

Evaluation of Thoracic Aorta Injuries Sustained by Riders in Comparison to Pillion Passengers in Fatal Motorcycle Collision Accidents

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Background: *Since motorcycles are the most popular form of transportation in Thailand, deaths from motorcycle accidents have become the majority of all road traffic deaths. Such mortalities are largely caused by thoracic aorta injuries.*

Objective: *To compare thoracic aorta injuries sustained by motorcycle riders with those sustained by pillion passengers in fatal motorcycle collision accidents.*

Material and Method: *We reviewed the autopsy reports from the Department of Forensic Medicine and Faculty of Medicine at Srinakharinwirot University between January 2011 and December 2015. The research team identified 39 cases of motorcycle accidents with thoracic aorta injuries, which caused the riders 28 deaths and 11 deaths of the pillion passengers. The types of collision and the position of the victim on the motorcycle were obtained from the police reports, which are also included in the study. The characteristic of injuries and fatal causes were evaluated and compared using Chi-square test (χ^2).*

Results: *The result showed that 41% of cases involved in frontal impact collision. For both riders and pillion passengers, the majority of thoracic aorta injuries occurred at the aortic isthmus (57.7%). Thoracic aorta injury was higher in riders than pillion passengers, but these differences were not statistically significant ($p = 0.235$). In addition, we found that riders were more likely to suffer from impact injuries than pillion passengers, while the pillion passengers were more likely to sustain more tumbling injuries than riders. Sternal fractures and left sided serial rib fractures were predictive of thoracic aorta injury.*

Conclusion: *Thoracic aorta injuries play a significant role in causing mortalities in motorcycle accidents. The findings in the present study could help guide medico-legal examinations, particularly in identifying riders among victims. The present research provided an insight into decreasing the mortality rate by integrating medical aspects into future motorcycle designs.*

Keywords: *Thoracic aorta injuries, Motorcycle accidents, Riders, Pillions*

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Over the last decade, there has been a marked increase in the number of motorcycle registrations in Thailand. As a consequence, there has been a rise in number of injuries resulting from accidents involving these vehicles, with collision of motorcycles with other type of vehicles, and fixed objects, being the most common type of accident. Such incidents have caused injuries to motorcycle riders and pillion passengers more frequently than other types of road users^(1,2). The present research investigated traumatic aortic rupture injuries sustained by both motorcycle riders and pillion passengers.

Traumatic aortic rupture is the second most common cause of death in victims of blunt chest trauma

from motor vehicle accidents⁽³⁾. Most deaths (85%) usually occur at the crash scene^(3,4). Only 10 to 16% of the cases reflect long term survival rates even though accidents take place in areas with access to advanced trauma care⁽⁵⁾. Studies since the 1960s stated that the incidence of traumatic aortic rupture ranges from 12 to 26% in deceased motor vehicle occupants^(5,6). In about 80% of reported cases of thoracic aorta injury, the site of the aortic tear was at the aortic isthmus between the ostium of the left subclavian artery and the ostium of the third pair of intercostal arteries⁽⁷⁾. Several mechanisms have been postulated as to why the isthmus portion is the most common site of aortic rupture. The most widely accepted theory suggested that in blunt chest traumas, sudden high-velocity deceleration is accompanied by hyperflexion of the spine. This leads to sudden chest compression and traction on the aortic isthmus, which is the point where

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the mobile aortic arch meets the fixed proximal descending thoracic aorta^(5,8-10). Other studies have documented a high frequency of rib and sternal fractures which are seen coinciding with thoracic aorta injuries. This suggests that the cause of such injury is resulted from chest compression⁽⁵⁾. Moreover, previous autopsy research suggests that the presence of rib and sternal fractures predicts thoracic aortic injuries in motor vehicle accidents⁽¹¹⁾.

Previous studies have proposed that thoracic aortic injury due to blunt chest trauma from motorcycle accident is a highly lethal injury. However, no studies have directly compared thoracic aorta injury patterns between motorcycle riders and pillion passengers. To test whether there is a difference in thoracic aorta injury patterns between motorcycle riders and pillion passengers in motorcycle accidents, we investigated and compared such injury patterns including type of collision, type of fatal causes, location of thoracic aorta injury, and presence of bone fractures (rib and sternum). If a difference in thoracic aorta injury patterns actually exists, the discovery may provide essential evidence in identifying riders and pillion passengers. The purpose of the present paper, therefore, conducts a comparative analysis of thoracic aorta injury patterns between riders and pillion passengers from fatal motorcycle accidents emphasizing on directional impact in order to provide a better understanding of the mechanisms involved in thoracic aortic injury.

Material and Method

In a retrospective examination of autopsy reports between January 2011 and December 2015, all cases that died in motorcycle accidents including those who had blunt thoracic aortic injuries were selected from the archives at the Department of Forensic Medicine and the Faculty of Medicine, Srinakharinwirot University, Thailand. Victims involved in crashes who had underlying thoracic aortic disease, resuscitation, and operative procedures carried out were excluded, therefore, did not influence the study's results. The total numbers of all victims included in the present study were 39 cases. The data were compiled on the decedent demographics, rib fractures, sternal fractures, and location of thoracic aorta injury. In addition to the autopsy data, the type of collision and the position of the victim in the motorcycle were also considered compiled from the accident police reports. Similar data were analyzed from 39 control cases without thoracic aortic injuries.

The data were analyzed by using a statistical package SPSS 14.0 for Windows. The statistical association between the proper variables was performed by Chi-square test (χ^2) with odd ratio (OR) and 95% confidence interval (CI). A *p*-value less than 0.05 was considered statistically significant.

Results

Personal data

During the 5-year study period between 2011 and 2015, 235 cases of motorcycle accidents were discovered. All cases with thoracic aorta injuries matched the inclusion criteria were selected in the present study, 39 cases. As personal data shown in Table 1, divided by gender, there were 32 males (82%) and seven females (18%). Additionally, results were divided by riding position: 28 riders (72%) and 11 pillion passengers (28%).

The association between gender and riding position showed that males were 4.6 times more likely to ride the motorcycle than females. The mean age of all fatality was 27.3±9.5 (16 to 59) years old. The age group from 15 to 24 years old had the greatest number of fatalities (46%) in the data, followed by the 25 to 34 years old age group (39%).

Type of collision

The incidence of motorcycles colliding with other vehicles (multiple vehicle crashes) was 27 cases (69.2%), while there were 12 cases (30.8%) of motorcycles that crashed without other vehicles related (single vehicle crash) (Table 2). The frontal collisions (41%) were the most predominant collision type that resulted in death.

Characteristics of the motorcycle accidents were shown in Table 3. The collision of a motorcycle with four-wheeled vehicles was the most common

Table 1. Personal data of the motorcyclist fatalities (n = 39)

Personal characteristics	n (%)
Gender	
Male	32 (82)
Female	7 (18)
Riding position	
Rider	28 (72)
Pillion passenger	11 (28)
Age (years)	
15 to 24	18 (46)
25 to 34	15 (39)
35 to 44	4 (10)
≥45	2 (5)

cause of motorcycle accidents (51.3%). The study also found that 2.5% of crash objects were undetermined. The fixed object that was struck with the greatest frequency was a tree.

Type of fatal causes

In the present investigation, the most common fatal cause was impact. The fatal causes were significantly different between riders and pillion passengers ($p = 0.002$). In addition, we found that motorcycle riders were more likely to suffer from impact injuries than pillion passengers, but the pillion passengers were more likely to sustain tumbling injuries than riders (Table 4).

Table 2. Type of collision (n = 39)

Type of collision	n (%)
Single vehicle crash	12 (30.8)
Multiple vehicle crash	
Frontal	16 (41.0)
Rear-end	4 (10.2)
Side	7 (18.0)

Table 3. Type of object struck (n = 39)

Object struck	n (%)
Fall & fixed object	12 (30.8)
Two-wheel vehicles	3 (7.7)
Four-wheel vehicles	20 (51.3)
Large vehicles	3 (7.7)
Undetermined	1 (2.5)

Table 4. Comparison of fatal causes between riders (n = 28) and pillion passengers (n = 11)

Fatal causes	Fatalities because of	Rider	Pillion passenger	Total n (%)
Impact	Impact injuries	24	3	27 (69)
Fall	Tumbling injuries	3	7	10 (26)
Run-over	Crush injuries	1	1	2 (5)

Table 5. Location of thoracic aorta injury compared between fatal causes of riders (n = 37) and fatal causes of pillion passengers (n = 15)

	Rider			Pillion passenger			Total n (%)
	Impact	Fall	Run-over	Impact	Fall	Run-over	
Ascending aorta	5	0	1	1	0	1	8 (15.4)
Aortic arch	0	0	1	0	0	1	2 (3.8)
Aortic isthmus	20	3	1	2	3	1	30 (57.7)
Descending aorta	6	0	0	2	4	0	12 (23.1)
Total n (%)	31 (59.6)	3 (5.8)	3 (5.8)	5 (9.6)	7 (13.5)	3 (5.8)	52 (100)

Location of thoracic aorta injury compared between riders and pillion passengers

The study included 39 deceased persons with 52 thoracic aorta injuries, of which 28 (72%) had a single and 11 (28%) had multiple thoracic aorta injuries. Thoracic aorta injuries were higher in riders than pillion passengers, but these differences were not statistically significant ($p = 0.235$). The majority of the injuries in both riders and pillion passengers occurred at the aortic isthmus (57.7%) and impact injuries were the most common cause of aortic isthmus injuries (Table 5).

Rib and sternal fractures in riders and pillion passengers compared between the thoracic aorta injury group and the control group

In the present study, all deceased persons in the thoracic aorta injury group and the control group without thoracic aorta injury died instantly or within one hour after sustaining traumatic injuries without resuscitation.

No significant differences in the distribution of fatal causes were identified between the thoracic aorta injury group and the control group without thoracic aorta injury. Serial rib fractures were present in 31 cases (79.5%) from the thoracic aorta injury group, and in 24 cases (61.5%) from the control group (Table 6).

Interestingly, in riders, left sided serial rib fractures were found in 82.1% from the thoracic aorta injury group, but in only 28.5% from the control group. Likewise, in pillion passengers, left sided serial rib fractures were present in 45.5% from the thoracic aorta injury group and in 63.6% from the control group. These findings were statistically significant ($p = 0.045$) indicating that the presence of left-sided serial rib fractures predicts thoracic aorta injuries involved in riders and pillion passengers. In contrast, right-sided rib fractures were almost equally distributed in the study groups.

Table 6. Frequency of left and right sided serial rib fractures in riders and pillion passengers in the thoracic aorta injury group vs. the control group

	Rider			Pillion passenger		
	Rib fracture		Sternal fracture	Rib fracture		Sternal fracture
	Right	Left		Right	Left	
Thoracic aorta injury group	12 (42.9)	23 (82.1)	23 (82.1)	4 (36.4)	5 (45.5)	6 (54.5)
Control group	11 (39.3)	8 (28.5)	4 (14.3)	5 (45.5)	7 (63.6)	5 (45.5)

In riders, sternal fractures were present in 82.1% from the thoracic aorta injury group and in 14.3% from the control group. Likewise, in pillion passengers, 54.5% of victims from the thoracic aorta injury group and 45.5% from the control group had sternal fractures. This was statistically significant ($p = 0.044$), which indicates a predictive usefulness of sternal fractures for thoracic aorta injury.

Discussion

In developing countries, motorcycles are one of the most important means of transportation, commonly used to reduce commuting times. Motorcycle accidents continue to be the major cause of fatality for road users and a common mechanism responsible for thoracic aorta injury⁽¹²⁾.

Some studies suggest that vascular disease predispose individuals to thoracic aortic injury^(5,6,13). In the present study, victims who were involved in crashes who had underlying vascular diseases, resuscitation, and operative procedures carried out were excluded.

Our data suggested that thoracic aorta injury outstandingly had highest incidence in juveniles ages 15 to 24 years compared to any other age groups (Table 1). The young male rider is the most common characteristic out of the motorcyclist fatalities with thoracic aortic injury. Motorcycling injuries among juvenile riders have long been identified as a global problem because of potential behavior risk factors and the lack of driving experience⁽¹⁴⁾.

Four-wheeled vehicles were the greatest group that crashed with motorcycles in the present study (Table 2). The faster velocity while travelling in the four-wheeled vehicles compared to other modes might be the factor that made it harder to avoid crashing during road accidents. Motorcycle accidents without collision with another vehicle were the most common occurrence of fatal cases from previous studies⁽¹⁵⁾. However, for the present study, single vehicle crashes such as motorcycles falling and crashing with fixed objects were found to be the second most common

cause of motorcycle accidents that resulted in thoracic aorta injuries and fatalities (Table 2).

Existing research indicates that the most common site of thoracic aortic injury in blunt chest trauma is at the aortic isthmus^(5,12,16-19). Similarly in the present study, regarding the location of thoracic aorta injury, it was strikingly found that the aortic isthmus (57.7%) were more often affected than other parts of the aorta. Previous studies have shown that thoracic aortic injury has been linked to impact direction^(5,12,13,20-22). We found that in our series of fatal motorcycle collisions, thoracic aorta injuries were more frequent in frontal collisions than in side and rear-end collisions (Table 2). This leads to evidence that shows the forces on the thoracic aorta are concentrated more anteriorly in frontal impacts, and that some parts of the injury mechanisms could be due to chest compression and deceleration. In other collision types, victims were ejected before impact. This caused the impact site to be farther away from the anterior side resulting in less anterior forces to the body compared to the frontal impact type.

Our data suggested that the pathogenesis of frontal collisions involving a sudden chest compression and deceleration is the major injury mechanism that resulted in aortic injury at or near its fixed point at the aortic isthmus. The aortic isthmus is the least mobile portion of the thoracic aorta as it is attached to the pulmonary trunk via the ligamentum arteriosum. Several mechanisms have been postulated as to why the aortic isthmus is the most common site of thoracic aorta injury. The most widely accepted theory proposes that in blunt chest traumas, sudden high-velocity deceleration is accompanied by hyperflexion of the spine leading to sudden chest compression and traction on the aortic isthmus, the point at which the mobile aortic arch meets the fixed proximal descending thoracic aorta^(5,8-10). Another theory submits a “shoveling effect”, meaning lower thoracic impact results in cranial displacement of the mediastinum and torsion of the isthmus⁽¹⁰⁾. The “osseous pinch” theory suggests that the proximal descending aorta is pinched between

the sternum, upper ribs, and clavicles anteriorly and the vertebral column posteriorly⁽²³⁾. A less favorable theory offers a “water-hammer” effect, where an acute rise in aortic pressure exerts maximum stress on the aortic isthmus⁽⁸⁾.

In the present study, the most common fatal cause was the impact injury and the majority of thoracic aorta injury occurred in riders ($p = 0.002$). In addition, we found that motorcycle riders were more likely to suffer from impact injuries than pillion passengers, but the pillion passengers were more likely to sustain tumbling injuries than riders (Table 4). In motorcycle frontal collisions, the consequences leading to impact injury can be explained as follows:

At the early stage of the accident, the riders would grip the handlebars with their hands thus preventing them from being thrown in the air and catapulting them forward over the saddle. For this reason, the rider’s chest region is typically directly exposed to the front end of oncoming vehicles or fixed obstacles. This leads them to impact injuries in these areas from the mechanism of chest compression and rapid deceleration. On the other hand, pillion passengers would support themselves by gripping the haunches of the rider in front of them. Because of such weakly balanced position, the pillion passengers would be expected to be thrown in the air and fall to the ground leading them to tumbling injuries rather than the former description of injury. In some rare cases, they can be expected to suffer thoracic aorta injuries as well if their chest hit the ground directly upon the fall. In motorcycle side and rear-end collisions, riders and pillion passengers tend to be thrown a further distance before the impact. This resulted in tumbling injuries and, less often, run-over injuries.

Other studies have documented a high frequency of rib and sternal fractures coexisting with thoracic aorta injury suggesting that the cause of injury is resulted from chest compression⁽⁵⁾. Our results suggest that the presence of left sided serial rib fractures and sternal fractures predicts the presence of thoracic aorta injuries, whereas the presence of right sided rib fractures was not predictive of thoracic aorta injury. These findings again underline the importance of a thorough thoracic aorta investigation of patients who present after motorcycle collisions with rib and sternal fractures.

Thoracic aortic injuries have a high mortality rate. Therefore, integrating this knowledge into better motorcycle design in the future is essential to prevent this type of injury. Engineers need more specific data

gathered from autopsy and biomechanical analyses to better design safety equipment to prevent the occurrence of such injury in the future, hence, reducing mortality rates for overall road traffic accidents.

There was limitation to the present study. In our retrospective study between 2011 and 2015, victims who were involved in crashes who had underlying thoracic aortic disease, resuscitation, and operative procedures carried out were excluded from the study. Therefore, making available sample size limited. Future studies may involve longer duration and include larger sample size.

Conclusion

Motorcycle accidents, one of the most common types of road traffic accidents, usually result in more serious injuries to motorcyclists than other motor vehicle users. Thoracic aorta injuries contribute widely to morbidity and mortality in trauma patients after motorcycle crashes. An early diagnosis and adequate therapy can prevent life-threatening consequences in patients with such injuries. In assessing thoracic aorta injury, victims in motorcycle accidents, knowledge about the commonest sites of injuries sustained is often required. In the present research, it was found that sternal fractures and left-sided serial rib fractures might suggest thoracic aorta injuries in motorcycle occupants after road traffic accidents. For this reason, proper monitoring of the victims with rib and sternal fractures is desired for enhanced management of thoracic aorta injury cases. Moreover, distinguishing motorcycle riders from pillions is important but an often-challenging task because both victims are typically thrown out of the motorcycle in collisions. The findings of the present study will be useful in guiding medico-legal examinations in identifying riders amongst victims involved in road traffic accidents. Additionally, the present research will also act as a valuable stepping stone for future innovations in reducing morbidity and mortality in road traffic accidents, particularly those involving motorcycles.

What is already known on this topic?

Traumatic aortic rupture is the second most common cause of death in victims from motorcycle accidents. The most common site of the injury is the aortic isthmus. Many theories exist to explain the mechanism of why such injury occurs at the aortic isthmus including the high-velocity deceleration that leads to chest compression, the “shoveling effect”, the

“osseous pinch”, and the “water-hammer” effect theories.

What this study adds?

Most findings in this study are in agreement with previous existing researches on this topic. In addition, this study finds that motorcycle riders were more likely to suffer from impact injuries than pillion passengers, but the pillion passengers were more likely to sustain tumbling injuries than riders. Moreover, we found that thoracic aorta injuries were higher in riders than pillion passengers, but these differences were not statistically significant ($p>0.05$). Finally, the research team investigated that left sided serial rib fractures and sternal fractures predicts the presence of thoracic aorta injuries, whereas the presence of right sided rib fractures was not predictive of thoracic aorta injury. This study could help to guide medico-legal examinations, particularly in identifying riders among victims. By integrating the knowledge from this research into patients care and future motorcycle designs, morbidity and mortality from traffic road accidents involving motor vehicles could be significantly reduced.

Potential conflicts of interest

None.

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การศึกษาและเปรียบเทียบการบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอกในผู้ซึ่งรถจักรยานยนต์กับผู้ซ้อนท้ายที่เสียชีวิตจากอุบัติเหตุรถจักรยานยนต์

วีระศักดิ์ จรัสชัยศรี

ภูมิหลัง: ตั้งแต่รถจักรยานยนต์เป็นรูปแบบการขนส่งที่ได้รับความนิยมมากที่สุดของในประเทศไทย พบว่าการเสียชีวิตจากอุบัติเหตุรถจักรยานยนต์ได้กลายเป็นสาเหตุหลักของการเสียชีวิตในอุบัติเหตุจราจร โดยการเสียชีวิตดังกล่าวส่วนใหญ่เป็นผลมาจากการบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอก

วัตถุประสงค์: เพื่อศึกษาและเปรียบเทียบการบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอกในผู้ซึ่งรถจักรยานยนต์กับผู้ซ้อนท้ายที่เสียชีวิตจากอุบัติเหตุรถจักรยานยนต์

วัสดุและวิธีการ: เป็นการทบทวนรายงานการชันสูตรศพในภาควิชานิติเวชศาสตร์ คณะแพทยศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ ตั้งแต่เดือนมกราคม พ.ศ. 2554 ถึง ธันวาคม พ.ศ. 2558 พบว่ามีผู้เสียชีวิตจากอุบัติเหตุรถจักรยานยนต์ทั้งหมดที่มีการบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอกจำนวน 39 ราย แบ่งเป็นผู้ขับขี่ 28 ราย และผู้ซ้อนท้าย 11 ราย รูปแบบการชนและตำแหน่งของผู้เสียชีวิตบนรถจักรยานยนต์ได้จากการรายงานของตำรวจ ลักษณะของการบาดเจ็บและสาเหตุของการเสียชีวิตวิเคราะห์โดยใช้ *Chi-square test (χ^2)*

ผลการศึกษา: ผลการศึกษาพบว่า 41% ของกลุ่มตัวอย่าง เป็นการชนทางด้านหน้า โดยพบว่าทั้งผู้ขับขี่และผู้ซ้อนท้ายมีการบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอกในตำแหน่ง *aortic isthmus* เป็นส่วนใหญ่ (57.7%) และพบการบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอกในผู้ขับขี่มากกว่าผู้ซ้อนท้าย โดยความแตกต่างนี้ไม่ได้มีนัยสำคัญทางสถิติ ($p = 0.235$) อย่างไรก็ตามผู้ขับขี่มีแนวโน้มเกิดการบาดเจ็บจากการชนปะทะมากกว่าผู้ซ้อนท้าย ในขณะที่ผู้ซ้อนท้ายมีแนวโน้มเกิดการบาดเจ็บจากการหมุนกลิ้งมากกว่าผู้ขับขี่ สำหรับการหักของกระดูกอกและกระดูกซี่โครงข้างซ้าย สามารถนำมาใช้ในการคาดการณ์การบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอกได้

สรุป: การบาดเจ็บบริเวณหลอดเลือดเอออร์ตาในระดับทรวงอก เป็นต้นเหตุสำคัญในการก่อให้เกิดการเสียชีวิตในอุบัติเหตุรถจักรยานยนต์ ผลการศึกษาในการศึกษานี้จะช่วยเป็นแนวทางในการตรวจชันสูตรในทางนิติเวชศาสตร์ โดยเฉพาะอย่างยิ่งในการระบุผู้ขับขี่ในกลุ่มของผู้ที่เสียชีวิต และการศึกษาวิจัยให้ข้อมูลเชิงลึกในการลดอัตราการเสียชีวิตด้วยการบูรณาการด้านการแพทย์ในการออกแบบรถจักรยานยนต์ในอนาคต