries, three-wheeler vehicles are a popular mode of transportation. However due to poor vehicle safety features and road conditions, this vehicle is more vulnerable to accidents. In this regard, we hypothesize that the occupants of three-wheelers sustain a different pattern of injuries compared to occupants of other vehicles, which cause a fatal outcome.

Methods: This was a retrospective study from 2005 to 2014. The study samples were occupants of three-wheelers succumbed from road traffic accidents reported to 3 medico-legal units in Sri Lanka.

Results: In our study, majority of the victims were young males. The commonest site of fatal injury was head (78.8%), which was more common in passengers. The commonest skull fracture was on base (70.5%). Majority had brain contusion (36.4%) and subarachnoid haemorrhage (31%) was the commonest type of intracranial haemorrhage. Chest injuries directly contributed to death in 57 cases while rib fractures were seen in all such cases. Spinal injuries were seen in 41(31%) cases where cervical spine injuries were the commonest which was seen in 30(73.2 %) cases. In the present study, 65.2% of deaths have taken place within the first hour following the incident. Out of all the fatal cases, 84.8% of the victims were trapped inside the vehicle and others (15.2%) were thrown away. Toppling of the three-wheeler was seen in 27.3% of cases.

Conclusion: The poor safety structure of the three-wheeler plays a major role in the type of injuries sustained by the deceased and the safety of the occupants should be improved.

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1. Introduction

Injuries and fatalities occur in all forms of transportation, but numerically road traffic accidents account for the great majority worldwide. The number of vehicles have increased disproportionately to the development of roads. Therefore, regulations have been introduced for the safety of road users, including vehicle occupants and pedestrians [1].

Many fatalities occur due to road traffic accidents in developing countries with poor economic status like Sri Lanka, India, Bangladesh, etc. Several factors are responsible for the high incidence of road accidents in Sri Lanka. Use of unsafe vehicles such as three-wheelers accounts for a considerably high fatality rate. According to national transport statistics issued by the national transport commission, 8% of the fatal accidents involved three-wheelers in 2014 [2].

Majority of persons interested in owning a vehicle, tend to select three-wheelers, as purchasing and maintenance cost is much less compared to other vehicles. This vehicle is able to transport 4 to 5 people including the driver and therefore commonly selected as a family vehicle. As a result, three-wheeler is a popular mode of transport in most part of the country. Sometimes the owner hires the vehicle on part time basis for passenger transportation. Furthermore it is also an economical and convenient method of transportation for tourists who may face tragic situation.

The three-wheeler is considered more unsafe than four-wheel vehicles due to following reasons: Unstable and prone to topple (Figure 1); fragile cabin structure causes easy deformation (Figure 2); open sides may cause occupants to be thrown out (Figure 1); compact passenger compartment leading to injuries from being thrown forward; and absence of safety measures like seat belts, airbags, ABS brakes and so on (Figure 3). Therefore, an injury sustained by three-wheeler occupants following an accident differs from that of other vehicle occupants. However, studies regarding the pattern of injuries in fatal accidents are scanty.

In this regard, we hypothesized that occupants of three-wheelers sustain a different pattern of injuries as compared to occupants of other vehicles. With regard to injuries sustained by occupants of three-wheelers who have succumbed to these injuries aim of this study is to identify the injury pattern, and ascertain the cause of death.

2. Materials and Methods

This was a retrospective study from 2005 to 2014. The study samples were occupants of three-wheelers succumbed from road traffic accidents in Kandy, Peradeniya and Kalubowila tertiary care hospital and their medico-legal units in Sri Lanka. Injuries sustained and the causes of death was documented using a data sheet from information obtained from postmortem reports and police investigations which included eyewitnesses' accounts adhering to the ethical guidelines of the Faculty of Medicine, University of Peradeniya (2017/EC/28). The data were analyzed using Microsoft Excel 2013 and SPSS v.22. Exclusion criteria of the study were those: (a) had succumbed due to suspicious circumstances; (b) whose location within the three-wheeler was in doubt; (c) having a collision with a train; (c) having compli-

Figure 1. The three wheels making it unstable and prone to topple; Open sides with canvas top-easy to thrown away

Figure 2. Frame of a three-wheeler used to built with small iron pipes and thin iron sheet making it a fragile structure and easy to distort in collision

Table 1. Age distribution of the victims

Age Group (Year)	Number of Fatal Cases	Percentage (n=132)
5-10	7	5.3
11-20	9	6.9
21-30	38	28.8
31-40	21	15.9
41-50	21	15.9
51-60	18	13.6
>60	18	13.6

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cations of natural diseases or intoxication (alcohol and drugs); and (d) were in a position which may have affected the normal mechanism of injury causation e.g., child on mother's lap, adult lying on backseat, etc.

3. Results

A total of 132 cases were studied including 57(43%) drivers and 75(57%) back seat passengers. Male to female ratio was 5:1 (Table 1). Majority of the victims aged between 21 and 30 years. Site of fatally injured region according to the driver and the back seat passenger was analyzed and the percentages were calculated (Table 2). The commonest site of fatal injury (Abbreviated Injury Scale or AIS 5 and 6) was to the head. Fatal injuries to the chest, abdomen, and neck were slightly higher in drivers than in back seat passengers while fatal injuries to head was higher in back seat passengers by approximately 6% when compared to drivers. The most frequent fatal injury combination involved the head and chest (12.1%) followed by head and abdomen (3.8%).

Scalp injuries were reported in 120 cases. Laceration was the commonest type of scalp injury which was reported in 64(53.3%) with scalp contusions in 39(32.5%) and abrasions in 6(5.0%). Skull fractures were reported in 78(59.1%) with commonest location being the base of the skull (70.5%). Parietal bone, frontal bone, temporal bone and occipital bone fractures were reported in 34(43.6%), 32(41%), 21(26.9%) and 6(7.7%) cases, respectively.

The commonest brain injury was brain contusion, which occurred in 48(36.4%) victims while laceration and gross destruction accounted for 11(8.3%) cases each. Seven victims had primary brainstem haemorrhage, while five had secondary brainstem haemorrhage. The analysis on the type of intracranial hemorrhage revealed that the commonest intracranial hemorrhage was subarachnoid hemorrhage, which had occurred in 41 cases (31.1%) (Figure 4).

When considering cutaneous injuries to the neck, abrasions and lacerations had occurred in 7(5.3%) victims each while contusion and cut injury was reported in 2(1.5%) victims each. Cervical vertebral fractures were the commonest injury (22.7%) that had occurred to deep structures of neck. Blood vessel injuries and cervical spine

Table 2. Site of fatal injury

Site	Percentage (n=132)	Driver		Back Seat Passenger	
		Number of Victims	Percentage (n=57)	Number of Victims	Percentage (n=75)
Head	78.8	43	75.4	61	81.3
Chest	43.2	27	47.4	30	40.0
Abdomen	24.2	16	28.1	16	21.3
Neck	22.7	14	24.6	16	21.3

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Figure 3 . Metal cabin and unsafely features: small seats, iron cabin, less leg space and no seat belts, headrest

dislocations each had occurred in 5(3.8%) victims while only in two victims, damage to the trachea was reported.

Abrasions were seen in 20(15.2%) victims while contusions were seen in 9(6.8%) victims. Lacerations and cut injuries were seen in 5 (3.8%) and 2(1.5%) victims, respectively. Chest injuries directly contributed to death in 57(43.2%) cases. Rib fractures were observed to be common in all such cases during the analysis on the type of injuries to thoracic cage (Figure 5). The analysis of internal injuries of the chest, lung contusions were observed to be the commonest of all lung injuries (Table 3).

Abrasions were identified in 5 victims which accounted for 62.5% of cutaneous injuries in abdomen while skin laceration was seem in 3(37.5%) victims. None of the victims had contusions or cut injuries. Studying of the internal injuries to the abdominal and pelvic region, the most affected visceral organ was the liver and majority sustained lacerations. Hemoperitoneum was seen in 27(20.5%) victims. Only two (1.5%) victims had a splenic injury (Table 4). The commonest spinal injury was cervical spinal injury which accounts for 73.2% of

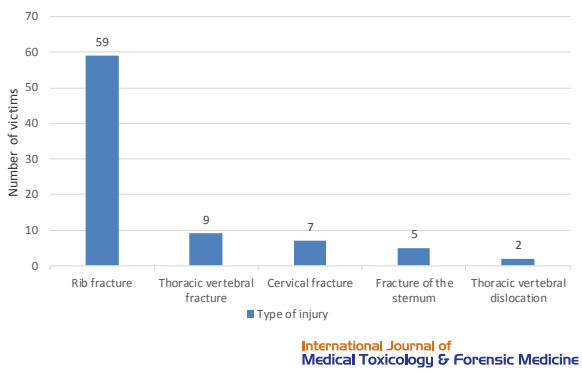

Figure 5. Types of injuries to thoracic cage

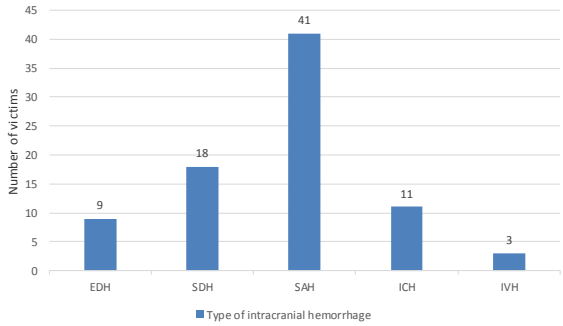

Figure 4. Types of intracranial haemorrhage

all the spinal injuries. Thoracic spinal injury was reported in 9 victims. Only two victims had lumber spinal injury. The analysis on the injury pattern of cervical spine revealed that, cervical spinal injuries of majority of cases were occurred at C6 (Figure 6).

Non-fatal limb injuries (AIS 1, 2 & 3) were seen in 76.5% of the victims. Abrasions were the commonest cutaneous injuries seen in all four limbs except the hand, where lacerations were the commonest (Table 5). When considered on the site of fracture of both upper and lower limbs, the commonest bone to sustain fractures was the femur (Figure 7). About the survival period, the majority (65.2%) of deaths have taken place within the first hour following the accident and 77.3% of victims died within 24 hours. About 13.6% have died one week after the accident (Figure 8). Out of all victims, 84.8% were trapped inside the vehicle while 15.2% were thrown away. Toppling of the three-wheeler was reported in 27.3% of cases. Majority of the victims died due to frontal collisions (75.5%) compared to side collisions in 24.5% of cases.

4. Discussion

Three-wheel is a vehicle similar to that of a small van but has three wheels, one in front and two at the rear. It has two compartments; the driver's and passengers'

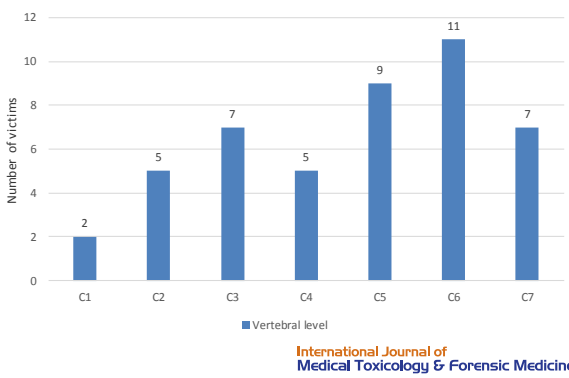

Figure 6. Injury pattern of cervical spine

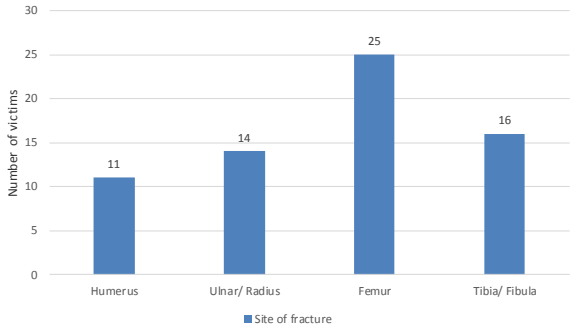

Figure 7. Site of fracture of both upper and lower limbs

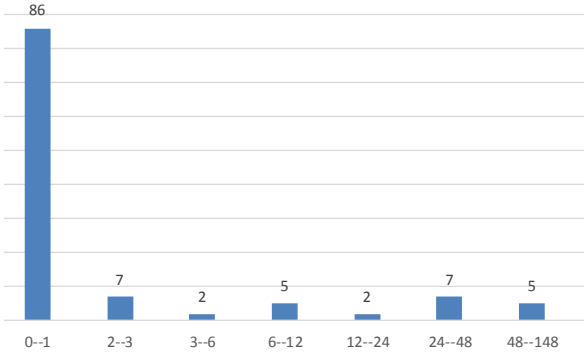

Figure 8. Survival period

compartment separated by metal bars. The engine is located at the back of the vehicle below the passengers' seat. The sides of the vehicle are open and some have a half door on one side of the passenger compartment. The body is made out of metal bars covered by a canvass sheet. Petrol/gasoline, diesel and gas can be used as fuel, but majority use petrol. The steering wheel is similar to that of a motorbike and some have a dash board made out of a thin sheet of metal or plastic (Figures 1 and 2).

In our study, a majority of the victims (28.8%) aged between 21 and 30 years. This result is similar to that of a survey conducted in Sri Lanka in 2015, where a majority of victims were between 21 and 30 years old [2]. Similar findings were seen in studies done in India [3-6]. This study revealed a male to female ratio of 5:1, which agrees well with the statistics of a survey conducted in Sri Lanka in 2015 where 82% of the victims were male [2]. This is consistent with a South Indian study where the male to female ratio was 5:1 [7].

However the two Indian studies have considered fatalities to pedestrians as well as occupants while this study focused only on fatalities to vehicle occupants. 2000 WHO statistics revealed that the male to female ratio of fatalities was 3:1 [8]. The countries in the Indian subcontinent are developing countries where a majority of drivers are male. This could be one reason for the difference between WHO data and data in the Indian subcontinent. However it should also be noted that the WHO survey included all road traffic accidents and not three-wheeler crashes alone.

Considering those who succumbed, our study revealed that 43% were drivers, and 57% were back seat passengers which are similar to previous local and international studies [9, 10]. However these studies included all types of vehicles. Based on this study results, fatal injuries to chest, abdomen and neck were slightly higher in drivers while head injuries were higher in back seat passengers by approximately 6% when compared to drivers. This may be due to the fact that, the driver first contact with the steering wheel (similar to that of a motor bike) during an accident resulting in chest and abdominal injuries. A similar pattern was seen in vehicle occupants of four-wheeled vehicle with a lower frequency of head injuries [10]. Head injuries of the passengers occur due to impact of head against the metal bars which separate the driver's compartment from the rear compartment or due to being thrown out of the vehicle. The risk of such

Table 3. Types of injury to internal chest

Structure	Injury Pattern	Number of Victims	Percentage (n=132)
Lung	Lung contusion	25	18.9
	Lung laceration	16	12.1
	Lung collapse	5	3.8
Thoracic cavity	Hemothorax	34	25.8
	Pneumothorax	2	1.5
Blood vessel		5	3.8

injuries is further increased because of the absence of seat belts in three-wheelers.

This study revealed that the proportion of drivers who sustained fatal injuries to chest was lower compared to drivers of four-wheeled vehicles [10]. In a four-wheeled vehicle the driver collides with the steering wheel during an accident which causes injuries both to the chest and abdomen as the steering wheel is located at the level of the thorax and the abdomen [1, 11]. However the steering wheel of a three-wheeler is located below the level of the chest (abdominal level). Therefore, during an accident, the driver's chest is less likely to hit the steering wheel. This also explains the higher percentage (28.1%) of fatal injuries to abdomen in drivers seen in our study compared to drivers of four wheeled vehicles (11%) [10].

In this study, the fatal injuries to chest and abdomen of drivers were higher than similar injuries in those who succumbed due to motorcycle accidents [10]. This may be due to the fact that the three-wheel drivers sustain injuries due to contact with the cabin frame and or being thrown out of the vehicle (at a low velocity) since the sides of the vehicle are not covered. In motorcycle accidents, fatal injuries mainly occur due to being thrown away from the vehicle [1]. However chest and abdominal injuries maybe lower due to the fact that they are thrown away at a higher speed (resulting in more head injuries) and due to wearing of protective clothing.

The commonest anatomical region of fatal injury (AIS 5 & 6) in our study was the head (78.8%). This is similar to a study carried out in the US. in 1962 on motorcyclists, where 80% of the victims succumbed to head injury. This is higher when compared to the fatal head injuries sustained by four-wheeled vehicle occupants [10], where the vehicle is covered on all sides. Since the sides of the three-wheelers are also not covered, the risk of three-wheeler occupants being thrown out of the vehicle is high. The cabin of the three wheeler is not strong and will easily get deformed during an accident. This may explain the higher percentage of head injuries sustained by three-wheel occupants compared to occupants of four-wheeled vehicles.

In our study sample, skull fractures were reported in 59% of cases. In a series of 23 motorcycle fatalities, it was noted that 70% had skull fractures compared to 53% of motor car occupants [10]. Therefore the incidence of skull fractures in our study lies between the incidence of skull fractures in motorcycle and four-wheeled vehicles. This may be because of some protection from the cabin to the three-wheeler occupant (despite the sides being open) in contrast to the motor cycle [1].

This study revealed that base of the skull fracture accounted for 70.5% of all skull fractures. Similar results were observed in motorcyclists and occupants of four-wheeled vehicles [1, 5, 10]. Brain injuries in road traffic accidents range from surface contusions to gross laceration or even extrusion [10]. This study revealed that the

Table 4. Injury pattern of abdominal and pelvic viscera

Structure	Injury Pattern	Number of Victims	Percentage (n=132)
Liver	Liver laceration	18	13.6
	Gross destruction of liver	9	6.8
	Liver contusion	2	1.5
Diaphragm	Rupture	0	0
	Contusion	2	1.5
Peritoneal cavity	Hemoperitoneum	27	20.5
Spleen		2	1.5
Small intestine		5	3.8
Mesentery		2	1.5
Pelvic fracture or dislocation		5	3.8

commonest injury to the brain was contusion followed by laceration and gross destruction. Subarachnoid hemorrhage was the commonest type of intracranial hemorrhage identified in our study (31%) with the second most common being subdural haemorrhage (13.6%). However a similar study done in India revealed that the subdural hemorrhage was the commonest type of intracranial hemorrhage [5]. Rib fractures in our study (44.7%) is lower compared to four-wheeled vehicle occupants (70%) [10, 12].

In our study, the commonest affected viscus was the lungs. This result is similar to that of other studies done on occupants of other vehicles [4, 10, 13]. This is because more injuries occur to the chest than to the abdomen where lungs impact against the rib cage and spine [10]. However the percentage of lung injuries in our study is less compared to that of four-wheeled vehicles (68%) [10]. As previously explained, this may be due to the level of the steering wheel.

Hyperflexion of the cervical spine when the head swings can cause fractures or dislocations. The injury may be worsened if the head strikes an object in front causing a rebound hyperextension. Therefore cervical spine injuries are common compared to other spinal injuries [1]. This pattern was observed in our study as well as in other studies [10, 12, 13].

In our study, 76% of the victims had non-fatal limb injuries. These injuries are caused by impact with objects inside or outside the vehicle. In contrast to a four-wheeled vehicle, this may also occur due to friction against the road surface, or easily being thrown out of the vehicle, or being crushed/trapped inside the vehicle due to deformation of the structure. Lower limb fractures are more common compared to upper limb fractures in four-wheeled vehicle occupants [1, 10]. A similar pattern was observed in this study. In 3- and 4-wheeled vehicles this can be explained by forward movement following a head on collision which results in the lower limbs striking the

Table 5. Injury pattern of upper and lower limbs

Segment	Region	Injury Pattern	Number of Victims	Percentage (n=132)
Upper limb	Upper arm	Abrasion	39	29.5
		Laceration	23	17.4
		Contusion	7	5.3
	Lower arm	Abrasion	36	27.3
		Laceration	18	13.6
		Contusion	2	1.5
	Hand	Abrasion	14	10.6
		Laceration	16	12.1
		Contusion	5	3.8
Lower limb	Upper leg	Abrasion	48	36.4
		Laceration	36	27.3
		Contusion	14	10.6
	Lower leg	Abrasion	55	41.6
		Laceration	27	20.5
		Contusion	9	6.8
	Foot	Abrasion	23	17.4
		Laceration	5	3.8
		Contusion	0	0

dash board or front seat [4]; however, in motorcycle fatalities, the occurrence of upper limb fractures are high compared to lower limb fractures as a person would extend his or her upper limbs to avoid falling [1, 4].

In our study, 3.8% had pelvic fracture/dislocation which were low compared to pelvic injuries in four-wheeled vehicle accidents [1, 10]. Pelvic fractures or injuries in three- or four-wheeled vehicle crashes occur due to transmission of energy from the femur to pelvis due to impact with the dashboard of the vehicle. Compared to a four-wheeled vehicles, three-wheeler has a dashboard made of a thin layer of plastic or metal and is weaker. In some instances no dashboard is present. Therefore the force of energy created on impact by the dashboard, if present, is less, causing negligible or no injury to the pelvis. Therefore pelvic injuries would be low compared to motorcyclists' [4]. However the absence or the presence of a weak dashboard may facilitate ejection of the occupant.

In this study, majority (65.2%) of deaths occurred within the first hour following the incident and 77% of victims died within the first 24 hours. This pattern is similar to observations made in other studies where most victims succumbed within 24 hours of the incident [2, 3, 10]. Of all fatal cases in our study, 15.2% were thrown out of the vehicle that may be considered high compared to four-wheeled vehicles [10]. The reason for this may be the absence of safety devises like seat belts and enclosed secured structures in three-wheelers. Air bags in a four-wheeled vehicle help prevent ejection from the vehicle by interposing itself in between the occupant and frontal structures of the cabin [1]. Doors and a strong structure of the four-wheeled vehicle also helps prevent ejection. However none of the above features are present in a three-wheeler.

In this study, toppling of the three-wheeler was seen in 27% of cases. This result was high compared to four-wheeled vehicle accidents [10, 14]. The design of a three-wheeler is similar to a cuboid balance on 3 wheels, one wheel in front and two at the rear. The wheels are small with a tire width of 9.5 cm. This makes the vehicle unsteady and easy to topple.

5. Conclusion

Our study highlighted that, young male occupants of three-wheel vehicle succumbed in a very short period and mainly due to injuries to the head. The injury pattern in most instances lies between victims of motorcycle and four-wheeled vehicles. It is now time to consider safety features/modification of three-wheelers to reduce the grave consequences of its users.

Ethical Considerations

Compliance with ethical guidelines

The Ethical approval was granted by the Ethical Review Committee, University of Peradeniya, Peradeniya, Sri Lanka (2017/EC/28).

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Conflict of interest

There is no conflict of interest regarding publication of this paper.

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