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Original Research Article

Injuries to the great vessels: an autopsy-based study

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ABSTRACT

Background: Injuries of the chest causing disruption of the thoracic cage, damaging the great vessels are increasing daily. Aorta is most vulnerable to injury in deceleration trauma from road and air accidents, fall from height and penetrating injuries. Incidence of traumatic rupture of the aorta is rising with higher travel speed.
Methods: In this study we analysed the pattern of injury to great vessels and the socio-demographic pattern of the victims in trauma. 250 cases brought to a tertiary care institution for autopsy were studied from 1st January 2005 to 30th November 2005 (1st July 2005 - 30th November prospectively, and 1st January - 30th June 2005, retrospectively). A cross sectional study design including all cases of trauma to the chest was done with consecutive sampling. Data was collected in pro forma and analysed.
Results: 206 victims were males. Commonest cause of chest injury was trauma. 130 (52%) were victims of road traffic accidents and the vehicle implicated the most was bus (41 cases, 16.4%). Pedestrians constituted the majority (26.4%). 15 cases (6%) involved major blood vessels of the thorax. Descending part of the thoracic aorta was vulnerable, with transection of the great vessels in 5 cases (2%). Haemothorax was observed in 102 cases on right side and 94 cases on the left side. 9 cases (4%) of bronchial or tracheal ruptures with 6 cases of severance and 3 incidences of tear were recorded.
Conclusions: The wound of aorta or pulmonary artery are immediately fatal and commonly seen in case of vehicular accident or fall from height due to the intense compression to the chest with or without any sign of external injury. Most ruptures are due to automobile accidents and the mechanism of injury is sudden motion of the heart and great vessels.

Keywords: Accident, Aorta, Aortic injury, Great vessels, Trauma

INTRODUCTION

Aorta

Aorta is the great arterial trunk which arises from the aortic orifice of the left ventricle behind the third left intercostals space at the margin of the sternum. It ends on the anterior surface of the fourth lumbar vertebra by dividing in to right and left common iliac arteries.[1]

It has three parts 1) ascending aorta 2) arch of aorta 3) descending aorta

Ascending aorta is the first part of aorta. It runs upwards, forwards and to the right, to join the arch of aorta behind

the right half of the sternal angle. It is enclosed with the pulmonary trunk in a sheath of serous pericardium. The ascending aorta has four dilatations on its wall.[1] Three aortic dilatations (sinuses) at the root corresponding to the valvules of aortic valve.[2] The bulb of the aorta, which is a swelling of the right border which receives the full thrust of blood discharged from the left ventricle– a common site for the formation an abnormal dilatation or aneurysm.

Arch of aorta begins posterior to the right half of sternal angle. It passes posteriorly with a slight inclination and convexity to the left, while arching through the lower half of the superior mediastinum. It joins the descending aorta on the left of the disc between the fourth and fifth thoracic vertebral bodies. The branches are brachiocephalic trunk (first and the largest), the left common carotid and left subclavian artery.

Descending aorta begins on the left side of the fourth thoracic intervertebral disc and oesophagus and descends through the posterior mediastinum between the left pleura and the thoracic duct and azygos vein. It enters the abdomen posterior to the dorsal edge of diaphragm (median arcuate ligament) at the level of the twelfth thoracic vertebra. Its branches from the anterior surface are (1) two left bronchial arteries (2) several oesophageal branches (3) small branches to the fat and lymph nodes of the mediastinum, the pericardium and the diaphragm. From the posterior surface nine pairs of posterior intercostal arteries and one pair of subcostal arteries arise.

Pulmonary trunk

This great artery begins at the level of the pulmonary valvules. The trunk, approximately 5 cm long and 2 cm wide, winds round the left side of ascending aorta to end in the concavity of the aortic arch by dividing in to right and left pulmonary arteries, taking deoxygenated blood to the lungs.[1]

Pulmonary veins

These are four in number and drain oxygenated blood from the lungs to the left atrium of the heart. On each upper half the left atrium superior and inferior pulmonary veins end, close to the lateral margins of the posterior surface, with the superior one on a plane anterior to the inferior veins.

Trauma to the aorta

Aorta is the most vulnerable vessel that suffers injury in deceleration trauma from road and air accidents, fall from height and penetrating injuries.[2] Rupture of the thoracic aorta may result from direct injury or from pressure on the abdomen which is transmitted along the column of blood in the aorta in accordance with pascal's law.[3] Traumatic rupture of the aorta has until recently been regarded as a relatively uncommon occurrence, but the incidence is rising with higher travel speed. Many lacerations of the aorta associated with fracture of thoracic spine in air craft accidents. It is not a common feature of civilian automobile accident. They have seen only one case in a series of 100 cases of multiple injuries.[4] In spite of this, blunt trauma is more common, when the violence is indirect rather than a direct one like steering wheel or dash board injuries, and may be partial or complete.[5] Aorta is commonly injured because of sudden deceleration in an automobile accident; fall from height or due to air plane crash. The injury results from the disparate speeds of a fixed and a mobile portion of the vessel. The fixed portion comes to an abrupt halt while the mobile portion continues on its course. A shearing force develops and disrupts the vessel. The thoracic aorta is involved with overwhelming frequency in this type of injury, while the vessels are affected less commonly.[6]

Traumatic disruption of the thoracic aorta occurs most often at the aortic isthmus just distal to the origin of the left subclavian artery, where the aorta is fixed by the ligamentum arteriosum. Less commonly, the rupture is at the aortic root or at the diaphragmatic aortic hiatus. Usually the vessel wall is circumferentially transected and two ends retract and the victim dies from exsanguination.[7] Sometimes there may be multiple parallel intimal tears near the main transection, the so-called "ladder–rung tears". In deceleration trauma, these incomplete tears which affect only the intima and inner tunica media, may be found without major transection. In cases where death is delayed, false aneurysms and dissections may occur later.[8]

Less commonly rupture may occur in the ascending aorta just above the aortic valve. Here the tear is usually horizontal and doesn't encircle the vessel completely. The mechanism is probably a direct violence to the vessel wall or increased intravascular presence associated with other injuries.[3]

In a study of 100 deaths from multiple injuries by Polson and Gee, there were 33 instances of ruptured aorta, of which 27 occurred at the junction of arch and descending aorta and 6 involved the ascending aorta9. Ruptures occur almost constantly at a point 1.5cm distal to the attachment of ligamentum arteriosum, the remnant of the ductus38. This high incidence probably depends on fixation of the aortic arch by the great vessels arising from the convexity and by the attachment of the arch to the pulmonary artery by ligamentum arteriosum.[5] In a series of deaths from trauma, seven instances of aortic rupture were found. In all seven cases the lesion was at 1.5 cm distal to the attachment of ligamentum arteriosum, four of the cases were suicides, where the deceased jumped from a height. The other cases were road and air accidents. In all these cases a sharp deceleration strain applied to the caudal end of the body caused by abdominal or thoracic viscera to be forced caudal wards and in this manner the aorta was ruptured.[10]

An alternative explanation for these injuries that has been suggested is that the rapid deceleration strains cause a sudden great elevation in the intravascular pressure of the aorta and it is this elevation that is responsible for aortic ruptures.[2]

Eighty five percent of patients sustaining traumatic aortic transections die within minutes of the injury from exsanguination. An additional 5 to 8 percent succumb during transport and preparation for surgery. For the fortunate who survive long enough to have an operation, the mortality rate is 5 to 20%. Finally, in 2 to 3%, the diagnosis is overlooked and the mediastinal haematoma organizes and years later, a calcified pseudo aneurysm may be discovered.[7]

Penetrating injury to the great vessels may result from either missile or stab wounds. The wound may vary from a clean, near-surgical type of stab wound to a jagged, large defect with loss of tissue substance. This may lead to massive hemorrhage. Rarely a clot may temporarily seal the defect and stop bleeding. If the intra thoracic portion of the vessel is involved, it produces massive haemothorax, while extra thoracic subclavian injuries produce supraclavicular subcutaneous haematoma.[7]

In other instances, adjacent segments of thoracic spine may be luxated through the intervertrebral disc and produce transverse tears of aorta, which are either partial or complete. Death is caused by a profuse intra thoracic haemorrhage.[11]

Injury to the inferior vena cava

The inferior vena cava is torn occasionally by a violence which forces the liver down wards. The tear is transverse and partial at the point where the vessel emerges from the pericardium. Death may result from hemorrhage in to the pericardium or on to the abdominal cavity.

Injury to the pulmonary vessels

The pulmonary artery is much less vulnerable to blast trauma than aorta but in stamping assaults and steering wheel impacts, it may be damaged by depressed rib cage and sterna fracture. The pulmonary artery and veins may also be damaged in the root of lung, where hilar tears are not uncommon.

METHODS

This study was aimed at analyzing the pattern of injuries sustained to thorax following various types of trauma, with special reference to lung injury. 250 known dead bodies of both sexes with thoracic injuries brought for medico-legal autopsies to the mortuary of the Department of Forensic Medicine in a tertiary care institution were included in the present study. All cases from 1st July 2005 till 30th November were selected prospectively and from 1st January till 30th June 2005, retrospectively. Descriptive study design was followed.

A meticulous external examination was made and details were entered in a proforma. From the autopsy records, the relevant details were retrieved: date of death, age and sex of the victim, height and weight of the body. The present investigation included the nature, dimensions and exact site of the injury. Autopsy was conducted by modified Rokitansky's method of in situ dissection in part and en masse removal. As in any medicolegal autopsy, this was done as follows. The skin of the chest wall was reflected on both sides as flaps by cutting through the chest muscles, leaving the ribs bare. In cases of suspected pneumothorax, the skin flap was reflected up to the axilla, creating a pocket, which was filled with water and chest wall punctured through one of the inter-costal spaces underwater with a scalpel so that air bubbles through if pneumothorax is present. The rib cage was examined for the presence of trauma, its extent and location. The thoracic cavity was then opened by cutting through cartilaginous portions of the ribs using a cartilage knife. The second rib was divided first, about 1 cm lateral to sternum, and then the line of cut extended downwards by cutting the cartilaginous portions of the ribs close to the chostochondral junctions. The sternum was lifted up from the mediastinum, but the sternoclavicular joints and first ribs were left intact at this stage. Pleural cavities were examined for the presence of blood or other fluids. The pericardial cavity was also examined. The sternum was retracted anteriorly towards the head to exert tension and the joints were cut by a knife from the posterior aspect, removing the sterna plate. Then, both first ribs were cut. The thoracic and abdominal organs were removed en masse.

All thoracic organs were examined for injury and when present, details like nature of injury, locations and dimensions were recorded. The injuries to the lungs and respiratory passages were studied meticulously and recorded. Attempt was made to correlate the external injuries with the internal injuries. Photographs were taken wherever possible.

RESULTS

A total 206 victims were males. 130 (52%) were victims of road traffic accidents. Pedestrians constituted the majority (26.4%). 70.6% belonged to the working age group (21-60 years) (Table 1). External injuries were not found in 67 cases (26.8%). Haemothorax was observed in the range of 50-150 ml. Large quantity was due to transaction of pulmonary vessels and bronchus. Massive haemothorax was not observed. We noticed that blood in the pleural cavity remained in a fluid state, as observed by Wilson before.[5]

In our study, major blood vessels of the thorax were affected in 17 cases. Descending part of the thoracic aorta is the most vulnerable part and in 5 cases (33.3%), there

was transection of the great vessels. 14 (82%) were males and 3 (18%) were females. Youngest case was a 15-year-old boy who fell down from height and the eldest case was of an 82-year-old male who was run over by train. Majority of the cases were brought dead to hospital (12, 70.5%). Survival period was half an hour for one case (6%), one hour for one case (6%), three hours for two cases (12%), eight and half hours for one case (6%) (Table 2). 2 (12%) cases showed ethyl alcohol above permitted legal limit.

Table 1: Age distribution.

Age group	Number
15-20	4
21-30	3
31-40	3
41-50	4
51-70	-
71-80	2
81-90	1

Pedestrians were hit in 3 (18%) cases. Heavy vehicles hit two wheelers in 7 (41%) cases, of which 5 (29.4%) were due to buses. Rail run over was noted in 2 (12%) cases. Fall from height, fall of heavy object on the body, skidding of vehicle and stab injury were recorded in one case each (6%).

Table 2: Survival period.

Survival period	Number
Brought dead	12
1/2 hour	1
1 hour	1
3 hours	2
8 1/2 hours	1

Infiltration at root of aorta was noted in a case of fall from height (6%). 2 cases of fall of heavy object on the body showed contusion of root of great vessels (12%). Run over injuries comprised aortic rupture, tear at root of aorta, tear in left pulmonary vessel, transection of descending aorta and transection of descending aorta in one case each (6%). Transection of trachea and bronchi was noted in run over cases. Puncture of thoracic aorta was seen in a stab injury case (6%). Intimal tears of aorta were recorded in one case of train run over (6%). Road traffic accidents showed infiltration of ascending aorta and tear in superior vena cava in one case each (6%) (Table 3).

Table 3: Injuries to vessels.

		Infiltration	Contusion	Tear	Transection	Puncture
Inferior vena cava		**1**				
Superior vena cava				**1**		
Pulmonary veins	Right		**1**		**3**	
	Left	**1**	**1**		**1**	
	Bilateral				**2**	
Aorta	Ascending	**2**		**2**	**1**	
	Arch					
	Descending			**1**	**2**	**1**
	Root	**1**				
Root of whole vessels			**1**			
Aorta and pulmonary veins		**1**		**1**		

Laceration of tracheal bifurcation was associated with some cases. In majority of cases, II to V ribs were found fractured. Lower cervical vertebrae, fourth and fifth thoracic vertebrae were most commonly involved. One case was due to homicide, all other cases were accidental (94%). Combination of injuries was the most common cause of death.

DISCUSSION

The wound of aorta or pulmonary artery are immediately fatal and commonly seen in case of vehicular accident or fall from height due to the intense compression to the chest with or without any sign of external injury.[12]

The classic deceleration lesion in this category is aortic injury including both laceration and transaction. The most common location of injury is the aortic isthmus, a few centimeters distal to the origin of the left subclavian artery. Aortic injuries are associated with a large magnitude of force. Multiple mechanisms of aortic injury have been proposed, including differential deceleration of the heart and aortic arch relative to the anchored segments of thoracic aorta and increased intravascular pressure and hemodynamic forces in the setting of vehicular accidents.[13]

The alternative and frequently cited mechanism for aortic transaction or laceration is the osseous pinch, whereby

the aorta is crushed or pinched between the vertebral column and the inner surface of the manubrium, first rib and clavicle during anteroposterior thoracic compressive deformation. The latter mechanism explains the consistent location of aortic injury, since the isthmus will be compressed between the bony anterior thoracic structures and the fourth vertebral body. Moreover, this mechanism provides an explanation for the aortic injuries occurring in the setting of low speed crushing injuries. This mechanism is also consistent with the frequent evidence of impact against an interior vehicle component.

Traumatic aortic rupture is a common cause of sudden death after an automobile collision or fall from great height. For immediate survivors, salvage is frequently possible if aortic rupture is identified and treated early. Patients with aortic rupture, who are potentially salvageable, tend to have an incomplete laceration near the ligamentum arteriosum of the aorta. Continuity maintained by an intact adventitial layer or contained mediastinal hematoma prevents immediate death. Many of the surviving patients die in the hospital if left untreated. Some blood may escape into the mediastinum but one characteristic shared by all survivors is that this is a contained hematoma.[4]

Rupture of aorta may also occur due to blunt force injuries on the abdomen and sudden efflux of blood. Rupture of thoracic aorta is common in steering wheel injuries. Traumatic rupture may be complete or incomplete and occur usually in the aorta after branching of the left subclavian artery at the level of ligamentum arteriosum. Traumatic rupture of aorta is usually transverse. Natural rupture of aorta may occur in case of aneurysm and atherosclerotic changes. Rupture of abdominal aorta due to indirect force is very rare.[14]

The most vulnerable vessel is the aorta– which commonly suffers injury in the deceleration trauma from both road and air accidents, as well as from falls from a height. When the thorax is suddenly decelerated, the heart, being actively mobile in the chest, attempts to continue in the original direction. This causes severe traction on the right side of the heart, and a common sequel is the complete or partial rupture of the aorta in the descending part of the arch. In falls from height, Fiddler (1946) claims that the lesion is the result of the abdominal or thoracic viscera being forced due to the abrupt deceleration when landing on the feet or buttocks. Tannenbaum and Lasky (1974) has reviewed the biomechanics of impact injury of aorta. According to Fiddler, rupture occurs almost constantly at a point 1.5 cm distal to the attachment of ligamentum arteriosum, the remnant of the ductus arteriosus. The lower thoracic aorta is closely bound to the anterior longitudinal segment on the front of the dorsal spine until it reaches the termination of the arch of aorta where it curves forwards. This appears to be the weak point and transaction occurs at this level. Sometimes it closely looks like a surgical incision. The tear is annular and at right angle to the arch of aorta. Sometimes, there may be multiple parallel intimal tears near the main transaction, the so-called "ladder rung tears". In deceleration trauma, these incomplete tears, which affect only the intima and inner media, may be found without major transaction. Where death is delayed, false aneurysm and dissections may be diagnosed on aortogram.[15]

The great vessels are often involved in penetrating injuries, notably stab wounds. Stab of the upper part of chest may pass directly into the arch of the aorta, especially on the right side of the sternum. Here even a shallow injury may reach the aorta. Stabs that are either too high or are directed too laterally to puncture the chambers of the heart may penetrate the ascending aorta or pulmonary artery. If the wound is below the reflection of the pericardium, haemopericardium and perhaps cardiac tamponade may result. Other stab wounds enter the root of lung to injure the large primary branches of the pulmonary artery or veins, causing gross bleeding into the corresponding pleural cavity or mediastinum.[15]

CONCLUSION

The current study observed that major blood vessels were involved in 17 cases out of total 250 cases, majority of the victims were brought dead to hospital, 16 cases were due to blunt trauma. descending aorta was the most vulnerable part of the aorta. In majority of cases, head, chest and abdomen were involved along with brain and liver, hemothorax was present in 9 cases. liver showed lacerations in 9 cases and some cases showed fractures of sternum.

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