The Heart Surgery Forum #2007-1098
10 (6), 2007 [Epub December 2007]
doi: 10.1532/HSF98.20071098

Online address: http://cardenjennings.metapress.com

Surgical Challenges for Urgent Approach in Penetrating Heart Injuries

Celalettin Gunay, Faruk Cingoz, Erkan Kuralay, Ufuk Demirkilic, Harun Tatar

Gulhane Military Medical Academy, Department of Cardiovascular Surgery, Ankara, Turkey

ABSTRACT

The aim of this clinical study is to assess the characteristics of penetrating heart injury and its surgical challenges for urgent surgical approach.

Materials and Methods: Seventeen patients suffering from penetrating heart wounds were evaluated retrospectively in the department of cardiovascular surgery between 1996 and 2004. All patients were male, with ages ranging from 19 to 36 years, with a mean age of 23.6 ± 5 years.

Results: Median sternotomy, left anterior thoracotomy, and right anterior thoracotomy were performed to control the bleeding or to reach the heart for internal cardiac massage in 5, 11 and, 1 control, respectively. The right ventricle was the most commonly injured chamber (64.7%, n = 12), followed by left ventricle (17.7%, n = 4), and right atrium (17.6%, n = 3); a left atrial injury was not seen. Mortality rate was 29% (5 cases), and 12 controls were discharged without any complications.

Conclusion: Although the most important factor affecting mortality in penetrating heart injuries is rapid transport, an urgent approach applied by a specialist team can decrease potential mortality and morbidity rates.

INTRODUCTION

Although penetrating heart injuries are less common when compared to other injuries, they are of great importance due to their high mortality rates [Asensio 2001; Campbell 1997; Goins 1996; Thourani 1999]. Thoracal injury accounts for 10.4% of all urgent surgical interventions, and cardiac injury is noticed in only 1% of these cases. Early diagnosis in penetrating heart injury is an important step in saving lives, and doubting a penetrating heart injury in thoracal traumas may change the timing of a potential surgical approach and mortality rate. The possibility of a heart injury should always be in mind with every injury located between the left anterior axillary line and the right vertical mammarian line, as well as between the jugulary area and upper epigastrium [Cullford 1989]. When a medical team receives a patient with penetrating heart injury, they do not have enough time to make a diagnosis and they can not predict what they should do. In this article, through clinical data and experiences, we want to explain how to manage this very difficult and challenging period.

MATERIALS AND METHODS

We analyzed 17 retrospective cases of penetrating heart injury that had surgical intervention in our clinic between the years 1996 and 2004. All patients were male, with ages ranging from 19 to 36 years (mean age, 23.6 ± 5 years). Two patients were transported to the hospital by ambulance, and the other 15 patients were brought to the emergency department by nonemergency vehicles. Three patients were unconscious at admission; all of their wounds were located on the front chest and caused by stabbing. One intubated patient was brought to the emergency department with external cardiac massage. Two patients were intubated at the emergency room and were taken to the operating room with external cardiac massage. Eleven patients had signs of hypovolemic shock (sistolic systolic blood pressure 60 to 80 mmHg, very weak pulse, pale, cold and sweaty extremities, unclear consciousness, and superficial respiration). The blood pressure could not be measured on 3 patients with superficial respiration. The first intervention in all patients was establishing by an intravenous line with a 16 gauge catheter, and 0.9% isotonic solution (around 1000 cc) was quickly given with or without cardiac massage. External cardiac massage was performed on 6 patients, and 9 patients were taken to the operating room without cardiac massage. Left anterior thoracotomy and internal cardiac massage were performed on 2 patients due to increased bleeding from the skin wound caused by the intubation and external cardiac massage.

RESULTS

Transportation times ranged from 10 to 45 minutes (mean, 31 ± 14 minutes). Inspection and palpation of the wound and general condition of the patient were the main diagnostic

Received April 26, 2007; received in revised form July 23, 2007; accepted August 1, 2007

Correspondence: Faruk Cingoz, MD, GATA Subay Lojmanlari, Serter Apt.2/9, 06018, Etlık, Ankara, Turkey; +90 312 3046789 (e-mail: fcingoz@yaboo.com).

tools. In 3 patients cardiac tamponade was diagnosed with echocardiography based on the presence of fluid in the pericardial space. Pericardiocentesis was made for the cardiac tamponade to decrease symptoms. Hemorrhagic fluid was emptied with thoracentesis in 3 patients whose chest x-rays revealed some fluid line in the pleural space. The other patients were taken directly to the operating room because of their unstable hemodynamic conditions, without performing invasive or noninvasive tests.

The right ventricle was the most commonly injured chamber (64.7%, n = 12), followed by left ventricle (17.7%, n = 4), and right atrium (17.6%, n = 3). Left atrial injury was not observed. Five patients were explored through median sternotomy. Eleven patients underwent left anterior thoracotomy, and right anterior thoracotomy was performed on 1 patient. A pericardiotomy above the phrenic nerve was performed in all patients to relieve cardiac tamponade, and the bleeding areas were immediately controlled with finger pressing. Ventricular fibrillation was noticed in 5 patients, and internal electrical defibrillation followed in these cases. Extracorporeal circulation was not required in any patient. Cardiorraphy using teflon supported sutures was performed on the cases with ventricular wounds, and primary suture was used for right atrial injury. There was no left atrial injury in our cases (Tables 1 and 2).

Four cases had coronary artery injury. In 1 patient the injury was at the middle part of left anterior descending artery (LAD). After bleeding was controlled and hemodynamic stability was established, left internal mammarian artery graft was harvested and anastomosed to LAD, in this case through left thoracotomy [Cingoz 2006]. Coronary injuries were located distally in diagonal and circumflex artery branches in the other 3 patients. Bleeding from these distal coronary injuries was controlled with epicardial stitches and coronary arteries were ligated. During the postoperative period, positive inotropic support was necessary in 7 patients. No patient required an intraaortic ballon pump (IABP).

Table1. Summary of Cases Studied*

Surgical Approach	
Median Sternotomy	5 patients
Left Anterior Thoracotomy	11 patients
Right Anterior Thoracotomy	1 patient
Wounded Cardiac Chambers	
Right Ventricle	12 patients
Left Ventricle	4 patients
Right Atrium	3 patients
Left Atrium	0 patients
Additional Injuries	
Coronary Artery Injury	
LAD	1 patient
D_1	1 patient
OM_2	2 patients
Left Pulmonary Paranchima	2 patients
Pulmonary Artery	1 patient

*LAD indicates left anterior descending artery; D_1, first diagonal branch of LAD; OM_2, second branch of the circumflex artery.

In 5 patients, the mortality rate was 29%. Two patients who experienced coronary artery injury died in the early postoperative period, 1 of whom died in the operating room from cardiac standstill. The other patient died 20 days later; he could not be weaned from the ventilator, and brain death was diagnosed 3 days following the operation. One of 2 patients who was transported by ambulance died (50%), and 4 of 15 patients who were transported by regular vehicles died (26.7%). There was no statistically significant difference between them ($P = .515$). Mortality rates were higher in patients with unresponsive mental conditions, compared to the patients with responsive mental status (50.0% versus 18.2%); and in patients who received external cardiac massage versus patients not receiving external cardiac massage (50.0% versus 18.2%). Mortality rates were also high in patients who received internal cardiac massage versus those who did not receive internal cardiac massage.(44.4% versus 12.5%). Although there were no significant statistical differences between them ($P > .05$), we think that significant differences may occur in studying the control groups with more cases. According to the number of injured cardiac chambers, mortality rates were 0% for the left ventricle, 30% for the right ventricle, 0% for right atrium, and 100% for injuries to both ventricles. There were no significant statistical differences in regards to the involved cardiac chamber ($P > .05$). Additional coronary injuries had no significant statistical effect on mortality rates ($P > .05$). Though 5 patients who died were brought to the hospital in 27.0 ± 13.6 minutes (minimum, 25 minutes; maximum, 45 minutes), 10 surviving patients arrived at the hospital in 36.0 ± 7.4 minutes (minimum, 10 minutes; maximum, 45 minutes). Although there were no significant statistical differences between them ($P = .254$), significant differences may occur in a larger study group. Exploring the patients via thoracotomy (left or right) or median sternotomy had no significant statistical effect on mortality rates ($P > .05$).

Twelve (71%) patients were discharged without any complication. The hospitalization period ranged from 9 to 23 days with a mean period of 13 ± 5 days, and there were no complications at the end of the third month and the first year follow-up periods.

DISCUSSION

Penetrating heart injuries are very difficult clinical problems in emergency and cardiovascular departments. There are many factors affecting mortality rates, such as transportation time, type of injury, other organ damages, coronary artery lesions, amount of blood loss, and surgical experience of the medical and surgical team. In addition, according to our experiences, there are 2 main factors that help the surgical team determine what they should do for patients' conditions to predict the mortality rate in penetrating heart injuries. Quick decision making and rapid surgical approach to decrease mortality rate will be discussed later in this article.

Table 2. Patient Characteristics and Outcomes*

Patient Number	Transportation/ Time, min†	Mental Condition	External Cardiac Massage	Internal Cardiac Massage	WoundedCardiac Chambers	Additional Injuries	Surgical Approach	Surgical Therapy	Outcome
1	Ambulance/50	Unresponsive	Yes	Yes	Right ventricle, left ventricle	OM_2	Median sternotomy	Cardiorraphy, ligation	Death/cardiac standstill
2	Casual vehicle/15	Responsive	No	No	Right ventricle	No	Left anterior thoracotomy	Cardiorraphy, ligation	Discharge
3	Casual vehicle/10	Responsive	No	No	Right ventricle	Pulmonary artery	Left anterior thoracotomy	Cardiorraphy, primary suture	Discharge
4	Casual vehicle/25	Responsive	No	Yes	Right ventricle	No	Left anterior thoracotomy	Cardiorraphy	Death/brain death, 7 days later
5	Casual vehicle/ Unknown	Unresponsive	Yes	Yes	Right ventricle	Left pulmonary paranchima	Left anterior thoracotomy	Cardiorraphy	Discharge
6	Casual vehicle/30	Responsive	No	No	Right Atrium	No	Right anterior thoracotomy	Cardiorraphy	Discharge
7	Ambulance/45	Unresponsive	Yes	Yes	Right ventricle	No	Left anterior thoracotomy	Cardiorraphy	Discharge
8	Casual vehicle/ Unknown	Responsive	No	No	Right Atrium	No	Left anterior thoracotomy	Cardiorraphy	Discharge
9	Casual vehicle/35	Responsive	No	No	Right ventricle	No	Left anterior thoracotomy	Cardiorraphy	Discharge
10	Casual vehicle/30	Unresponsive	Yes	Yes	Right ventricle	No	Median sternotomy	Cardiorraphy	Discharge
11	Casual vehicle/35	Unresponsive	Yes	Yes	Right ventricle	Left pulmonary paranchima	Left anterior thoracotomy	Cardiorraphy	Death/infection, 12 days later
12	Casual vehicle/45	Responsive	No	Yes	Left ventricle	D_1	Left anterior thoracotomy	Cardiorraphy, ligation	Discharge
13	Casual vehicle/15	Responsive	No	No	Left ventricle	OM_2	Left anterior thoracotomy	Cardiorraphy, ligation	Discharge
14	Casual vehicle/10	Responsive	No	Yes	Right ventricle	No	Median sternotomy	Cardiorraphy	Discharge
15	Casual vehicle/35	Unresponsive	Yes	No	Right ventricle, left ventricle	LAD	Left anterior thoracotomy	Cardiorraphy, LIMA-LAD	Death/brain death, 20 days later
16	Casual vehicle/35	Responsive	No	No	Right Atrium	No	Median sternotomy	Cardiorraphy	Discharge
17	Casual vehicle/40	Responsive	No	Yes	Right ventricle	No	Median sternotomy	Cardiorraphy	Death/cardiac standstill

*OM_2 indicates second branch of the circumflex artery; D_1, first diagonal branch of the left anterior descending artery; LAD, left anterior descending artery; LIMA, left internal mammarian artery.
†Times are approximate.

Due to the increasing number of traffic accidents, there has been a significant increase in organ injuries. There are no detailed data about the etiology, cure, and mortality rates of penetrating heart injuries. Although the main etiologic cause of penetrating heart injuries is gunshot wounds (44%-71.2%), in the USA stabbing wounds are the most widely encountered causative factor (70%-100%) in developing countries [Asensio 1994; Campbell 1997; Cullford 1989; Goins 1996, Thourani 1999]. In all of our cases, a stabbing wound is the sole causative factor in penetrating heart injuries.

Because of anatomic localization of the right ventricle, the left ventricle and the right atrium are the most involved cardiac chambers in penetrating heart injuries [Beall 1966; Cullford 1989]. Determining a diagnosis and establishing doubt of a heart injury are the first steps for any medical team. In patients with penetrating heart injury, diagnosis it is often made by inspection of the wound and based on the clinical state of the patient. The following are helpful for an exact diagnosis of the patient's condition (including penetrating heart injury) if there is enough time to do so: localization of the wound; hemorrhagie from the skin wound; drawing blood with pericardiocentesis or pleuracentesis; low hemoglobin and hematocrit values; findings in chest x-ray; or echocardiography [Beall 1966; Aaland 1994]. Theoretically, a diagnosis should be made quickly for penetrating heart injuries, priority should be given to control the bleeding, and the decision for diagnostic tests should be made according to the hemodynamic state. This is a very important point for managing patients with cardiac injury. Our 6 cases allowed some time to make a diagnosis, and some interventional diagnostic works were performed before surgery, although 11 patients were transported to the operating room without doing diagnostic work.

Pericardiocentesis can be used for both diagnosis and treatment in heart injuries; not only is it a diagnostic tool, but it also helps provide time for surgical intervention. Removing as little as 30 mL of fluid from the pericardial sac can improve ventricular diastolic filling enough to support the patient's hemodynamic status [Frank 1971; Moreno 1986]. We were able to make the pericardiocentesis for only 3 patients who had good hemodynamic parameters. We want to emphasize another topic we encountered. Although a pericardial incision was found in all patients, classic Beck's triad occurred in only 3 of them. Echocardiography could be performed in 5 hemodynamically stable patients, but increasing pericardial fluid was found only in 3, and there was no trace of fluid in the other 2 patients. This is a very interesting point because the other 2 patients had cardiac wounds, but the pericardial space was empty [Cingoz 2007]. After opening the chests of these 2 patients, we noticed that the pleural space was connected with the pericardial space. Although the pericardial fluid that was shown on the echocardiography is a decisive criteria for diagnosis, we believe that the lack of fluid in the pericardial sac is not an adequate sign to exclude a cardiac injury, and that it should be kept in mind.

Cardiac massage should be performed in every patient with circulatory arrest to keep up the circulation [Boyd 1965]. External cardiac massage may increase the defect size and also increase extravasation of the blood from the intravascular area. In the presence of pericardial fluid, the diastolic filling of the heart is impaired and the external cardiac massage is not effective and does not provide a sufficient cerebral perfusion [Boyd 1965; Frank 1971; Lorenz 1992; Millham 1993]. In these cases, external cardiac massage time should be as short as possible. If the external cardiac massage tends to be prolonged, this means that either there has been an increase in bleeding or the cerebral perfusion is not sufficient. We think that internal cardiac massage would be a better choice, and external cardiac massage should be performed with the intention of saving time to explore the patients surgically. For these reasons, after making a diagnosis, the first thing to do is to prepare the patient for internal cardiac massage, which is of great importance in preserving life. It can provide an effective circulation and partially help control the bleeding. During our initial findings of cardiac injury, external cardiac massage was performed on all patients, and the time that was thought for surgical preparation was too long. However, performing internal cardiac massage is the main goal in our cases after doubting or diagnosing cardiac injury. The other thing we want to emphasize is that only 3 patients had ventricular fibrillation upon their arrival, and 5 more ventricular fibrillations occurred after opening the pericardium. We noticed that patients' hearts were empty due to a large amount of bleeding, and their heartbeats did not provide enough arterial pressure. Under these circumstances, bleeding should stop quickly, and large volume amounts should be given immediately.

A quick and proper surgical approach is of great importance in these emergency conditions [Boyd 1965; Lorenz 1992]. The surgical team should decide quickly the approaching site that will provide an effective field. Thoracotomy is the first choice because it can be made without special surgical tools. Median sternotomy was performed in 5 patients, left anterior thoracotomy was performed in 11 patients, and right anterior thoracotomy was performed in 1 patient. In patients with stable hemodynamic parameters, when considering the wound localization, median sternotomy was the preferred technique to obtain better exposure. In the other patients, left or right thoracotomy was performed according to the wound localization. None of the patients required a second incision. We followed the skin wound, and a surgical incision was made quickly at this point. In most cases, the lateral thoracotomy should be the first selection.

In other literature, the mortality rate of penetrating heart injuries is reported to be 10% to 81% [Buckman 1993; Campbell 1997; Goins 1996]. Reportedly, 78% of deaths occur in the first hour after an injury is sustained, and the prehospital mortality rate is approximately 80% [Buckman 1993; Goins 1996].

In addition to cardiac chamber injuries, the coronary artery, heart valves and neighboring tissue injuries can be seen and they may play a significant role in increasing the mortality rate in penetrating heart injuries [Campbell 1997]. In our study the mortality rate was 29% (5 patients), and coronary artery injury was seen in 4 cases. Ultimately, we lost 2 of the 5 patients (50%). The most important factor affecting mortality rates is the transportation time from the field to the hospital. Transportation time is reported to be 5 to 9 minutes in the USA [Buck-

man 1993; Goins 1996]. Two of our patients were transported by ambulance, and the other 15 patients were brought to the emergency department by nonemergency vehicles. Transportation time ranged from 15 to 45 minutes. Although there were no statistical differences between the occurrence of death, injured chambers, skin incision, coronary trauma, transportation time, and hemodynamic situation, we believe that transportation time is a very important factor in mortality rates. Also, impaired cerebral perfusion due to ineffective cardiac massage and profound blood loss were the reasons for these mortalities.

CONCLUSION

Decreasing mortality rates in patients with penetrating heart injuries should be the first goal of any medical team. For this reason, the patient should be evaluated quickly and time should not be wasted on laboratory tests to determine an exact diagnosis.

A sufficient intravenous line is very important to manage patients' conditions, but it should be kept in mind that if there is a heart wound, bleeding may be profuse; therefore, compensating the blood loss with crystalloid solutions will not be sufficient. Given this very kind of condition, bleeding should be controlled quickly. Spending too much time opening an IV line is unnecessary; fluids can be given after the chest is opened.

Cardiac massage is necessary if cardiac arrest has occurred. However, cerebral perfusion will not be sufficient, otherwise the cardiac wound may increase due to external massage. In cardiac injury, the maximum effort of the medical team should be directed on performing an effective surgical approach; hence, the chest should be opened immediately.

Ultimately, an experienced staff and medical team play a tremendous role in decreasing mortality rates and morbidity rates in patients with penetrating heart injury.

REFERENCES

Aaland MO, Bryan FC 3rd, Sherman R. 1994. Two-dimensional echocardiogram in hemodynamically stable victims of penetrating precordial trauma. Am Surg 60:412-5.

Asensio JA, Roldan G, Petrone P, Forno F, Rowe V, Salim A. 2001. Cardiac trauma. Trauma 3:69-77.

Beall AC Jr, Diethrich EB, Crawford HW, Cooley DA, De Bakey ME. 1966. Surgical management of penetrating cardiac injuries. Am J Surg 112:686-92.

Boyd TF, Strieder JW. 1965. Immediate surgery for traumatic heart disease. J Thorac Cardiovasc Surg 50:305-15.

Buckman RF Jr, Badellino MM, Mauro LH, et al. 1993. Penetrating cardiac wounds: prospective study of factors influencing initial resuscitation. J Trauma 34:717-27.

Campbell NC, Thomson SR, Muckart DJ, Meumann CM, Van Middelkoop I, Botha JB. 1997. Review of 1198 cases of penetrating cardiac trauma. Br J Surg 84:1737-40.

Cingoz F, Bingol H, Kuralay E, Demirkilic U, Tatar H. 2006. Coronary artery revascularization without cardiopulmonary bypass after a cardiac stab wound. Internet Journal of Thoracic and Cardiovascular Surgery 8(1).

Cingoz F, Bingol H, Kuralay E, Tatar H. 2007. A concealed penetrating cardiac injury. J Card Surg 22:350-2.

Cullford AT. 1989. Penetrating cardiac injuries. Hood RM, Boyd AD, Cullitbrd AT, eds. Thoracic Trauma. Philadelphia: WB Sauders; 78-210.

Frank MJ, Nadimi M, Lesniak LJ, Hilmi KI, Levinson GE. 1971. Effects of cardiac tamponade on myocardial performance, blood flow, and metabolism. Am J Physiol 220:179-85.

Goins WA, Ford DH. 1996. The lethality of penetrating cardiac wounds. Am Surg 62:987-93.

Lorenz HP, Steinmetz B, Lieberman J, Schecoter WP, Macho JR. 1992. Emergency thoracotomy: survival correlates with physiologic status. J Trauma 32:780-5.

Moreno C, Moore EE, Majune JA, Hopeman AR. 1986. Pericardial tamponade: a critical determinant for survival following penetrating cardiac wounds. J Trauma 26:821-5.

Millham FH, Grindlinger GA. 1993. Survival determinants in patients undergoing emergency room thoracotomy for penetrating chest injury. J Trauma 34:332-6.

Thourani VH, Feliciano DV, Cooper WA, et al. 1999. Penetrating cardiac trauma at an urban trauma center: a 22-year perspective. Am Surg 65:811-6.