Effect of early surgical intervention on the outcome of cases with penetrating cardiac trauma

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Background
Early management of penetrating cardiac injury is crucial to improve the outcome of trauma cases.
Aim
To assess the effect of early surgical intervention in cases with penetrating cardiac injury on patients' outcomes.
Methods
This observational study reviewed the hospital files of cases that presented to the emergency departments of two tertiary centers following chest trauma. The patients were categorized according to the time duration from presentation to surgical intervention into early intervention (within less than 30 min) and late intervention groups (after more than 30 min).
Results
The study included 29 cases. Early intervention occurred in 18 cases, whereas 11 cases had the intervention after 30 min. Early intervention was significantly associated with lowering the median ICU stay (P=0.009), the median duration of mechanical ventilation (P=0.008), and the rate of complications (P=0.048) as well as an excellent rating of satisfaction ($P<0.001$). On multivariate analysis, early intervention was associated significantly with lower ICU stay [odds ratio (OR): 0.063, 95% confidence interval (CI): 0.007–0.546, P=0.012] and hospital stays (OR: 0.184, 95% CI: 0.040–0.844, P=0.029) but did not significantly reduce the probability of complications (OR: 0.097, 95% CI: 0.009–1.022, P=0.052).
Conclusions
Early surgical intervention positively affects the patient's outcome after penetrating cardiac injuries. It reduces ICU and hospital stays and may decrease the rate of complications. Every effort should be directed toward reducing the time lag from emergency department to the operating theater.

Keywords:
cardiac surgery, cardiac tamponade, heart injury, penetrating wounds, thoracic injuries

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Introduction

Despite their low incidence, traumatic heart injuries are significantly associated with higher mortality and morbidity [1]. It is estimated that cardiac and aortic injuries account for 10–25% of all trauma-related mortalities [2,3]. The mortality rate is ~70 to 80% in case of penetrating cardiac injuries [4]. Most cases with penetrating cardiac injury expire before reaching the hospital [5]. However, advances in the transfer system of patients with trauma increased the number of surviving cases that reach the hospital [6].

Generally, the commonest etiology of chest trauma is road traffic accidents (RTAs) [7], but most penetrating cardiac injuries are caused by stabbing and shooting firearm weapons [8].

These cases represent a challenge to surgeons, particularly as a narrow therapeutic window is available in many cases [9]. Prompt early surgical intervention represents the cornerstone of management in such cases and is potentially crucial for patients' survival [10].

The patients who present after sustaining a blunt or penetrating chest trauma are first managed according to the advanced cardiac life support/advanced trauma life support guidelines, and thereafter, the definitive management. First, a primary survey is conducted immediately to identify and treat urgent findings such as airway obstruction, cardiac tamponade, pneumothorax, and massive hemothorax. A secondary survey follows to detect potentially life-threatening injuries (e.g. aortic disruption, myocardial contusion, and diaphragmatic injuries)

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[11]. Any foreign body should be left in place and removed only under vision [12].

The present study aimed to assess the value of early surgical exploration and intervention on the outcome of trauma cases with penetrating cardiac injury, avoiding losing time to complete the whole investigations while resuscitating cases in the presence of high clinical possibilities of cardiac injury.

Method

This observational retrospective study was conducted in two tertiary centers during the period between April 2018 and April 2020. The time taken for surgery was variable once needed according to the patient presentation and site of trauma, which may be misleading, the time taken to complete the investigations, and the presence of a cardiology team to do echocardiography once needed. Because of that, this study included 29 cases that were divided into the following: group I (n=18 cases), where early surgical interventions were done within 30 min, whereas group II (n=11 cases), where the surgical intervention was done after 30 min. The study reviewed and collected data from the hospital files of victims with suspicion of cardiac injury who presented to the emergency department (ED). The study included all patients who sustained a penetrating cardiac injury, regardless of their age or sex. Cases with blunt trauma causing cardiac contusion were excluded. Ethical approval was obtained before initiation of the study. Confidentiality of the patient's data was ascertained by assigning a code number to each victim and keeping the data collection sheets anonymous.

Data collection

The hospital records of the included cases were reviewed to extract relevant data in a data collection sheet. The extracted data included the patient's age, sex, weight, height, smoking, drinking alcohol, chronic illnesses, and nature of trauma; presentation to the ED; associated injuries; Glasgow Coma Score (GCS); hemodynamics and blood hemoglobin concentration at presentation; emergency management (cardiopulmonary resuscitation and the need for inotropes); findings of chest radiography, echocardiography, and computed tomography (CT) scan; operative procedures; the time between presentation and surgical intervention; type of chest incision; chest radiography after surgery; length of ICU and hospital stays; postoperative complications; and patient satisfaction. The injured cases were categorized into two groups according to the time duration from presentation to surgical intervention: group I (n=18 cases), which was the early intervention group (within less than 30 min), and group II (n=11 cases), which was the late intervention group (after more than 30 min). The studied outcomes included complications, ICU stay, and hospital stay (primary outcomes) as well as postoperative satisfaction (secondary outcomes). Pain was scored on a numerical pain score out of 10, and this was added to the questionnaire that was given to the patient in the postoperative follow-up.

Statistical analysis

Data analysis was carried out using the Statistical Package for the Social Sciences (IBM SPSS Statistics), version 26, for Windows (IBM Corp., Armonk, New York, USA). Categorical variables were summarized as percentages and frequencies. Their association with the time to surgical intervention was assessed using Fisher's exact, Fisher–Freeman–Halton exact tests, and Pearson's χ^2. The distribution of numerical variables was assessed using the Shapiro–Wilk test. Variables that followed the normal distribution were presented as mean±SD. T test was used for independent samples to assess the differences between the groups. Variables that did not follow the normal distribution were summarized as the median and interquartile range (expressed as the 25th–75th percentiles). Mann–Whitney test was used for testing differences between the two groups. Univariate and multivariate logistic regression analyses were carried out to identify factors that significantly contributed to the studied outcomes. P value less than 0.05 was used to express statistically significant values.

Results

The present study included 29 patients with traumatic cardiac injuries. The age of the patients ranged from 10 to 70 years, with mean age of 42.2±15.9 years. Most patients were males (82.8%). The BMI varied widely from 13.9 to 40.4 kg/m^2, with an average (SD) of 27.2 (6.7) kg/m^2. Half the patients were smokers, and only 10% drank drink alcohol. Diabetes mellitus was reported in 58.6% of victims. The most frequent mechanism of trauma was stabbing (44.8%) and road traffic accident (RTAs) (31.0%). Bleeding was the most common presenting manifestation (58.6%), followed by hemodynamic instability (20.7%) and dyspnea (17.2%) (Table 1).

Based on the time of the intervention, the cases were categorized into two groups. The first group included cases that underwent intervention within less than

Table 1 Demographic characteristics and presentation of the studied patients (total *N*=29)

	Time for surgical intervention		Total (*N*=29)	Statistical tests	
	<30 min (*N*=18)	>30 min (*N*=11)		Test statistic	*P* value
Age (years)					
Mean±SD (minimum–maximum)	43.1±16.6 (10.0–70.0)	40.7±15.3 (26.0–65.0)	42.2±15.9 (10.0–70.0)	0.376a	0.710
Sex [*n* (%)]					
Female	3 (16.7)	2 (18.2)	5 (17.2)	FE	1.000
Male	15 (83.3)	9 (81.8)	24 (82.8)		
Weight (kg)					
Mean±SD (minimum–maximum)	70.6±21.4 (20.0–100.0)	88.9±14.2 (65.0–110.0)	77.6±20.8 (20.0–110.0)	2.505a	0.019*
Height (cm)					
Mean±SD (minimum–maximum)	167.3±20.0 (110.0–187.0)	168.9±8.4 (155.0–180.0)	167.9±16.3 (110.0–187.0)	0.248a	0.806
BMI (kg/cm^2)					
Mean±SD (minimum–maximum)	24.6±5.7 (13.9–36.7)	31.5±6.3 (21.0–40.4)	27.2±6.7 (13.9–40.4)	3.033a	0.005*
Special habits [*n* (%)]					
Smoking	8 (44.4)	7 (63.6)	15 (51.7)	1.007b	0.316
Alcohol	2 (11.1)	1 (9.1)	3 (10.3)	FE	1.000
Illness [*n* (%)]					
DM	11 (61.1)	6 (54.5)	17 (58.6)	FE	1.000
Hepatic	0	2 (18.2)	2 (6.9)	FE	0.135
Renal	2 (11.1)	2 (18.2)	4 (13.8)	FE	0.622
Hypothyroidism	1 (5.6)	0	1 (3.4)	FE	1.000
Neurological	0	1 (9.1)	1 (3.4)	FE	0.379
Nature of trauma [*n* (%)]					
Fall from height	1 (5.6)	1 (9.1)	2 (6.9)	2.743c	0.708
Gunshot	3 (16.7)	0	3 (10.3)		
Penetrating injury	1 (5.6)	1 (9.1)	2 (6.9)		
RTA	6 (33.3)	3 (27.3)	9 (31.0)		
Stab	7 (38.9)	6 (54.5)	13 (44.8)		
Presentation [*n* (%)]					
Bleeding	13 (72.2)	4 (36.4)	17 (58.6)	5.106c	0.127
Confusion	0	1 (9.1)	1 (3.4)		
Dyspnea	3 (16.7)	2 (18.2)	5 (17.2)		
Hemodynamic instability	2 (11.1)	4 (36.4)	6 (20.7)		
SBP (mmHg)					
Mean±SD (minimum–maximum)	106.1±15.0 (80.0–135.0)	93.8±15.4 (70.0–120.0)	101.4±16.1 (70.0–135.0)	2.108a	0.044*
DBP (mmHg)					
Mean±SD (minimum–maximum)	58.1±13.2 (40.0–80.0)	53.2±10.7 (40.0–80.0)	56.2±12.4 (40.0–80.0)	1.043a	0.306
Heart rate (beat/min)					
Mean±SD (minimum–maximum)	103.9±19.4 (70.0–140.0)	121.6±20.9 (85.0–150.0)	110.7±21.4 (70.0–150.0)	2.319a	0.028*
GCS					
Mean±SD (minimum–maximum)	14.9±0.3 (14.0–15.0)	13.9±1.8 (10.0–15.0)	14.5±1.2 (10.0–15.0)	1.774a	0.105

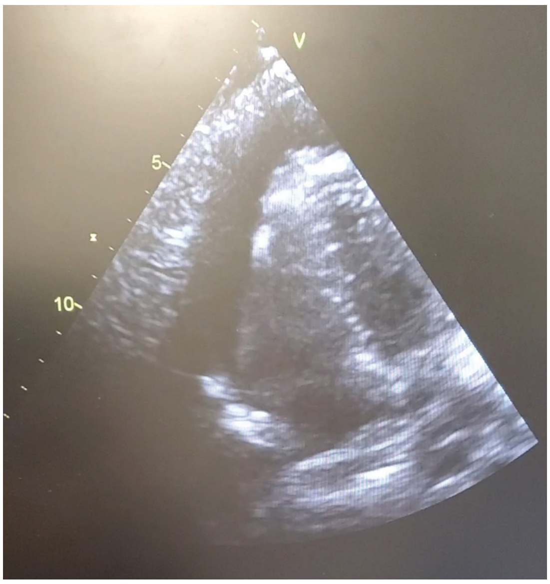
DBP, diastolic blood pressure; FE, Fisher's exact test; GCS, Glasgow Coma Scale; SBP, systolic blood pressure. [a]Independent samples *t* test. [b]Pearson's χ^2 test. [c]Fisher–Freeman–Halton exact test. *Significant at *P* value less than 0.05.

30 min (*n*=18), whereas the second group included those who had the intervention after 30 min (*n*=11). Comparison between the two groups showed that cases undergoing early intervention had a significantly lower BMI (24.6±5.7 vs. 31.5±6.3, *P*=0.005), higher mean systolic blood pressure (106.1±15.0 vs. 93.8±15.4, *P*=0.044), and lower heart rate (103.9±19.4 vs. 121.6±20.9, *P*=0.028). There was no significant difference between the two groups regarding age, sex, nature of trauma, presentation, diastolic blood pressure, and Glasgow Coma Score (*P*>0.05, Table 1).

Regarding the emergency management of the studied patients, only 17.2% of cases required cardiopulmonary resuscitation, whereas 48.3% received inotropes because of hemodynamic instability. The HB level in all cases was 8.8±1.7 g/dl. Most chest radiography showed opacity (69.0%), whereas pneumothorax and lung contusion were observed in 20.7 and 10.3%, respectively. Approximately two thirds of the victims had a CT scan of the chest, showing injuries including hemothorax (31%), pneumothorax (13.8%), and diaphragmatic injury (17.2%). Echocardiography demonstrated varied grades of pericardial effusion, with moderate effusion in 24.1%, large effusion in 20.7%, and cardiac tamponade in 34.5% (Fig. 1). The most common associated injuries included hemothorax (69.0%) and pneumothorax (10.3%). Comparison between the two groups revealed that early intervention was significantly associated with lower use of inotropes (33.3 vs. 72.7%, *P*=0.039), lower mean HB% (8.2±1.5 vs. 9.7±1.6, *P*=0.016), and presence of hemothorax on CT scan (50.0 vs. 0%, *P*=0.006). Diaphragmatic injuries on CT scans were found in five cases. There was no significant association between the time to intervention and the need for CPR, chest radiography and echocardiographic findings, as well as associated injuries (*P*>0.05, Table 2).

Nearly half of the patients underwent pericardiocentesis, and blood transfusion was performed in all cases. Operative findings revealed left ventricular and right atrial injuries in 48.3 and 13.8% of cases, respectively (Fig. 2). In addition, pericardial tamponade was detected in 55.2% of all

Figure 1



Transthoracic echocardiography showed moderate pericardial effusion.

cases, and aortic injury was also observed in 13.8% with varying grades of severity. Injuries to left anterior descending coronary artery and left internal mammary artery were detected in 6.9 and 3.4% of cases, respectively, in both groups. Overall, six cases had a diaphragmatic injury intraoperatively (Fig. 3). A left thoracotomy was used in more than half of the cases and sternotomy in more than one third, with two (6.9%) cases only undergoing right thoracotomy (Table 3) (Fig. 4).

Repair of the heart was done in all cases in association with diaphragmatic repair or other associated procedures according to each case. Two cases underwent saphenous vein anastomosis because of coronary injuries, one using a heart-lung machine and the other on a beating heart. Postoperative chest radiography showed no significant findings in 86.2%, whereas only four (3.4%) cases showed atelectasis, congestion (3.4%), and residual clots (6.9%, Table 3).

The comparison between the two studied groups revealed that early intervention was significantly associated with a higher rate of pericardiocentesis (66.7 vs. 27.3%, *P*=0.039) and sternotomy (61.1 vs. 0%, *P*=0.001). The operative findings, postoperative conventional radiography, and postoperative ejection fraction did not differ significantly between the two groups (*P*>0.05, Table 3).

Complications occurred in 11 (37.9%) cases, the commonest being wound infection (10.3%) and clotted hemothorax (6.9%). Death occurred in one (3.4%) case and brain death in another case (3.4%). The ICU stay varied from 1 to 78 days, with a median stay of 3 days. The hospital stay ranged from 4 to 78 days, with a median of 6 days. Satisfaction was rated as excellent in most cases (65.5%), poor in 20.7%, and good in 13.8%. Early intervention showed significant low rate of complications (22.2 vs. 63.6%, *P*=0.048) and an excellent rating of satisfaction (94.4 vs. 18.2%, *P*<0.001). Moreover, patients undergoing early intervention had a significantly lower median ICU stay (2 vs. 6 days, *P*=0.009), and median duration of mechanical ventilation (6 vs. 24 h, *P*=0.008). The two groups did not demonstrate significant differences in the rates of individual complications. The length of hospital stay tended to be lower with early intervention, but the difference was not statistically significant (*P*>0.05, Table 4).

Univariate logistic regression analysis was performed to assess whether relevant factors contributed significantly to the studied outcomes (complications, ICU stay, and

Table 2 Emergency management, radiological findings, and associated injuries of the studied patients (total *N*=29)

	Time for surgical intervention		Total (*N*=29)	Statistical tests	
	< 30 min (*N*=18)	>30 min (*N*=11)		*P* value	*P* value
CPR [*n* (%)]					
No	15 (83.3)	9 (81.8)	24 (82.8)	FE	1.000
Yes	3 (16.7)	2 (18.2)	5 (17.2)		
Inotropes [*n* (%)]					
No	12 (66.7)	3 (27.3)	15 (51.7)	4.243a	0.039*
Yes	6 (33.3)	8 (72.7)	14 (48.3)		
HB%					
Mean±SD (minimum– maximum)	8.2±1.5 (5.0–11.0)	9.7±1.6 (7.0–13.0)	8.8±1.7 (5.0–13.0)	2.576b	0.016*
Chest radiography [*n* (%)]					
Lung contusion	1 (5.6)	2 (18.2)	3 (10.3)	1.287c	0.702
Opacity	13 (72.2)	7 (63.6)	20 (69.0)		
Pneumothorax	4 (22.2)	2 (18.2)	6 (20.7)		
CT chest [*n* (%)]					
Not done	7 (38.9)	4 (36.4)	11 (37.9)	14.139c	0.001*
Diaphragmatic injury	0 $–	5 (45.5) $+	5 (17.2)		
Hemothorax	9 (50.0) $+	0 $–	9 (31.0)		
Pneumothorax	2 (11.1)	2 (18.2)	4 (13.8)		
Echo finding [*n* (%)]					
Hematoma	5 (27.8)	1 (9.1)	6 (6.920.7)	2.819	0.442
Moderate pericardial effusion	3 (16.7)	4 (36.4)	7 (24.1)		
Large pericardial effusion	3 (16.7)	3 (27.3)	6 (20.7)		
Tamponade	7 (38.9)	3 (27.3)	10 (34.5)		
Echo EF					
Mean±SD (minimum– maximum)	59.5±8.0 (45.0–70.0)	56.7±8.7 (40.0–70.0)	58.4±8.2 (40.0–70.0)	0.877b	0.389
Associated injuries [*n* (%)]					
Hemothorax	14 (77.8)	6 (54.5)	20 (69.0)	FE	0.237
Pneumothorax	2 (11.1)	1 (9.1)	3 (10.3)	FE	1.000
Abdominal collection	1 (5.6)	1 (9.1)	2 (6.9)	FE	1.000
Diaphragm	1 (5.6)	5 (45.5)	6 (20.7)	FE	1.000
Lung	1 (5.6)	1 (9.1)	2 (6.8)	FE	1.000
Neurology	0	1 (9.1)	1 (3.4)	FE	0.379

CPR, cardiopulmonary resuscitation; CT, computerized tomography; Echo, echocardiography; EF, ejection fraction; FE, Fisher's exact test; HB, hemoglobin. [a]Pearson's χ^2 test. [b]Independent samples *t* test. [c]Fisher–Freeman–Halton exact test. $+ significantly higher frequency than expected by chance. $– significantly lower frequency than expected by chance. *Significant at *P* value less than 0.05.

hospital stay). The ICU and hospital stays were entered as binomial dependent variables based on their median values in the studied sample. Independent variables that had a *P* value less than 0.1 in univariate analysis were included in a multivariate regression analysis. Early surgical intervention was significantly associated with a lower probability of prolonged ICU (OR: 0.063, 95% CI: 0.007–0.546, *P*=0.012) and hospital stays (OR: 0.184, 95% CI: 0.040–0.844, *P*=0.029) after adjusting for the confounders in the multivariate analysis but did not significantly reduce the probability of complications (OR: 0.097, 95% CI: 0.009–1.022, *P*=0. 052) (Table 5 and Figs. 4–7).

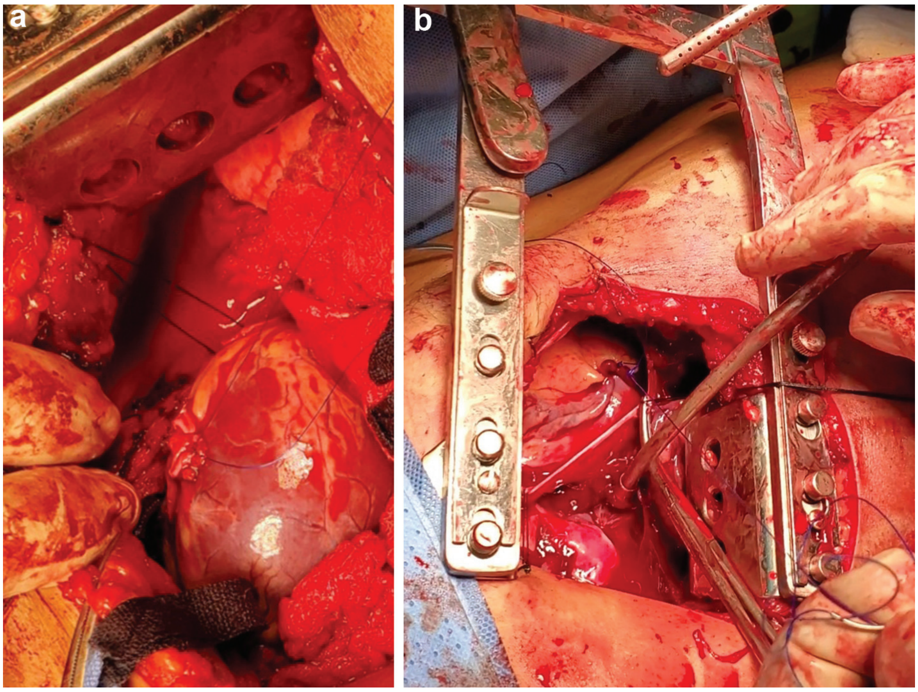
Discussion

The incidence of penetrating cardiac trauma is very low, accounting for less than 1% of trauma admissions [4]. This low incidence is a result of the high mortality rate, so only a small proportion of cases reach the hospitals alive [13]. The present study included 29 cases with traumatic cardiac injuries, with the aim to assess the effect of early surgical intervention in cases with penetrating cardiac injury on patients' outcomes.

Most of our cases were males (82.8%) with a mean age of 42.2 years, which was also observed by previous similar studies [6,8–10,13–15]. The predominance of young male patients could be explained by the involvement of young men in violent events and quarrels as well as the higher prevalence of male drivers. Moreover, young drivers may be more careless and consequently are more prone to accidents.

Trauma was the result of stabbing and RTAs in 44.8 and 31.0% of our cases, respectively, which partially agreed with the results of previous studies, which

Figure 2



(a) Left ventricular stab injury post pericardial patch repair. (b) Right ventricular injury post direct repair.

Figure 3

CT chest showed left side hemothorax with left diaphragmatic injury. CT, computed tomography

reported that the commonest mechanisms were gunshot [8,10,13,16] and stab wounds [8,10,13,16,17]. As RTAs were the mechanism of cardiac trauma in about one third of our cases, we recommend the adoption of strict measures by the government to improve the state of road safety and enhance the adherence to positive behaviors such as wearing seat belts, abstinence from substances that affect driving, and following the traffic regulations.

Approximately 79% of patients had varied grades of pericardial effusion on echocardiographic examination. The effusion was considerable in 34.5% of cases causing cardiac tamponade and large and in another 20.7%. The high rate of cardiac tamponade is the same with other studies that reported cardiac tamponade as the commonest clinical presentation [16]. Pericardiocentesis was done in 51.7% of the cases and was significantly associated with performing early surgical intervention (P=0.039). This association may be explained by the presence of cardiac tamponade, which represents a life-threatening condition, necessitating the performance of pericardiocentesis first as a temporary measure [18] and then the urgent surgical intervention. This inference is supported by Mishra *et al.* [9] who stated that the time from ED to surgery ranged from 19 to 36 min in cases with cardiac tamponade. Surgical management of cardiac tamponade entails the drainage of blood from the pericardial sac and repair of the cardiac injury [19].

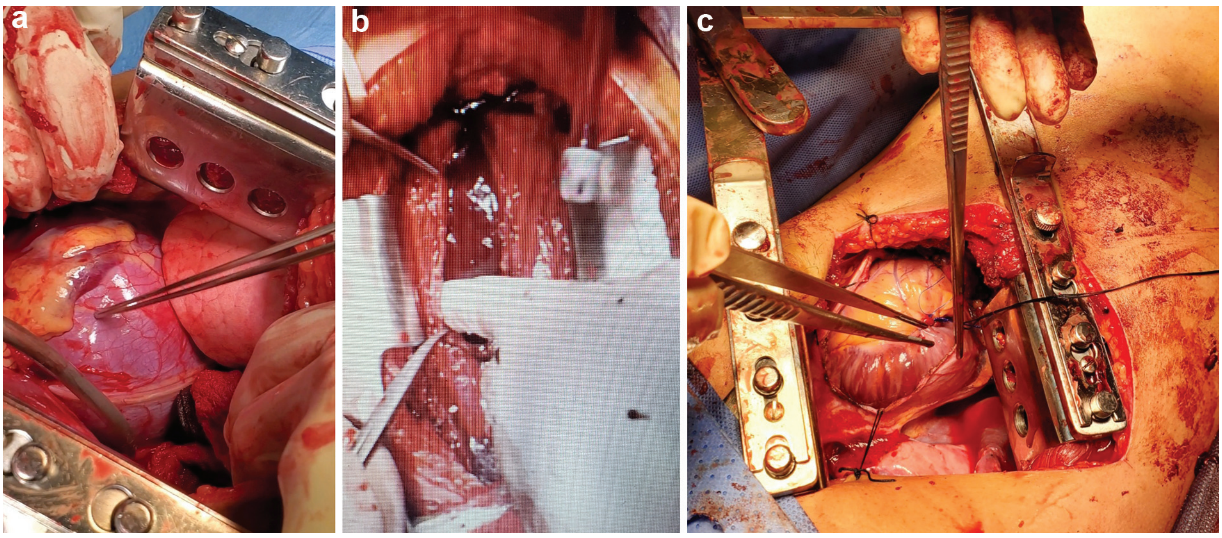
Most patients with penetrating cardiac injury require surgical management, whereas blunt cardiac trauma may be treated conservatively in many cases [8,13]. All of the patients in our series underwent cardiac surgery, which agrees with the study by Mishra *et al.* [9].

Table 3 Details of intervention and operative room findings in the studied patients (total *N*=29)

	Time for surgical intervention		Total (*N*=29)	Statistical tests	
	< 30 min (*N*=18)	>30 min (*N*=11)		Test statistic	*P* value
Pericardiocentesis [*n* (%)]					
No	6 (33.3)	8 (72.7)	14 (48.3)	4.243a	0.039*
Yes	12 (66.7)	3 (27.3)	15 (51.7)		
Blood transfusion [*n* (%)]					
Yes	18 (100.0)	11 (100.0)	29 (100.0)	NA	NA
Operative finding					
Left ventricular injury	11 (61.2)	3 (27.3)	14 (48.3)	3.131a	0.077
Right atrial injury	4 (22.2)	0	4 (13.8)	FE	0.268
Pericardial tamponade	10 (55.6)	6 (54.6)	16 (55.2)	FE	0.139
Aortic injury small	0	2 (18.2)	2 (6.9)	FE	0.135
Aortic injury medium	1 (5.6)	0	1 (3.4)	FE	1.000
Aortic injury large	0	1 (9.1)	1 (3.4)	FE	0.379
LAD injury	1 (5.6)	1 (9.1)	2 (6.9)	FE	1.000
LIMA	1 (5.6)	0	1 (3.4)	FE	1.000
Diaphragmatic injury	1 (5.6)	5 (45.5)	6 (20.7)	FE	0.135
Incision [*n* (%)]					
Left thoracotomy	6 (33.3) $–	10 (90.9) $+	16 (55.2)	12.076 b	0.001*
Right thoracotomy	1 (5.6)	1 (9.1)	2 (6.9)		
Sternotomy	11 (61.1) $+	0 $–	11 (37.9)		
Postoperative chest radiography [*n* (%)]					
Normal	16 (88.9)	9 (81.8)	25 (86.2)	3.939b	0.195
Atelectasis	1 (5.6)	0	1 (3.4)		
Congestion	1 (5.6)	0	1 (3.4)		
Residual clots	0	2 (18.2)	2 (6.9)		
Postoperative EF					
Mean±SD (minimum–maximum)	58.1±8.7 (35.0–70.0)	56.0±6.6 (45.0–65.0)	57.4±7.9 (35.0–70.0)	0.669c	0.510
Chest tube drainage					
Median (IQR) (minimum–maximum)	350 (350–560) (240–700)	–	350 (350–560) (240–700)	NA	NA

EF, ejection fraction; FE, Fisher's exact test; IQR, interquartile range (25th–75th percentiles); LAD, left anterior descending artery; LIMA, left internal mammary artery; NA, not applicable. [a]Pearson's χ^2 test. [b]Fisher–Freeman–Halton exact test. [c]Independent samples *t* test. $+ significantly higher frequency than expected by chance. $– significantly lower frequency than expected by chance. *Significant at *P* value less than 0.05.

Figure 4



(a) Left thoracotomy showed tense pericardium post stab trauma. (b) Clotted hemothorax through sternotomy. (c) Right thoracotomy post repair of tangential injury to the right atrium.

Table 4 Emergency management, radiological findings, and associated injuries of the studied patients (total *N*=29)

	Time for surgical intervention		Total (*N*=29)	Statistical tests	
	< 30 min (*N*=18)	>30 min (*N*=11)		Test statistic	*P* value
Complications [*n* (%)]					
Absent	14 (77.8)	4 (36.4)	18 (62.1)	FE	0.048*
Present	4 (22.2)	7 (63.6)	11 (37.9)		
Wound infection	3 (16.7)	0	3 (10.3)	FE	0.268
Clotted hemothorax	0	2 (18.2)	2 (6.9)	FE	0.135
DIC	0	1 (9.1)	1 (3.4)	FE	0.379
Impaired cardiac function	1 (5.6)	0	1 (3.4)	FE	1.000
Paraplegia	0	1 (9.1)	1 (3.4)	FE	0.379
Renal impairment	0	1 (9.1)	1 (3.4)	FE	0.379
Brain death	0	1 (9.1)	1 (3.4)	FE	0.379
Death	0	1 (9.1)	1 (3.4)	FE	0.379
ICU stay (days)					
Median (IQR) (minimum–maximum)	2.0 (2.0–3.0) (1.0–7.0)	6.0 (3.0–11.0) (1.0–78.0)	3.0 (2.0–5.0) (1.0–78.0)	2.624a	0.009*
Duration on mechanical ventilator (hours)					
Median (IQR) (minimum–maximum)	6.0 (6.0–6.0) (5.0–10.0)	24.0 (24.0–78.0) (10.0–840.0)	10.0 (6.0–24.0) (5.0–840.0)	2.554	0.008*
Hospital stay (days)					
Median (IQR) (minimum–maximum)	6.0 (5.0–7.0) (4.0–15.0)	10.0 (5.0–21.0) (4.0–78.0)	6.0 (5.0–10.0) (4.0–78.0)	1.867a	0.062
Satisfaction					
Excellent	17 (94.4) $+	2 (18.2) $–	19 (65.5)	18.124b	<0.001*
Good	1 (5.6)	3 (27.3)	4 (13.8)		
Poor	0 $–	6 (54.5) $+	6 (20.7)		

DIC, Disseminated intravascular coagulation; FE, Fisher's exact test. [a]Mann–Whitney test. [b]Fisher–Freeman–Halton exact test. $+ significantly higher frequency than expected by chance. $– significantly lower frequency than expected by chance. *Significant at *P* value less than 0.05.

The most frequently used incision for thoracic surgery was left thoracotomy (55.2%), followed by sternotomy (37.9%). Sternotomy was performed only in the early intervention group (P=0.001), which may be explained by the severity of injuries in these cases, which called for the use of sternotomy as it allows better visualization of the field [20]. Rahim Khan *et al.* [16] reported that median sternotomy was used in cases of penetrating cardiac trauma with good results. In addition, Isaza-Restrepo *et al.* [17] and Joo *et al.* [6] reported sternotomy as the adopted surgical approach for managing cases with penetrating chest trauma.

Patients with cardiac trauma who arrive alive at the hospital usually have a single affected cardiac chamber [8]. The most common sites of cardiac injury were the left ventricle and right atrium (48.3 and 13.8%, respectively). Aortic injuries affected 13.8% of cases with varying grades of severity. Other recorded vascular injuries involved the left anterior descending and left internal mammary arteries (6.9 and 3.4%, respectively). Other studies revealed that the most affected cardiac chamber was the right ventricle, followed by the right atrium, and then the left ventricle [6,9,10].

All patients in our series had associated injuries, the most common being hemothorax (69.0%) and pneumothorax (10.3%). Hemothorax has been frequently reported in cases of chest trauma [16]. Blood may arise from various sources, including the chest wall, great vessels, intercostal or internal mammary arteries, lung, myocardium, or diaphragm [21].

We found no significant association between the accompanying injuries and the time of surgical intervention. Meanwhile, early intervention was significantly associated with the detection of hemothorax on CT scans (50.0 vs. 0%, P=0.006). This may indicate that the decision of early intervention is affected by Trans thoracic echocardiography (TTE) if available and CT scan findings, with hemothorax presence prompting an urgent intervention. This is supported by the finding of Hajjar *et al.* [14] that hemothorax was an indication of emergency thoracotomy in most cases.

The rate of postoperative complications in the current study was 37.9%. The most frequent complications were wound infection (10.3%) and clotted

Table 5 Univariate and multivariate regression analysis to assess risk factors for complications, ICU stay above 3 days, and hospital stay above 6 days (total *N*=29)

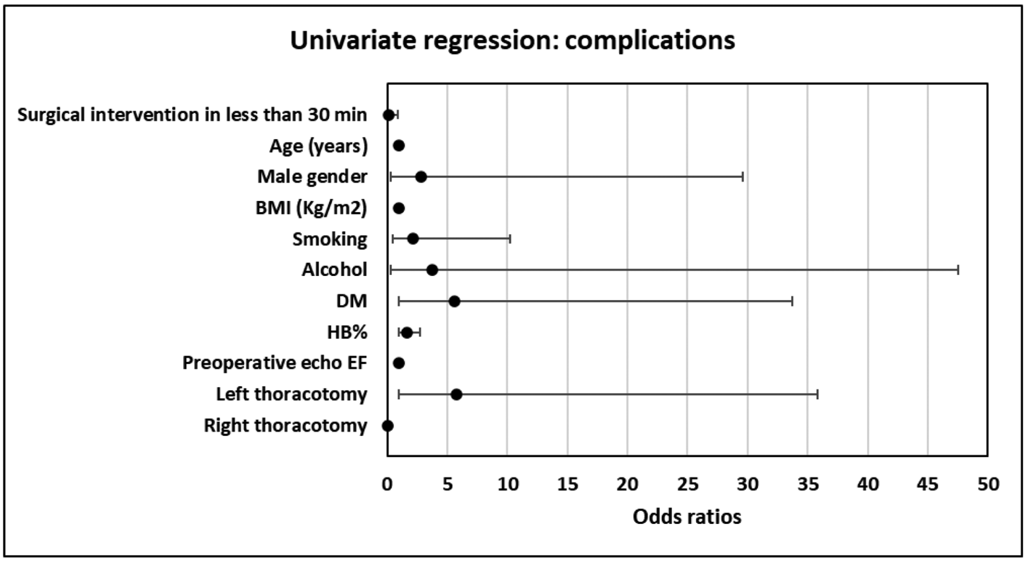
Outcome	Independent variables	Univariate analysis		Multivariate analysis	
		P value	Unadjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)
Complications	Surgical intervention in less than 30 min	0.032*	0.163 (0.031–0.856)	0.052	0.097 (0.009–1.022)
	Age (years)	0.982	0.999 (0.953–1.049)		
	Male sex	0.379	2.857 (0.276–29.564)		
	BMI (kg/m^2)	0.841	0.988 (0.882–1.107)		
	Smoking	0.319	2.187 (0.469–10.210)		
	Alcohol	0.304	3.778 (0.300–47.556)		
	DM	0.059	5.625 (0.937–33.764)	0.052	12.756 (0.975–166.897)
	HB%	0.087	1.598 (0.934–2.733)	0.430	0.871 (0.618–1.227)
	Preoperative echo EF	0.545	0.971 (0.883–1.068)		
	Incision (reference: sternotomy)				
	Left thoracotomy	0.059	5.786 (0.935–35.814)	0.421	2.910 (0.216–39.196)
	Right thoracotomy	0.999	0	0.999	0
ICU stay >3 days	Surgical intervention in less than 30 min	0.032*	0.163 (0.031–0.856)	0.012*	0.063 (0.007–0.546)
	Age (years)	0.963	0.999 (0.952–1.048)		
	Male sex	0.379	2.857 (0.276–29.564)		
	BMI (kg/m^2)	0.683	0.976 (0.871–1.095)		
	Smoking	0.319	2.187 (0.469–10.210)		
	Alcohol	0.304	3.778 (0.300–47.556)		
	DM	0.059	5.625 (0.937–33.764)	0.066	8.234 (0.871–77.871)
	HB%	0.129	1.487 (0.891–2.483)		
	Preoperative echo EF	0.132	0.924 (0.833–1.024)		
	Incision (reference: sternotomy)				
	Left thoracotomy	0.059	5.786 (0.935–35.814)	0.801	1.202 (0.286–5.053)
	Right thoracotomy	0.999	0	0.999	0
Hospital stay >6 days	Surgical intervention in less than 30 min	0.047*	0.188 (0.036–0.976)	0.029*	0.184 (0.040–0.844)
	Age (years)	0.951	1.001 (0.956–1.049)		
	Male sex	0.685	1.500 (0.211–10.649)		
	BMI (kg/m^2)	0.936	1.005 (0.900–1.121)		
	Smoking	0.196	2.700 (0.600–12.150)		
	Alcohol	0.510	2.333 (0.188–29.036)		
	DM	0.551	1.575 (0.354–6.998)		
	HB%	0.048*	1.763 (1.005–3.095)	0.090	1.129 (0.981–1.300)
	Preoperative echo EF	0.379	0.958 (0.872–1.054)		
	Incision (reference: sternotomy)				
	Left thoracotomy	0.187	2.917 (0.594–14.327)		
	Right thoracotomy	0.999	0		

CI, confidence interval; DM, diabetes mellitus; HB, hemoglobin; OR, odds ratio. *Significant at *P* value less than 0.05.

hemothorax (6.9%). Kaljusto *et al.* [10] stated that among the 14/31 survivors, one patient had a neurological complication due to brain hypoxia and another patient developed pneumonia during hospitalization.

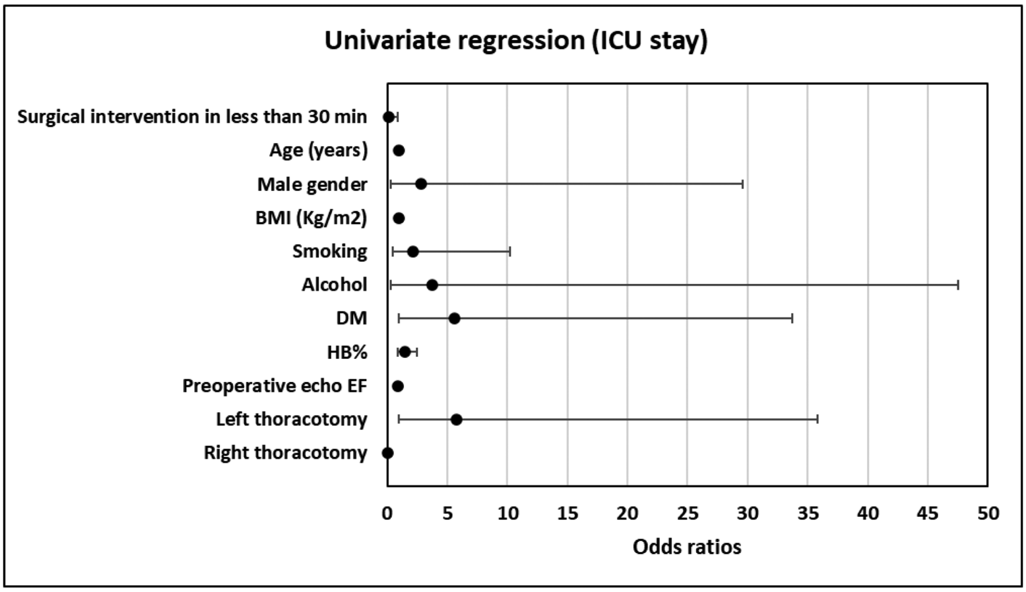
The recorded mortality rate among our series was low, with death reported in one (3.4%) case only who had a delayed intervention. Higher mortality rates of 20–28.5% were previously reported [6,9,16]. However, previous studies included extended time periods (10–20 years) to collect ample sample sizes; during this extended period, advances occurred in patient transfer, supportive care, and surgical techniques. Therefore, the mortality rate has considerably decreased in recent years.Analysis in our study revealed better patient survival and outcomes in the early intervention group. Univariate analysis showed that early intervention was significantly associated with less likelihood of complications (OR: 0.163, 95% CI: 0.031–0.856, *P*=0.032), prolonged ICU stay (OR: 0.163, 95% CI: 0.031–0.856, *P*=0.032), and prolonged hospital stay (OR: 0.188, 95% CI: 0.036–0.976, *P*=0.047). On multivariate analysis, the significant lowering of the risk was observed regarding the prolonged ICU stay (OR: 0.063, 95% CI: 0.007–0.546, *P*=0.012) and hospital stay (OR: 0.184, 95% CI: 0.040–0.844, *P*=0.029). However, the reduction in the likelihood of complications with early intervention was

Figure 5



Odds ratios (round marker) of factors potentially affecting the occurrence of complications in the studied victims (total *n*=29). Error bars represent 95% confidence intervals.

Figure 6



Odds ratios (round marker) of factors potentially affecting the intensive care unit (ICU) stay in the studied victims (total *n*=29). Error bars represent 95% confidence intervals.

nonsignificant, with a borderline *P* value of 0.052. The sample size was small owing to the low incidence of penetrating cardiac injuries arriving alive at hospitals, so the study was not powered for multivariate regression analysis. A larger sample size may reveal or exclude the presence of a significant effect of early intervention on the occurrence of complications in those victims.

Few studies assessed the effect of early intervention in cardiac patients. Fatimi *et al.* [22] reported that delayed management could negatively affect the outcome of cardiac trauma cases, with increased rates of morbidity and mortality. Isaza-Restrepo *et al.* [17] showed that most patients who underwent surgical intervention within the first 60 min after trauma were rescued. A recent study by Aslaner [15] found intervention within the first 30, 60, and 120 min was associated with survival rates of 90.9, 54.5, and 27.3%, respectively.

Figure 7

Odds ratios (round marker) of factors potentially affecting the intensive care unit (ICU) stay in the studied victims (total *n*=29). Error bars represent 95% confidence intervals.

Satisfaction of the patients/families was rated as excellent, good, and poor in 65.5, 13.8, and 20.7%, respectively, with a significantly higher excellent rating in the early intervention group (94.4 vs. 18.2%, $P<0.001$). The higher satisfaction with early intervention could be attributed to better patient outcomes. In addition, sternotomy is associated with less postoperative pain, which improves the patient's comfort [17,23]. Moreover, the perception of families of the initiation of prompt and early management could partially contribute to the satisfaction of families and patients.

The current study endeavored to fill a gap in our knowledge about the effect of early intervention on outcomes of patients with penetrating cardiac trauma. The study possessed its points of strength, such as including patients from two tertiary centers. Meanwhile, it was limited by the available data in the patient's medical records whose accuracy could vary depending on the treating physicians and the individuals who performed data entry. Moreover, the sample size was relatively small owing to the low incidence of this type of trauma, so the results of regression analysis should be interpreted cautiously. We recommend the conduct of similar studies that encompass several trauma centers to ensure the inclusion of a larger sample size.

Conclusion

Early surgical intervention positively affects the patient's outcome after penetrating cardiac injuries. It reduces ICU and hospital stays and may decrease the rate of complications. Every effort should be directed toward reducing the time lag from ED to the operating theater. Further studies are required to estimate the extent of early intervention on patient mortality.

Limitations

This study included a small number of cases that were divided in two groups, which needs a multicenter analysis for more data. Actually, penetrating cardiac injuries are present but in small number when compared with other types of traumas, as well many cases not surviving till reach the hospital. There was a protocol in each center to accept these cases according to the availability of cardiothoracic surgery service, which may affect the outcome.

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Conflicts of interest

There are no conflicts of interest.

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