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Cardiac and great vessel injuries after chest trauma: our 10-year experience

Göğüs travması sonrasında gelişen kalp ve büyük damar yaralanmaları: 10 yıllık deneyimimiz

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BACKGROUND

Cardiovascular injuries after trauma present with high mortality. The aim of the study was to present our experience in cardiac and great vessel injuries after chest trauma.

METHODS

During the 10-year period, 104 patients with cardiac (n=94) and great vessel (n=10) injuries presented to our hospital. The demographic data, mechanism of injury, location of injury, other associated injuries, timing of surgical intervention, surgical approach, and clinical outcome were reviewed.

RESULTS

Eighty-eight (84.6%) males presented after chest trauma. The mean age of the patients was 32.5±8.2 years (range: 12-76). Penetrating injuries (62.5%) were the most common cause of trauma. Computed tomography was performed in most cases and echocardiography was used in some stable cases. Cardiac injuries mostly included the right ventricle (58.5%). Great vessel injuries involved the subclavian vein in 6, innominate vein in 1, vena cava in 1, and descending aorta in 2 patients. Early operations after admission to the emergency were performed in 75.9% of the patients. Thoracotomy was performed in 89.5% of the patients. Operative mortality was significantly high in penetrating injuries (p=0.01).

CONCLUSION

Clinicians should suspect cardiac and great vessel trauma in every patient presenting to the emergency unit after chest trauma. Computed tomography and echocardiography are beneficial in the management of chest trauma. Operative timing depends on hemodynamic status, and a multidisciplinary team approach improves the patient's prognosis.

Key Words: Cardiac injury; great vessel injury; thoracic trauma.

AMAÇ

Göğüs travmasına bağlı kardiyovasküler yaralanmaları yüksek bir mortaliteye sahiptir. Bu çalışmanın amacı, göğüs travması sonrasında gelişen kalp ve büyük damar yaralanmalarının tedavisinde tecrübemizi sunmaktır.

GEREÇ VE YÖNTEM

On yıllık süre içinde 104 hasta kalp (n=94) ve büyük damar (n=10) yaralanmaları ile başvurdu. Bu hastalarda demografik bilgiler, yaralanma sebepleri, yaralanma yerleri, ek yaralanmalar, cerrahi girişimin zamanlaması, cerrahi yaklaşım ve klinik sonuçlar gözden geçirildi.

BULGULAR

Göğüs travması sonrasında 88 (%84,6) erkek hasta başvurdu. Tüm hastaların ortalama yaşı 32,5±8,2 yıl (dağılım 12 ile 76 yaş) idi. Penetran yaralanmalar (%62,5) en sık sebep olarak karşımıza çıktı. Bigisayarlı tomografi genel olarak uygulanırken, durumu stabil olguların bir bölümüne ekokardiyografi yapıldı. Kalp yaralanmalarında sıklıkla sağ ventrikül (%58,5) etkilendi. Büyük damar yaralanmaları subklaviyen ven (6), innominate ven (1) ve desendan aorta (2) da tespit edildi. Hastaların %75,9'una acil servise başvurduktan sonra erken dönemde ameliyat yapıldı. Torakotomi hastaların %89,5'inde uygulandı. Cerrahi mortalite penetran yaralanmalarda anlamlı derecede yüksekti (p=0,01).

SONUÇ

Klinisyenler acil servise göğüs travması ile başvuran her hastada kalp ve damar yaralanması olasılığını düşünmelidir. Bilgisayarlı tomografi ve ekokardiyografi göğüs travmasının klinik takibinde faydalıdır. Cerrahi girişimin zamanlaması hastaların hemodinamik durumlarına bağlıdır ve multidisipliner yaklaşım hastaların prognozunu iyileştirir.

Anahtar Sözcükler: Kalp yaralanması; büyük damar yaralanması; göğüs travması.

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Thoracic trauma associated with blunt or penetrating injury is a major cause of hospitalization in the world and carries a mortality rate ranging from 15 to 77%.[1] It comprises 10-15% of all traumas, and 25% of the deaths can be directly related to thoracic trauma.[2] In chest trauma, cardiovascular injuries are the second cause of death after central nervous system injuries. Despite recent advances in diagnostic modalities and surgical techniques, cardiac and great vessel injuries are still an important predictor of the outcome following chest trauma. Our clinical experience in chest trauma, as a trauma hospital in Istanbul with a large patient population, has confirmed that these injuries almost always require an aggressive multidisciplinary approach in the emergency unit setting. Patients with cardiac injury often require immediate surgical exploration, whereas injuries to the great vessels after chest trauma may require an injury-oriented management.

The purpose of this study was to present our trauma experience in cardiac and great vessel injuries, to determine the incidence of primary injuries and associated pathologies, to assess the current management strategy, and to evaluate hospital outcome at a single institution for a 10-year period.

MATERIALS AND METHODS

Our hospital is a trauma center and an education hospital in Istanbul, Turkey. Because our hospital covers a large region with an intense patient population and is located near an important motorway, the incidence of chest injury is relatively higher than at other centers in nearby areas. Between January 2000 and January 2010, 104 trauma victims presented with cardiac or great vessel injury after chest trauma. Great vessel injuries were injuries to vascular structures within the thorax that included the great arteries and veins. The demographic data, mechanism of injury, Injury Severity Score (ISS), location of injury, other associated injuries, timing of surgical repair, surgical approach, and the resultant mortalities (outcome of cardiovascular trauma) were reviewed. On diagnosis, chest X-rays and chest computed tomography (CT) were preferred on admission. Transthoracic echocardiography (TTE) imaging was not used in unstable cases, but it was used in stable cases. For the purposes of our study, surgical interventions performed promptly in unstable patients were termed as 'early', while those performed in stable patients after clinical and radiological work-up were termed 'late'.

This is a descriptive study. Statistical calculations were performed using the GraphPad Prism V.3 program for Windows (GraphPad Software, Inc., La Jolla, CA, USA). All values were expressed as mean and standard deviation. A p value less than 0.05 was considered to be significant.

RESULTS

During the 10-year period, 104 patients presented to our hospital with cardiac (n=94) and great vessel (n=10) injuries after chest trauma. There were 88 male and 16 female patients, with a mean age of 32.5±8.2 years (range: 12-76). The injury mechanism was penetrating in 62.5% of patients and blunt in 37.5% of patients (Table 1). No patient was identified as having both major blunt and penetrating injuries. Stab wounds were the leading cause of penetrating injuries, whereas traffic accidents were the most common in blunt injuries.

Tube thoracostomy was performed in 78 (75%) patients with pleural complications such as hemopneumothorax. Drainage was set to a mild evacuation level to avoid recurrent life-threatening massive bleeding. With respect to timing of surgical explorations, the number of early operations was significantly higher than of late operations (p=0.01, Table 2). Of all patients, 79 (75.9%) underwent an early operation. In these operations, penetrating cardiac injuries (69.6%, 55/79) were the most common cause. The most common indication of early procedures was pericardial tamponade in 61.5% of patients. Thoracotomy incision was performed in 89.5% of cases according to the localization and suggested mechanism of injuries (62.5% left anterolateral thoracotomy; 26.9% right an-

Table 1. The causes of chest trauma and distribution of cardiac and great vessel injuries

		Cardiac injury	Great vessel injury	
Etiology	Causes		Artery	Vein
Penetrating injury (n=65, 62.5%)	Stab wounds	54 (50.9)	–	3 (2.8)
	Gunshot wounds	7 (6.7)	–	–
	Foreign body	–	–	1 (0.9)
Blunt injury (n=39, 37.5%)	Traffic accidents	31 (28.8)	2 (1.9)	3 (2.8)
	Falls	2 (1.9)	–	1 (0.9)
			2	8
Total		94 (90.4)	10 (9.6)	

* Data are presented as number of patients (percentage).

Table 2. Distribution of patients according to the etiology of trauma and timing of surgery

	Timing of surgery		
Etiology	Early	Late	p
Penetrating injury	55 (52.8)	10 (9.6)	0.01
Blunt injury	24 (23.1)	15 (14.5)	0.03
Total	79 (75.9)	25 (24.1)	0.01

* Data are presented as number of patients (percentage).

terolateral thoracotomy). Sternotomy was performed in only 10.5% of the cases.

Table 3 shows the distribution of cardiac and great vessel injuries according to the cause of chest trauma. Injury to the right ventricle was observed in 58.5% of patients, and it was common in both penetrating and blunt chest trauma. In our series, only one patient had a postmortem diagnosis of combined right ventricular injury and ventricular septal defect after a penetrating trauma. Primary suturing reinforced with Teflon pledgets or felts was used for the repair of cardiac injuries. Cardiopulmonary bypass (CPB) was not used due to the unavailability of surgical equipment and trained personnel in our hospital. Some patients were transferred to a nearby specialized cardiovascular surgery center for repair; these patients were not included in this series.

Great vessel injuries included subclavian vein injury in six, innominate vein injury in one, superior vena cava injury in one, and descending aortic transection in two patients. Venous injuries were repaired by primary suturing in this series. Patients with acute aortic transection were unstable and had a widened mediastinum on chest radiographs and CT scans. Because patients' hemodynamic instability prevented their transfer to a specialized cardiovascular surgery center, they were taken immediately to the operating room, and left anterolateral thoracotomy was performed. Aortic transections distal to the left subclavian artery were repaired by tube graft interposition (Dacron graft, no. 22) with favorable outcomes. Total aortic clamping times in these cases were 30 and 25 minutes.

Additional injuries are presented in Table 4. Pulmonary lacerations, diagnosed in 12.5% of patients, were the most common injury in this series, followed by intercostal vessel injuries in 11.5% of patients. Multiple rib fractures (more than 3 ribs) and sternum fracture presented only in blunt injuries, with ratios of 9.6% and 7.6%, respectively. Internal thoracic (7.6%) and coronary artery (3.8%) injuries were detected in penetrating injuries. The other injuries included diaphragm rupture in three patients, hepatic laceration in two and ventricular septal defect associated with a penetrating injury in one. The diagnosis of ventricular septal defect was made postmortem.

Table 3. Distribution of cardiac and great vessel injuries according to the cause of chest trauma

	Penetrating injury	Blunt injury	Total
Cardiac injury (n=94)			
Right ventricle	35	19	54
Right atrium	19	5	24
Left ventricle	9	2	11
Left atrium	3	1	4
Right ventricle + VSD	1	–	1
Great vein injury (n=8)			
Subclavian vein	3	3	6
Innominate vein	–	1	1
Superior vena cava	1	–	1
Aortic injury (n=2)			
Descending aorta (transection)	–	2	2

VSD: Ventricular septal defect.

Table 4. Additional injuries diagnosed during surgical exploration

	Penetrating injury	Blunt injury	Total
Pulmonary laceration	8 (7.6)	5 (4.8)	13 (12.5)
Intercostal vessel injury	8 (7.6)	4 (3.8)	12 (11.5)
Rib fracture (>3 ribs)	–	10 (9.6)	10 (9.6)
Sternum fracture	–	8 (7.6)	8 (7.6)
LITA injury	4 (3.8)	1 (0.9)	5 (4.8)
Coronary artery injury	4 (3.8)	–	4 (3.8)
Left anterior descending	2 (1.9)	–	2 (1.9)
Diagonal	2 (1.9)	–	2 (1.9)
RITA injury	3 (2.8)	–	3 (2.8)
Diaphragm rupture	–	3 (2.8)	3 (2.8)
Hepatic laceration	2 (1.9)	–	2 (1.9)
Ventricular septal defect	1 (0.9)	–	1 (0.9)

* Data are presented as number of patients (percentage).
LITA: Left internal thoracic artery; RITA: Right internal thoracic artery.

The overall morbidity rate in our series was 43.2%. Atelectasia was the most common morbidity, with an incidence of 60%, followed by respiratory failure in 9.6% of patients. Two patients (4.9%) with blunt trauma had increased cardiac enzyme levels and required inotropic support in the postoperative period. They were accepted as having myocardial contusion. Only 28 cases were followed-up in the intensive care unit (ICU). Echocardiographic examination of all patients before discharge did not demonstrate pericardial collection after surgery.

In this series, the mortality rate in all patients was 18.2% (Table 5). Only five patients with blunt injury were lost during the ICU stay (3 due to cranial injuries, 2 due to renal failure). Operative mortality occurred in

Table 5. Analysis of the patients according to type of injury, mortality, injury severity score, and hospital stay

	Penetrating injury	Blunt injury	p	Total
Overall mortality	10 (9.6)	9 (8.6)	NS	19 (18.2)
Operative mortality	10 (9.6)	4 (3.8)	0.01	14 (13.4)
Injury Severity Score	18.4±4.8	16.6±1.2	NS	–
Hospital stay (days)	12.1±4.3	9.5±2.2	NS	–

* Data are presented as number of patients (percentage) and mean values with standard deviation.
A p value less than 0.05 was considered significant.

14 patients (13.4%). Four of them died after blunt injury to the liver (2 patients), right atrium (1 patient) and subclavian vein (1 patient). The other 10 patients died during operations after penetrating injury to the left ventricle (3 patients), right ventricle (2 patients), left atrium (2 patients), right ventricle and ventricular septum (1 patient), superior vena cava (1 patient), and subclavian vein (1 patient). Operative mortality of penetrating injuries was significantly higher than that of blunt injuries (p=0.01). Hospital stay and ISS score were higher in penetrating injuries. The mean hospital stay was 12.1±3.6 days (range: 5-28) (9.5 days in blunt and 12.1 days in penetrating injuries). The mean ISS was 16.6±1.2 in blunt and 18.4±4.8 in penetrating injuries.

DISCUSSION

Thoracic trauma remains a major cause of hospitalization in developing countries. Blunt injuries, especially traffic accidents, are generally much more frequent than penetrating injuries in general chest trauma.[3,4] In our series, we observed that cardiac and great vessel injuries presented with an incidence of 2% within general chest trauma. The major cause of cardiac and great vessel injuries in the current series was penetrating injuries. Similarly, the ratio of associated injuries in chest trauma has been reported as up to 35% in the literature, and cardiac injuries develop in less than 2% of the victims who are able to admit to the hospital. These injuries can be highly lethal immediately after trauma and on admission of the victims.

In our series, 62.5% of all cases with cardiovascular trauma had penetrating injuries, of which 87.6% were due to stab wounds. Penetrating heart traumas were generally observed in young patients with low socioeconomic status. It has been reported that cardiovascular injuries are frequently caused by penetrating chest trauma such as stab wounds and less commonly by gunshots.[3,5] Conversely, the incidence of cardiac injury after blunt chest trauma is difficult to determine, but ranges from 8% to 76%.[6] This wide range is mainly due to the variation in diagnostic criteria used and the fact that there is no gold standard test for the diagnosis. Although CT and echocardiography are both widely used modalities in the emergency unit, the clinical presentation of patients and hemodynamic instability on hospital admission may affect the calculation of the exact ratio of such injuries.

Greater than 90% of injuries to the great vessels occur after penetrating trauma.[7] Similarly, in our experience, great vessel injuries in penetrating trauma were mostly due to stab wounds. These injuries frequently involved the subclavian vein, followed by the superior vena cava and innominate vein. We observed that localization of the body of the sternum in the anatomic midline and the ribs on each side prevented an injury to the mediastinal great vessels including the vena cava, pulmonary artery and ascending aorta. Nevertheless, in some cases, chest wall damage after trauma, such as rib or sternum fracture, was associated with venous injuries.

According to the principles of Advanced Trauma Life Support (ATLS), the management of such injuries necessitates an urgent and specific approach as a primary survey because a life-threatening massive hemorrhage may complicate the prognosis of patients. Our experience in chest trauma proved that the management is based on prompt diagnosis and treatment.[4] The management strategy for cardiac and great vessel injuries at our institution is based upon the location and type of injury, and involves a multidisciplinary team approach. Cardiovascular surgeons manage cardiovascular injuries, thoracic surgeons address associated pulmonary parenchymal lacerations, and orthopedic or general surgery consultations are made when necessary.

On arrival to the emergency department, the hospital triage doctor, who was a specialist in emergency medicine, first assessed the victims and requested consultation of surgery fellows. Cardiothoracic surgeons determined the priority for admission to the emergency room or operating theater. We used an algorithm in the management of patients (Fig. 1). Based on the location and mechanism of chest injury, underlying injuries to the mediastinal structures were suggested. Patients presenting with hypotension or massive blood loss were evaluated immediately on admission. Clinically, cardiac injuries and associated pericardial tamponade presented with a variable degree of hypotension, brady/

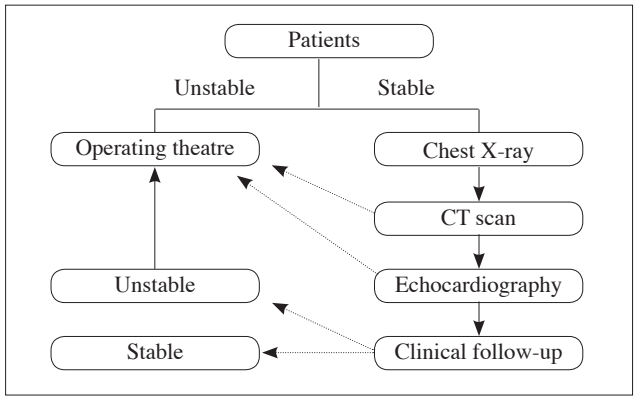

Fig. 1. Management algorithm for cardiac and great vessel injuries after chest trauma.

tachycardia, sweating, dyspnea, and sometimes diminished cardiac sounds. Great vessel injuries mostly presented with unstable vital signs, dyspnea, hemothorax, and mediastinal enlargement. Chest X-rays were taken on admission, and chest CT imaging was performed in all stable patients. TTE was not used in unstable cases on admission, but was used in stable cases. All patients with cardiac injury had a 2-dimensional echocardiogram before hospital discharge.

In our clinical practice, the trauma victims presenting with stable clinical state were managed after initial assessment and fluid replacement. All these patients were investigated with a chest roentgenogram and CT imaging to diagnose intrathoracic pathologies in detail. If mediastinal enlargement or a considerable amount of pericardial effusion was evident, TTE was performed to clarify the diagnosis and to assess myocardial performance, valve functions, and integrity of the atrioventricular septum. Burack et al.[8] noted that unstable patients with mediastinal injuries require surgery, but in stable cases, TTE and chest CT are effective screening tools. All stable patients in the current series eventually underwent surgical exploration. Our experience showed that patients with blunt injuries had a considerable time to be managed before surgery; however, those with penetrating injuries required a prompt intervention to repair the anatomical defects that might affect the outcome.

We observed that 75.9% of the victims underwent early operations due to the presence of unstable hemodynamic state on admission, and most had a penetrating injury. Considering the timing of surgery, we observed that the total number of patients undergoing early operations was significantly higher in both penetrating and blunt injuries. This might show the severity of cardiovascular injuries and may be a warning for emergency staff to be aware of the necessity of surgical exploration. However, no difference was determined in ISS between patients with blunt versus penetrating injuries. Liman et al.[9] noted that mortality of chest trauma is higher if ISS is ≥16. The authors concluded that patients having significantly higher risk for morbidity and mortality necessitate the establishment of treatment priorities and efficient management of existing injuries. In our series, the mean ISS was 16.6±1.2 in blunt and 18.4±4.8 in penetrating injuries. Therefore, emergency staff should always keep in mind that an injury to the mediastinum can be mortal and may require prompt surgery.

In general, patients with cardiac or great vessel injury triage themselves between the operative intervention or evaluation and observation. The initial presentation of the victims determines the severity of trauma and the decision to perform a prompt operation for exploration. An unstable hemodynamic state was determined by the presence of cardiac arrest or near arrest, cardiac tamponade, persistent ATLS class III shock despite fluid resuscitation,[2] chest tube output >1500 ml on insertion, >500 ml/hour for the initial hour, or >200 ml hourly for 4 hours, and massive hemothorax after chest tube drainage. In the current series of 104 patients, 75.9% presented with unstable hemodynamics and all underwent an early operation. Of these cases, 69.6% presented with penetrating chest injury. For purposes of our study, surgical interventions performed promptly in unstable patients were recorded as 'early', while those performed in stable patients after clinical and radiological work-up were termed 'late'.

Intercostal tube drainage is usually used as a routine preoperative procedure for chest trauma if pleural complications such as hemopneumothorax are evident. However, the use of tube thoracostomy in suspected cardiovascular injuries should be controlled and be set to a level of mild evacuation of blood. Increased evacuation may cause a life-threatening recurrent bleeding from the cardiac wound because of decompression and clot dislodging. This event is also true after operations if insidious bleeding from the laceration site continues despite surgical repair. In our experience, tube thoracostomy was performed in 75% of patients with pleural complications. Chest tubes were always placed in the operating room and before surgical incision. Drainage was set to a mild evacuation level under supervision of the surgeon to avoid life-threatening massive bleeding. Similarly, Gao et al.[10] recommended that tube drainage should be instituted for penetrating cardiac injury with hemopneumothorax immediately before the initiation of general anesthesia. Additionally, pericardial tube drainage or pericardiocentesis in the emergency unit was not performed to avoid massive bleeding and associated mortality. In patients who underwent pericardial exploration through the thoracotomy incision, pericardial window above the phrenic nerve was performed.

Despite evolving advances in endoscopic surgery, cardiac and mediastinal great vessel injuries are com-

monly treated with conventional open repair techniques. Thoracotomy and sternotomy incisions are the two choices for surgical exploration. In our clinical practice, the decision regarding the type and site of surgical incision is made according to the localization and suggested mechanism of the injuries. In unstable hemodynamics, we performed mostly anterolateral thoracotomy as the first choice, and this incision was extended laterally if further exposure was needed. Conversely, sternotomy was performed in 10.5% of the cases. This incision is generally used after the diagnosis of pericardial fluid collection by echocardiography. These cases were stable clinically before surgery. Although sternotomy incision is preferred for better exposure in isolated cardiac injuries, thoracotomy incision can be useful in patients with chest trauma and associated injuries, especially in cardiac and great vessel injuries.[10,11]

Emergency room thoracotomy is known to be a very useful tool and should be in the surgeon's armamentarium as a lifesaving procedure to repair cardiovascular injuries. This intervention can be the first choice in hemodynamically unstable patients associated with blood loss into the pleural or pericardial space, but it remains a challenging procedure and may not be easily accessible to all surgeons.[12] In our hospital, an operating theater is located in the emergency unit, and thoracic surgery staff are available around the clock. Therefore, all unstable patients are transferred directly to the operating room, rather than having a surgical incision done in the emergency resuscitation room. Our approach appears to be more suitable to prevent infection and to manage patients in an optimal location.

Penetrating injuries cause damage to the cardiac chambers or vessels through the tract of predisposing trauma. There may be an isolated injury to the cardiac chambers or a combined pathology with surrounding structures such as the lungs, pericardium or pleura. [13] Conversely, possible mechanisms of injuries after blunt trauma differ from penetrating injuries on several points. The predisposing mechanisms include a direct blow to the chest, compression of the heart through bidirectional forces, deceleration, or rapid rotation with fixation of the great vessels, transmission of venous pressure following compression of the abdomen, and rupture of the myocardium by a fractured rib.[14] Of note, deceleration trauma can be responsible for cardiac lacerations. The vena cava, aorta, pulmonary trunk, and the pulmonary arteries and veins firmly support the superior and posterior portion of the heart. During deceleration, the anterior part of the heart moves rapidly forward and this may cause cardiac injury in the absence of sternum or rib fractures. In survivors of cardiac injury, hemorrhage can sometimes be tamponaded by surrounding tissues in the mediastinum or pericardial sac, and this may allow the survivors to admit to the hospital. Cardiac contusion and concussion are also major pathologies that should be kept in mind after blunt trauma. Autopsy studies noted that the incidence of cardiac concussion ranged between 14% and 16%.[15] In such cases, contusion is usually confined to the traumatized cardiac muscle bundles that include patchy necrosis and hemorrhage causing myocardial dysfunction.

In our series, the right ventricle was the most commonly injured chamber in both penetrating and blunt chest trauma; 58.5% of patients with cardiac injury presented with right ventricular injury, of which 38.2% was due to penetrating injury and 20.2% to a blunt injury. There was no injury to more than one cardiac chamber in this series. Our results were similar to the literature.[3,11-13] Rodrigues et al.[16] noted that 94.3% of the cases with penetrating injury had only one cardiac chamber injured, which was usually the right ventricle (37%).

Most injuries of the great venous structures are usually due to penetrating trauma. Blunt trauma as the cause is rare, presumably because of their distensibility and low pressure. The overall incidence of great vessel injury in penetrating trauma is approximately 5% with gunshot wounds and 2% with stab wounds.[17] In our series, both penetrating and blunt injury caused great vein injury with an incidence of 3.7%. We believe that choice of surgical incision should be made based on mechanism of injury and clinical suspicion. Our experience showed that thoracotomy incision provided an excellent exposure in the surgical repair of vascular injuries as well as in the presence of associated pathologies including pulmonary lacerations, rib fractures and diaphragmatic injury. On the other hand, median sternotomy provided excellent access to the heart in isolated cardiac injuries, but this incision was used in rare cases.

The overall mortality in this experience was 18.2%, and the operative mortality accounted for 73.6% of deaths. The operative mortality rate was 13.4% for all cases, and was generally associated with penetrating cardiac injuries. All these cases were unstable at admission, and they were early operations. Nevertheless, the operative mortality in penetrating injuries was 15.3%. Most cardiac injuries were due to stab wounds, and this ratio was lower than the operative mortality of penetrating cardiac injuries from gunshot wounds, reported as between 20% to 35%.[18,19] Rodrigues et al.[16] noted that overall mortality in penetrating cardiac injury was 32.9% for patients who arrived at the hospital alive. In our series, the mortality rates of penetrating and blunt injuries in unstable patients were 18.1% and 16.6%, respectively. Meanwhile, we observed that penetrating injuries had a significantly higher operative mortality than blunt injuries. In blunt trauma, operative mortality occurred in 3.8% of the patients. These cases were unstable on admission due

to rupture of the right atrium and subclavian vein injury; however, the mortalities occurred due to associated injuries, such as liver laceration. Of note, the entire operative mortality of penetrating cardiac injuries was associated with primary chest injury.

In our series, 26.3% of the mortality developed during the ICU follow-ups and in patients with blunt chest injury; there was no operative mortality for late operations. Considering the high mortality risk of cardiovascular injuries, this late mortality might be related to hemodynamically stable presentation at admission and the presence of associated injuries. Multiple injuries such as cranial injuries associated with cardiovascular trauma and renal failure in the postoperative period were the major cause for mortality in this series. Conversely, there was no mortality in the ICU follow-ups for penetrating injuries; all deaths occurred in the perioperative period.

In addition to laceration or rupture of cardiac chambers, intracardiac pathologies are important predictors of survival after penetrating or blunt injuries.[14] These pathologies include valvular damage, chordal or papillary muscle rupture and defect in the atrioventricular septum. Although the risk of intracardiac injuries in penetrating chest trauma is more frequent, blunt trauma may cause such pathologies in the early or late period of trauma.[14] Penetrating injuries causing a septal defect or acute valvular insufficiency may cause rapid deterioration in a patient's hemodynamic state, necessitating an urgent intervention. The diagnosis can be established by preoperative or intraoperative echocardiography.[9] Surgical repair necessitates the use of CPB. In our series, only one patient with penetrating injury had ventricular septal defect. Unfortunately, the diagnosis in this patient was made postmortem.

The role of CPB in the treatment of penetrating cardiac injuries is still controversial. Equipment for CPB and related staff are occasionally provided in trauma centers. Technically, injuries to the cardiac chambers can be treated with different surgical techniques without using CPB. However, CPB can be used to repair a proximal lesion of coronary arteries, multiple-chamber wounds and intra-cardiac lesions such as septal defects and valve dysfunction. In such cases, patients should be promptly transferred to a specialized center if preoperative diagnosis is made by echocardiography and the patients are hemodynamically stable. Nevertheless, this may not be possible in most trauma centers because of unstable presentation of most patients on admission.

In conclusion, cardiac and great vessel trauma after blunt and penetrating trauma carries a high mortality, and most patients present with unstable hemodynamics. All stable patients should undergo CT scanning of the chest and echocardiographic examination. Any penetrating wound of the thorax or upper abdomen should alert physicians to the possibility of cardiac injury. The emergency staff should be aware of the necessity of prompt surgical exploration. Operative timing should be based on hemodynamic status and the presence of other life-threatening injuries.

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