

PAPER**PATHOLOGY AND BIOLOGY**

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Cardiac Injuries Caused by Blunt Trauma: An Autopsy Based Assessment of the Injury Pattern

ABSTRACT: Nonpenetrating chest trauma with injury to the heart and aorta has become increasingly common, particularly as a result of rapid deceleration in high-speed vehicular accidents, over the past 2–3 decades. The high mortality rate of cardiac injuries and possible late onset complications make blunt cardiac injuries an important challenging point for legal medicine. One hundred and ninety cases with blunt cardiac injuries in a period of 3 years were analyzed retrospectively in terms of patterns of cardiac injury, survival times, and demographic profiles of the cases in this study.

KEYWORDS: forensic science, autopsy, pathology, blunt trauma, cardiac injury, cardiac rupture

Nonpenetrating chest trauma with injury to the heart and aorta has become increasingly common, particularly as a result of rapid deceleration in high-speed vehicular accidents, over the past 2–3 decades (1). Airplane crashes, falls from height, and other severe crushing injuries of the thorax and the lower body may also lead to the nonpenetrating cardiac injuries (1–7). Because blunt cardiac injury is the most clinically underdiagnosed traumatic injury in the adult and pediatric population (8), these kind of injuries significantly increase morbidity in polytrauma patients, and in many cases lead to death (9).

The incidence of cardiac injury is presented 20% after blunt chest trauma in postmortem studies (10). In the pediatric age group, the incidence is slightly lower and previous studies suggested that cardiac injury was found in 15–20% of the pediatric patients examined (5–11). The incidence might be as low as 0.5–0.8% in clinical studies for all age groups (5).

Although an increasing number of cases have been diagnosed during the past few years, mainly because of increased awareness and the availability of better diagnostic techniques, the mortality rate is still high and the majority of patients die before they arrive at the emergency department. Thus, the great majority of cardiac injuries are still diagnosed by systemic autopsy.

Materials and Methods

Autopsy reports of the 1597 fatalities caused by blunt trauma that were subjected to a medicolegal autopsy at the Council of

Forensic Medicine, Istanbul, in a period of 3 years from 2001 to 2003 were analyzed retrospectively. Cardiac injuries were assessed by a standardized study protocol based on the autopsy files and available clinical information.

Results

Study Population

Of a total of 9223 autopsies during the study period, 1597 (17.3%) fatalities attributable to blunt trauma were identified. Cardiac injuries were found in 190 cases (11.9%). In 86 (45.2%) cases, the cardiac injuries were the cause of death or contributed to the fatal outcome. Male to female ratio was 3.5:1 (male: 148 [77.9%], female: 42 [22.1%]). The ages of these individuals ranged from 3 to 86 (41.75 ± 17.6). One hundred and six (56%) cases were injured by vehicle accidents, 72 (38%) by a fall, 8 (4%) cases sustained crush injury, 2 (1%) were beaten and 1 (0.5%) had blunt trauma after an explosion due to terrorist attack. In one (0.5%) case, the cause of death was unclarified (Table 1).

Twenty-five (13%) of these patients were alive when they arrived to the emergency departments. They eventually died after a survival time varying from a few minutes to 7 days. The survival time was less than 24 h in 14 (56%) and more than 24 h in 11 (44%) cases. Blunt cardiac injuries were accompanied by pulmonary contusions in 84 (44.2%), sternal fractures in 62 (32.6%), serious head injuries in 79 (41.6%), fractures of long bones in 24 (12.6%), and soft tissue injuries in 1 (0.5%) of these cases (Table 2).

Cardiac Injury Pattern

Cardiac injuries were found in 190 cases (11.9%). These injuries were multiple in 41 (21.6%) cases. The most frequent finding was pericardial tearing and was seen in 52 (27.3%) cases. Pericardial tearing was an isolated finding in 13 (25%) cases. Tears caused by stretching of the epicardium and epicardial hematoma were present

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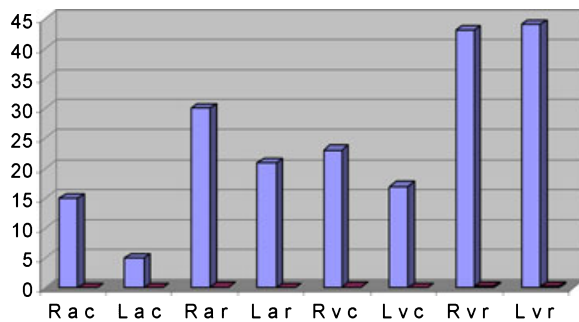
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TABLE 1—*Causes of blunt cardiac injury.*

Motor vehicle accidents	106 (56%)
Fall from a height	72 (38%)
Crush injury	8 (4%)
Beat by someone	2 (1%)
Explosion	1 (0.5%)
Unclassified	1 (0.5%)
Total	190 (100%)

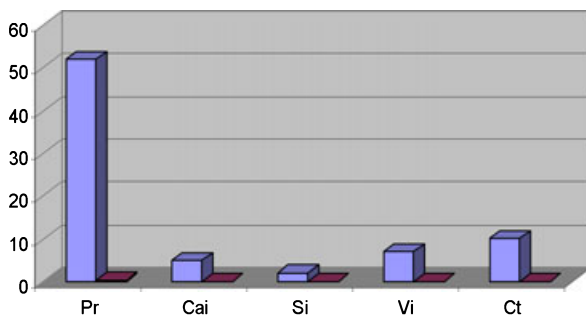
TABLE 2—*Traumatic injuries accompanied to the blunt cardiac injury.*

Pulmonary contusion	84 (44.2%)
Sternal fractures	62 (32.6%)
Head injury	79 (41.6%)
Fractures of long bones	24 (12.7%)
Soft tissue injury	1 (0.5%)
Isolated cardiac injury	2 (1%)
Total	190 (100%)



Rac: Right atrial contusion, **Lac:** Left atrial contusion, **Rar:** Right atrial rupture, **Lar:** Left atrial rupture, **Rvc:** Right ventricular contusion, **Lvc:** Left ventricular contusion

FIG. 1—Cardiac injury Pattern 1.



Pr: Pericardial rupture, **Cai:** Coronary artery injury, **Si:** Septal injury, **Vi:** Valvular injury, **Ct:** Complete torn-off

FIG. 2—Cardiac injury Pattern 2.

in four (7.7%) cases. Pericardial tearing was accompanied by injury of great vessels in 15 (28.8%) cases and by atrial and/or ventricular rupture in 20 (38.5%) cases. These tears were almost all located near the area where inferior vena cava leads into the right atrium.

Contusions of the right and left atrium were found in 19 (10%) and 5 (2.6%) cases, respectively. Transmural ruptures involved the right atrium in 30 (15.8%) and the left atrium in 21 (11.1%) cases.

Atrial ruptures were located predominantly in the areas where the great veins lead into the atria. Transmural tears of the right and left ventricles were seen in 43 (22.6%) and 44 (23.2%) cases. All atrial and ventricular ruptures were found related to high-speed motor vehicle accidents and to falls from height. Ventricular wall contusions were found in the right and left ventricle in 23 (12.1%) and 17 (8.9%) cases, respectively.

Coronary arteries were affected in five (2.6%) cases. Only one case had isolated rupture at the left anterior descending coronary artery. Two (1%) cases showed interventricular septal tears. Heart valve injuries were found in seven (3.6%) cases. Heart valve injuries were predominantly seen in tricuspid and aortic valves. Papillary muscle ruptures of the mitral valve were found in two cases. The heart was completely torn off at the base in 10 (5.2%) cases.

Discussion

The mechanism of cardiac injury involves a sequence of events beginning with direct impact to the chest wall with transmission of the kinetic force to the patient, causing compression of the heart between the sternum and the spine. Both the atria and ventricles appear to be more vulnerable to these compressive forces (12–15). The rapid deceleration with resultant disruption of the atria from their junctions with the vena cava and pulmonary veins is another reported theory (12–15). Also the compression of the lower extremities and abdomen with rapid increase in intrathoracic hydrostatic pressure, because of the transmission of the raised venous pressure directly to the atria, is another mechanism of injury to the heart. In such cases, upward displacement of the viscera can result in cardiac injury, a phenomenon known as the “Hydraulic Ram Effect” (14). Cardiac injury also may be caused by severe changes in atmospheric pressure surrounding the body, as commonly seen in victims of explosion (14).

There is a wide spectrum of potential injuries to the heart after blunt chest trauma, including myocardial contusion, myocardial rupture, valvular disruptions, and injury to the great vessels, pericardium, or the coronary arteries. A number of factors, such as the force applied to the chest, the compliance of the chest wall, and the exact timing of the application of force during the cardiac cycle can affect the spectrum of blunt cardiac injury, ranging from myocardial contusions to anatomic disruptions (5,16,17).

Cardiac and great vessel injuries after blunt chest trauma are usually directly responsible or contribute to the death process in the majority of the blunt trauma cases. Türk et al. (9) reported that cardiac injuries were responsible for the fatal outcome in 48% of the cases. Similarly, in 86 (45.2%) of our cases, cardiac injuries, were the cause of death or contributed to the death process.

Twenty-five (13%) of these patients were alive when they arrived at the emergency departments and they eventually died after a survival time varying from a few minutes to 7 days. There was no correlation between the pattern of cardiac injury and the survival time like some previous studies (9). There were 12 (48%) atrial and/or ventricular contusions, 6 (24%) atrial and/or ventricular ruptures, 6 (24%) great vessel injuries, and 1 (4%) rupture of papillary muscle in cases who survived more than 24 h. Although there was no correlation between the pattern of cardiac injury and the survival time, the suggestion that patients with atrial and/or ventricular contusions live longer and die according to the late arrhythmic complications of the contusions might be supported by these findings.

Pericardial injuries are the most common findings of blunt cardiac trauma. Because the pericardium is more vulnerable to acceleration and rapid deceleration forces, pericardial injuries frequently accompany injuries of great vessels, atrial and/or

ventricular ruptures. The tears are almost located near the area where inferior vena cava leads into the right atrium (9,13). Pericardial injuries were accompanied by the injuries of great vessels in 15 (28.8%) and by atrial and/or ventricular rupture in 20 (38.4%) of the cases, and it was an isolated finding in 13 (25%), in this study. The tears caused by stretching of the epicardium and epicardial hematoma were present in four (7.6%) cases. Pericardial tamponade seen in these cases without the ruptures of great vessels and atrial and/or ventricular chambers, may be attributed to the pericardio-phrenic vessel ruptures.

Sixty-four atrial and/or ventricular contusions and 138 atrial and/or ventricular transmural ruptures were found in this study. Contusions of the right and left atrium were found in 19 (10%) and 5 (2.6%) cases, respectively. Transmural ruptures involved the right atrium in 30 (15.8%) and the left atrium in 21 (11.1%) cases. Transmural ruptures of the right and left ventricles were seen in 43 (22.6%) and 44 (23.2%) cases. Ventricular wall contusions were found in right and left ventricle in 23 (12.1%) and 17 (8.9%) cases. Although Leavit et al. (18) reported that the right atrium and right ventricle were twice as likely to be injured as the left atria and ventricles and Türk et al. (9) founded that transmural ruptures of the left ventricle occur much more rarely than ruptures of the right ventricle and atria, this study suggests that transmural ruptures of the atria and ventricles both occur with comparable frequencies. Mostly higher impact traumas in our study population, such as motor vehicle accidents, falls, and explosions might be responsible for this.

Coronary arteries were affected in five (2.6%) cases. Only one case had isolated rupture at the left main coronary artery. Two (1.05%) cases showed interventricular septal tears. Heart valve injuries were always seen with other cardiac injuries in this study. Valvular type injuries occurred in tricuspid (two cases) and aortic (three cases) valves. Papillary muscle ruptures of the mitral valve were found in two cases. The aortic valve is the most frequently involved in blunt cardiac injury, followed by the mitral and tricuspid valves. Aortic valve injuries occur as a result of sudden increase of intrathoracic and intra-abdominal pressure transmitted to the ventricle chamber during the diastolic phase. Mitral and tricuspid valves are most vulnerable during late diastolic and early systolic phases. Valvular injuries are almost always seen in association with other cardiac injuries (13,14).

Conclusions

The possibility of traumatic cardiac lesion must always be considered when physicians deal with a patient who has suffered a closed chest trauma. Also, the possibility of concomitant injuries of the lung, heart, trachea, bronchus, and esophagus has to be taken into account. A careful medical survey of patients who have been victims of a blunt chest trauma will be life saving, even if no major cardiac lesions were detected in the acute phase of the accident. In the management of these patients to eliminate this possibility, a close clinical evaluation, ECG monitoring, transthoracic, and transesophageal echo examinations, even cardiac enzyme analysis (CK-MB, Tn T, Tn I levels) are mandatory (6,19–23).

The high mortality rate of cardiac injuries makes blunt cardiac trauma an important challenging point for a forensic pathologist. A proper morphologic documentation and designation of an exact mechanism of injury are very important in terms of being a data pool for clinical examinations. In contrast, determining the causality

between trauma and death, especially for late onset deaths after trauma, has a decisive effect on legal mechanisms.

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