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Penetrating cardiac injuries: a 13-year retrospective evaluation from a Brazilian trauma center

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Abstract

To present our experience with penetrating cardiac injuries. We have retrospectively reviewed the records of 70 victims of penetrating cardiac injuries. A logistic regression has been performed in order to determine the association between death and clinical predictors. Penetrating injuries consisted of 43 stab wounds (61.4%) and 27 (38.6%) gunshot injuries ($P=0.72$). There were 63 (90%) male and 7 female (10%, $P<0.001$) victims. The mean age was 27.36 ± 11.51, ranging from 3 to 65 years. The overall mortality was 32.9%, 47.8% for gunshot wounds and 52.2% for stab wounds ($P=0.266$). Eight victims (11.4%) had associated intra-thoracic great vessel injuries and 17 (24.3%) presented associated intra-abdominal organ injuries. The incidence of injured chamber was: right ventricle 37.1%, right atrium 27.1%, left ventricle 25.7%, and left atrium 5.7%. Non-survivors had lower systolic blood pressure (37.50 ± 39.18 mmHg) than survivors (79.04 ± 41.04 mmHg; $P<0.001$) upon arrival at the hospital. Thirteen non-survival (56.5%) and 10 (21.3%) survival victims had systolic blood pressure (SBP) $\leq$50 mmHg ($P=0.001$). The level of systolic blood pressure (SBP $\leq$50 mmHg) and consciousness upon arrival at the hospital are predictors of outcome in victims of penetrating cardiac injuries.

Keywords: Penetrating cardiac injuries; Cardiac wounds; Heart wounds; Penetrating chest wounds; Penetrating chest trauma

1. Introduction

> *... Patroclus then aimed in his turn and the spear sped not from his hand in vain, for he hit Sarpedon just where the midriff surrounds the ever beating heart. He fell like some oak or silver poplar ...*
>
> *The Iliad, by Homer, translated by Samuel Butler (e-text from The Project Gutenberg-www.gutenberg.ne)*

Mankind has been using violence to solve conflicts since unmemorable times. Probably, as soon as humans had learned how to use sharply pointed tools as weapons, they realized that stabbing specific zones of the chest would almost certainly result in quick death. This is corroborated by the poetic description of Sarpedon's death, from the classical Greek epic *The Iliad*, one of the earliest descriptions of death caused by penetrating cardiac injury. Surprisingly, in spite of the extraordinary evolution of mankind, cardiac injury is still a quite challenging injury and, unfortunately, violence remains an onerous world problem according to 'The World report on violence and health 2002' (The World Health Organization-www.who.int/en/), mainly among the younger population. According to this report, youth homicide rates increased in many parts of the world between 1985 and 1994. In the present study, we report our experience with penetrating cardiac injuries.

2. Material and methods

We have retrospectively reviewed patient records from our hospital registry in order to identify all the victims of penetrating cardiac injuries assisted at our trauma center between January 1990 and January 2003. Our facilities for assistance of medical emergencies are located in the center of Ribeirao Preto, a city with 504,923 inhabitants. This hospital not only assists non-traumatic emergencies, but also deals with around 4000 cases of trauma per year from a region comprised of 1,000,000 people. The Attending trauma surgery staff provide around-the-clock coverage by supervising and actively participating in all resuscitations and surgical interventions. However, there are no cardiac surgeons or perfusionists on duty at the hospital.

Cardiac contusions and victims arriving dead to the hospital have not been included in the present report. Data concerning age, sex, cardiac chamber injuries, great vessel injuries, thoracic and abdominal associated injuries, vital signs on arrival and hospital survival have been collected. Only victims discharged from the hospital have been considered survivors. We have considered unconscious any unaware victim presenting no eye opening to verbal command.

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Table 1
Demographics and clinical condition upon arrival at the hospital

	All $N=70$	Survivors $N=47$	Non-survivors $N=23$	P
Age	27.36±11.52	26.36±10.31	29.43±13.62	0.294
Gender				
Male	63 (90%)	44 (93.6%)	19 (82.6%)	$P<0.001$*
Female	7 (10%)	3 (6.4%)	4 (17.4%)	
Signals and symptoms				
Cardiac rate (bpm)	97.23±43.56	99.90±31.29	92.14±61.16	0.513
SBP[1] (mmHg)	66.64±44.53	79.04±41.04	37.50±39.18	$P<0.001$
SBP≤50 mmHg	23 (32.8%)	10 (21.3%)	13 (56, 5%)	0.001
Unconscious	18 (25.7%)	7 (14.9%)	11 (47.8)	0.003
in extremis[2]	8 (11.4%)	1 (2.1%)	7 (30.4%)	0.001
Jugular venous distention	21 (30%)	16 (34%)	5 (21.7%)	0.291
Beck's Triad	11 (15.7%)	8 (17%)	3 (13%)	0.668
Hemothorax	54 (77.1%)	35 (74.5%)	19 (82.6%)	0.446

[1]SBP: systolic blood pressure; [2]*in extremis*: immeasurable blood pressure and unconscious; *comparing the proportion of males and females.

Continuous data are presented as means±standard deviations. A two-tailed *t* test has been used to compare means; Pearson Chi-Square or Fisher's exact test (if at least 1 cell had expected count less than 5) has been used to compare categorical data. Binomial test has been used to compare the observed frequencies of dichotomous variable. A logistic regression has been performed to determine the association between death and clinical predictors. The statistical software SPSS 12.0 for windows (SPSS Inc., Chicago, Illinois, USA) has been employed. A $P<0.05$ has been considered significant.

3. Results

Over a thirteen-year period (1990–1993), seventy victims of trauma sustaining penetrating cardiac injury arrived alive at our center. Forty-three had been victims of stab wounds (61.4%) and 27 (38.6%) of gunshot injuries ($P=0.72$). The cardiac wounds were repaired using a variety of non-absorbable sutures and techniques without use of cardiopulmonary bypass (CPB). Five victims were operated on by means of sternotomy (7.1%), 3 using right thoracotomy (4.3%), and the remainder were operated via left thoracotomy. The thoracotomies were extended by means of transverse sternotomy according to the surgeon's discretion.

Table 2
Wounded chambers and associated injuries

Injuries	All $N=70$	Survivors $N=47$	Non-survivors $N=23$	P
Thorax				
Right atrium	19 (27.1%)	14 (29.8%)2	5 (21.73%)	0.541
Left atrium	4 (5.7%)	2 (4.2%)4	2 (8.7%)4	0.423*
Right ventricle	26 (37.1%)	22 (46.8%)1	6 (26%)2	0.124
Left ventricle	18 (25.7%)	11 (23.4%)3	7 (30.4%)1	0.458
Coronary artery	7 (10%)	5 (10.64%)	2 (8.7%)	0.843*
Ascending aorta	2 (2.8%)	0	2 (8.7%)	0.098*
Pulmonary artery	2 (2.8%)	0	2 (8.7%)	0.098*
Venae cavae	4 (5.7%)	1 (2.1%)	3 (13%)	0.577*
Pulmonary veins	2 (2.8%)	2 (4.2%)	2 (8.7%)	0.098*
Lungs	26 (37.1%)	17 (36.2%)	9 (39.1%)	0.810*
Abdomen	17 (24.3%)	11 (23.4%)	6 (26.1%)	0.867
Liver	10 (14.1%)	7 (14.9%)	3 (13%)	1.000*
Stomach	5 (7.1%)	3 (6.4%)	2 (8.7%)	0.651*
Spleen	4 (5.7%)	2 (4.2%)	2 (8.7%)	0.587*
Small bowel	4 (5.7%)	3 (6.4%)	1 (4.3%)	1.000*
Colon	2 (2.9%)	2 (4.2%)	0	1.000*

*Fisher's exact test.

Sixty-three victims (90%) were males and 7 (10%) were females ($P<0.001$). The age ranged from 3 to 65 years, with a mean age of 27.36±11.51 years (Table 1). The overall mortality was 32.9% (23 deaths), 47.8% (11 deaths) in the case of gunshot wounds and 52.2% (12 deaths) in the case of stab wounds ($P=0.266$). Age and gender distributions were not significantly different when comparing survivors with non-survivors (Table 1).

Overall, 45 victims (64.3%) had systolic blood pressure (SBP) ≤90 mmHg, 23 (32.8%) had SBP≤50 mmHg, and 14 (20%) had immeasurable blood pressure. Non-survivors had lower SBP (37.50±39.18 mmHg) than survivors (79.04±41.04 mmHg; $P<0.001$) upon arrival at the hospital. Thirteen non-survivors (56.5%) and 10 survivors (21.3%) had SBP≤50 mmHg (Table 1, $P=0.001$).

Eighteen victims (25.7%) were unconscious upon arrival at the hospital, among them 11 (61.1%) had SBP≤50 mmHg (8 had no blood pressure). None of the victims had suffered penetrating wounds in the head or significant injury at the extremities. The proportion of unconscious victims among non-survivors (47.8%) was significantly higher than among survivors (14.9%, $P=0.003$). The proportion of victims in *extremis* (with immeasurable arterial blood pressure and unconscious) was significantly higher among non-survivors (Table 1).

The main cause of death was exsanguination. From the 23 deaths, only 4 occurred after the first 24 h of hospital admission, due to multiple organ failure and/or sepsis. Length of hospital stay for survivors ranged from 3 to 19 days, mean of 7.4±3.2 days, and for non-survivors the period ranged from 0 to 15 days, with a mean of 2.0±4.1 days ($P<0.001$). The length of stay in the intensive care unit for survivors ranged from 1 to 10 days, mean of 2.79±2.2 days; and from 0 to 15 days, mean of 1.7±3.9 days, for non-survivors ($P=0.235$).

Sixty-six victims (94.3%) suffered injury to only one cardiac chamber (Table 2), 4 (5.7%) had multi-chamber injuries, 8 (11.4%) had associated intra-thoracic great vessel injuries, and 17 (24.3%) presented associated abdominal organ injuries (Table 2). Overall, the right ventricle was

Table 3
Odds ratio and logistic regression coefficients

	Logistic coefficient	Odds ratio	95% confidence interval for odds ratio	
			lower	upper
SBP ≤ 50 (mmHg)	1.926	6.681	2.126	22.141
Unconscious	1.302	3.678	1.033	13.087
Constant	−3.255	0.039	–	–

Hosmer and Lemeshow Test Sig. = 0.874, Sig. of Change in −2 Log Likelihood for SBP ≤ 50 mmHg = 0.001 and for Unconscious = 0.043.

Model: Probability (death) = $\exp(-3.255+1.926 \times X_{SBP\leq 50}+1.302 \times X_{unconscious})/[1+\exp(-3.255+1.926 \times X_{SBP\leq 50}+1.302 \times X_{unconscious})]$. $X=1$ if the factor is present and 0 if absent.

the most frequently injured cardiac chamber (37.1%), followed by the right atrium (27.1%), left ventricle (25.7%), and left atrium (5.7%). This distribution was kept among survivors, but the left ventricle was the most injured chamber (30.4%) among non-survivors, followed by the right ventricle (26%). Nevertheless, concerning wounded chambers, the differences between survivors and non-survivors were not significant. Hemothorax of variable amount was found in 77.1% of victims, with a similar proportion between survivors and non-survivors (74.5% and 82.6%, respectively, $P=0.446$).

A logistic regression analysis showed that SBP ≤ 50 mmHg and unconsciousness at hospital admittance were the covariates that provided the best logistic model to predict death (Table 3). According to such model, the predicted probability of dying from a penetrating cardiac injury upon arriving at the emergency room unconscious and with SBP ≤ 50 mmHg is 78.2%, this probability would be 49.3% if the victim arrived conscious with SBP ≤ 50 mmHg, 34.3% if the victim arrived unconscious with SBP > 50 mmHg, and 12.4% if the victim arrived conscious with SBP > 50 mmHg. A collinearity diagnostic did not show a linear function between unconsciousness and SBP < 50 mmHg.

4. Discussion

In agreement with others, our results have shown that victims of penetrating cardiac injuries are predominantly young males [1,2], as is usual regarding urban violence (The World report on violence and health 2002). However, hospital mortality in our series was lower than what is usually reported [1–3], but still higher than in the cases of penetrating chest wounds without cardiac injuries [4]. Probably, our lower hospital mortality was influenced by the lack of a pre-hospital system of medical attention in the beginning of this series, since our system for pre-hospital care in the case of medical emergencies has only recently been established. Therefore, a significant proportion of victims may have perished before reaching the hospital. In addition, the incidence of victims with multiple chamber injuries and gunshot wounds arriving alive at the hospital was lower in our series, which may be due to pre-hospital selection as well. In the year 2000, almost 70% of the homicides in Brazil were perpetrated using firearms [5].

Trauma and physiological indexes and scores have been proposed in order to facilitate inter-institutional comparisons, field triage and to predict mortality [6–8]. Even though we have not formally incorporated these indexes in the present series, our data demonstrate, in agreement with them, that the cardiovascular condition of the victims and their consciousness status upon arrival at the hospital are significant predictors of outcome in penetrating cardiac injuries.

Since none of the victims presented evidences of penetrating head injury, unconsciousness could be a consequence of their poor hemodynamic status. Therefore, one would expect that a covariate indicating interaction between blood pressure and consciousness level would almost certainly be included in the logistic model, since Glasgow Coma Scale (GCS) in penetrating cardiac trauma may suffer influence from the victim hemodynamic status, as suggested by Asensio et al. [1]. However, such correlation does not seem to be perfect, as we found in our logistic regression analysis, probably because there may be some contribution from exogenous factors, such as alcohol, illicit drugs, or even unsuspected non-penetrating head trauma. Nevertheless, Buckman et al. observed that intoxication with alcohol or cocaine had no evident effect on resuscitation after penetrating cardiac injuries [9]. Even though there are several trauma score systems in use [6,8], we agree with Senkowski and McKenney's [6] statement that the prediction of outcomes cannot apply to clinical decision-making for an individual patient.

Blood loss certainly was the main cause of hypotension in our series, mainly among non-survivors, since the majority of them presented clear signs of hypovolemia (hypotension, hemothorax and absence of jugular venous distention), instead of signs of cardiac tamponade. Therefore, clinical signs of cardiac tamponade, if present, were concealed by hypovolemia. Although there are data supporting that pericardial tamponade is a determinant of survival in penetrating cardiac injuries [7,10,11], this was not what we found. However, paraphrasing Asensio et al. [7], we believe that the truth lies somewhere in the middle. It is really difficult to determine which mechanism – myocardium self-homeostasis, intrapericardial blood cloth, elevation of intrapericardial pressure, or the lower intracardiac pressure due to hemorrhage – was preponderant to avoid exsanguinations and was less deleterious to the victim. Since only 4 of all the non-survival victims lived more than 24 h after hospitalization, we were unable to determine factors related with late hospital mortality.

In spite of the fact that the 'emergency department thoracotomy' (EDT) is a very useful tool among the trauma surgeon's armamentarium, mainly as a lifesaving procedure to treat penetrating chest injuries, it remains a challenging procedure that may not be easily accessible to all surgeons [8]. In our institution, all the surgeons assisting trauma victims have general surgery and the Advanced Trauma Life Support® of the American College of Surgeons (ACS-ATLS) training, but the majority are not a specialist in trauma surgery. Consequently, many of them do not feel comfortable performing EDT. Therefore, all of the victims of this series were assisted according to the protocols outlined in the ACS-ATLS, but the majority were quickly transferred to

the operating room to have an emergency thoracotomy. Apparently, this approach was not prejudicial, judging by our lower hospital mortality. Interestingly, Karmy-Jones et al. [12] have found that for chest gunshot injuries there may be an independent benefit of performing emergent thoracotomy in a specialized resuscitation room or operating room.

Cardiopulmonary bypass (CBP) has been occasionally used in order to treat proximal lesion of coronary arteries [13], multiple-chamber wounds [14] and to repair intra-cardiac lesions. However, in the majority of the reports, CPB is only occasionally needed, besides the fact that many trauma centers do not have cardiac surgery staff around the clock. Moreover, the use of CPB as a lifesaving method seems to be discouraging [14]. Therefore, the role of the early use of CPB in the treatment of penetrating cardiac injury needs further studies.

In summary, our data have shown that the level of systolic blood pressure and consciousness upon arrival at the hospital are predictors of outcome in victims of penetrating cardiac injuries.

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