

# Penetrating Cardiac Injuries: Recent Experience in South Africa

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## Abstract

**Background:** Penetrating cardiac injury is a dramatic and lethal form of trauma. The majority of patients will die before reaching medical care, but for those who arrive at hospital alive, the diagnostic acumen and rapid surgical intervention of physicians and surgeons can lead to successful outcomes.

**Materials and Methods:** A structured diagnostic and management approach is used in our trauma unit to deal with penetrating cardiac injury. A retrospective study of 117 patients with penetrating trauma to the heart was conducted over 32 months; the purpose of this study was to describe our protocol and review overall outcome with this type of injury. Demographic details, mechanism of injury, and mode of presentation were recorded. Mortality and morbidity data were collated and echocardiographic follow-up was performed.

**Results:** There were 109 male patients, mean age 29 years (range: 15–54 years) and 8 female patients, mean age 35 years (range: 23–56 years). Most patients (96/117) had sustained stab wounds, and the associated mortality was 15.6%. Twenty-one patients had sustained gunshot wounds (GSW), with a mortality of 81%. Gunshot wounds were significantly more likely to result in death ( $P \leq 0.0001$ ). Five patients sustained multiple cardiac wounds, and three of them died. The risk of death was not different between patients sustaining single or multiple cardiac wounds ( $P = 0.11$ ). Eleven patients had thoracoabdominal injury, and 3/11 (27%) died; all of those that died had sustained GSW. The risk of death was not different between patients sustaining thoracoabdominal wounds and those with isolated thoracic injury ( $P = 1.0$ ). Among the 51 patients with stab wounds who presented with cardiac tamponade, the mortality was only 8%. Compared to the other patients with stab wounds, cardiac tamponade conferred a significant survival advantage ( $P = 0.02$ ).

**Conclusions:** A high index of suspicion for penetrating cardiac injury and an understanding of the modes of presentation can lead to rapid diagnosis even by inexperienced junior staff. Such a structured approach to patients with penetrating trauma to the chest leads to early definitive management and acceptable results.

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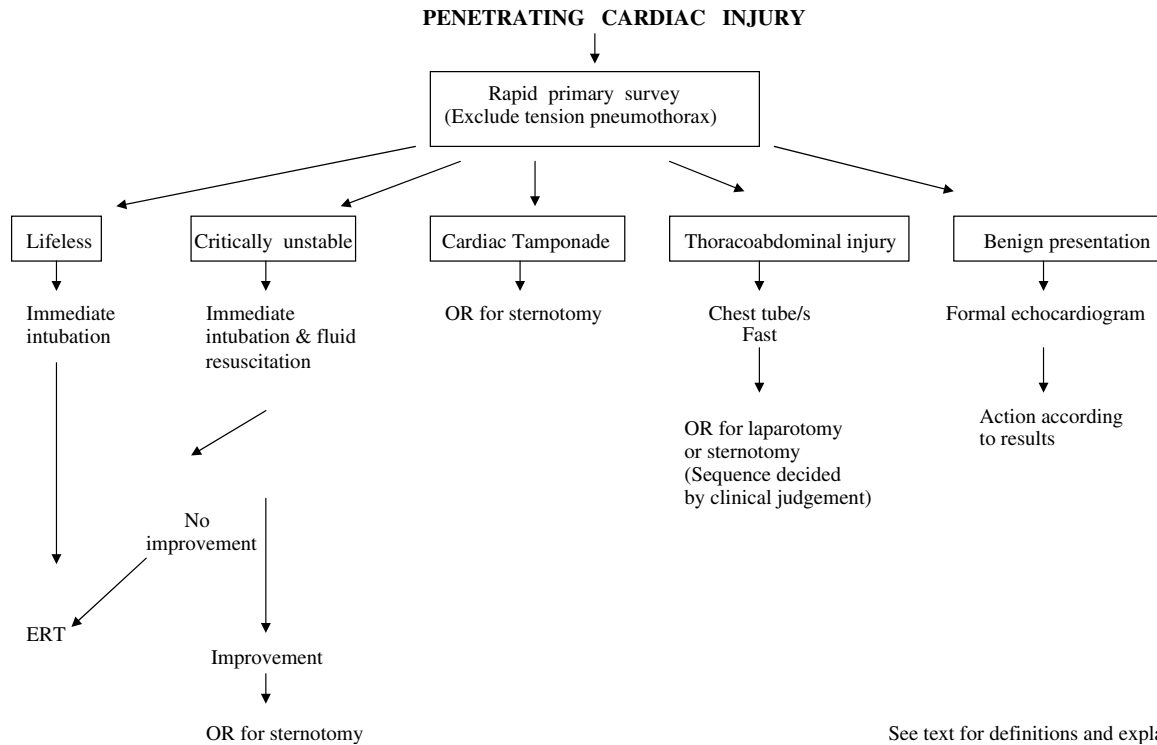
Penetrating trauma to the heart is among the most dramatic and lethal of all injuries. It is an injury commonly encountered in the Republic of South Africa,

and in one review of 1198 cases of penetrating cardiac trauma from the University of Natal Medical School only 6% arrived at the hospital alive.<sup>1</sup> Nevertheless, rapid diagnosis and operation can salvage patients who would otherwise be lost.<sup>2</sup>

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Since the transition to democracy in our country in 1994, there has been a gradual reduction in trauma, and



**Figure 1.** Algorithm of management of penetrating cardiac injury.

therefore we now see rather fewer injuries of this type. In 1994, a study from our institution documented an average of 69 cases of penetrating cardiac injury per year;<sup>2</sup> whereas we now see an average of 39 patients per year with this sort of injury. Contrary to this reduction in penetrating trauma seen in South Africa, other parts of the world, such as Europe, are experiencing increases in the incidence of penetrating trauma.<sup>3</sup>

In 1994, we presented a classification on presentation and preoperative management of penetrating cardiac injuries in an attempt to facilitate diagnosis and initial management by our staff.<sup>4</sup> The purpose of the present study was to describe our protocol and to review our overall outcome with this type of injury.

### MATERIALS AND METHODS

We retrospectively reviewed the files of 117 patients with a preoperative diagnosis of penetrating heart trauma that underwent operation at Chris Hani Baragwanath Hospital during the 2-year, 8-month period, January 1, 2002 to August 31, 2004. The beginning of the study was determined by the creation of a Trauma Directorate, the purpose of which was trauma auditing and improved trauma outcomes.

This hospital, with 3200 beds, is the largest teaching hospital of the University of the Witwatersrand and covers Soweto, Johannesburg. The Trauma Unit admits poly-trauma patients as well as patients with neck, trunk, and vascular injury. The Trauma Faculty comprises four full-time general surgeons; there are 10 medical officers or registrars and 10 house officers. Patients were resuscitated according to the ATLS (Advanced Trauma Life Support) principles, and all operations were undertaken by faculty or staff with adequate experience in trauma. Statistical analysis was by the Fisher exact test (Graphpad Software, San Diego, CA).

On arrival in the resuscitation room, patients were stratified into five groups and managed according to an algorithm (Fig. 1). These groups are designated lifeless, critically unstable, cardiac tamponade, thoracoabdominal injury, and benign presentation.

Lifeless patients are unconscious on presentation with no clinically detectable signs of life. Electrocardiography may show the presence of occasional QRS complexes or may be grossly abnormal. Emergency Room Thoracotomy (ERT) is not indicated for lifeless patients if vital signs have been absent for longer than 5 minutes before arrival to the ER if not intubated or 10 minutes if intubated.<sup>5</sup> When correctly instituted, ERT can yield a survivor after cardiac injury in up to 20% of instances.<sup>6</sup>

Critically unstable patients show signs of life but are profoundly hypotensive, and cardiac arrest appears to be imminent. At the time of the study, in our hospital, the distance between the resuscitation room and the operating room (OR) was less than 20 m. We never practice needle pericardiocentesis in patients with suspected penetrating cardiac trauma in our hospital, as we believe false negative results are relatively common. Occasionally computed tomography (CT) can be very helpful in delineating the trajectory of a transthoracic missile.<sup>7</sup>

Patients with cardiac tamponade show a variable degree of hypotension, raised Central Venous Pressure (CVP), and sometimes muffled cardiac sounds. A high degree of suspicion, based on the location of the thoracic wound in conjunction with these signs is sufficient to suggest a diagnosis of penetrating cardiac injury. Patients with cardiac tamponade may be agitated and unwilling to lie supine.<sup>8</sup> The absence of hyper-resonance of a hemithorax and tracheal deviation rules out tension pneumothorax. FAST (Focused Abdominal Sonogram for Trauma) ultrasound can rapidly diagnose the presence of pericardial blood with high levels of accuracy in skilled hands.<sup>9,10</sup>

Patients with thoracoabdominal injury may have sustained a single penetrating injury that has caused damage on both sides of the diaphragm or multiple, separate thoracic and abdominal injuries. A diagnosis of cardiac tamponade may be masked by the presence hemorrhage in the peritoneal cavity. An accurate preoperative diagnosis is often difficult; the clinician must then exercise judgement in deciding which lesion to address first. Chest tube output and clinical signs in the abdomen or of cardiac tamponade give clues as to which cavity is the site of the most life-threatening pathology.

Penetrating cardiac injury may present without symptoms or clinical signs of either cardiac tamponade or intrathoracic hemorrhage. Small myocardial wounds may stop bleeding, after which the patient responds to resuscitation, making the assessment of a stable patient difficult. Occult cardiac injuries also occur, and FAST ultrasound may occasionally be falsely negative<sup>11</sup>; a high index of suspicion is required, and in such cases we obtain a formal echocardiogram by a cardiologist or other similarly competent practitioner. Placement of a central line can be helpful as the finding of a raised central venous pressure is suspicious for cardiac injury. We never use pericardiocentesis, and we occasionally find the subxiphoid window to be helpful in establishing the diagnosis.

Patients with injury to intrapericardial great vessels were included in this study because preoperative differentiation of these injuries is impossible on clinical grounds

or diagnostic investigations. Standard techniques for repair of penetrating trauma to the heart were used and have been described in detail elsewhere.<sup>12</sup> Some of our staff favor the use of staples rather than sutures to repair simple cardiac lacerations because the results are good and the risk of needlestick is perceived to be less.<sup>13,14</sup> A needlestick is a concern in an environment of high prevalence of viral threats to medical staff.<sup>15</sup> Formal cardiac bypass was not used, due to resource challenges; although we recognize its utility.<sup>16,17</sup>

All our patients had a 2-dimensional echocardiogram before discharge and at follow-up 1 and 3 months after discharge.

## RESULTS

There were 109 male patients, mean age 29 years (range: 15–54 years) and 8 female patients, mean age 35 years (range: 23–56 years). Seventy-five percent of the patients were admitted on weekends, and 90% were admitted between 19:00 hours and 02:00 hours. Ninety-six patients had sustained stab wounds and 21 patients had gunshot wounds (GSW). Of the patients with single stab wounds, notation of the site of the wound in the hospital record was accurate in 59: of these injuries, 27 (46%) were in the precordium and 32 elsewhere in the chest. The mortality rate among patients with precordial stab wounds was 1/27 (4%), and that among patients with extra-precordial stab wounds was 8/32 (25%); this difference is statistically significant ( $P = 0.03$ )

Of the GSW, 12 wounds were of the precordium and 9 were elsewhere in the chest. Tables 1 and 2 demonstrate the number of patients who sustained stab and gunshot wounds, their classification, the operative approach, and associated mortality. Eleven patients presented in a lifeless condition and underwent ERT. All of these patients had an exsanguinating pattern of injury; three survived (27%), all of whom had sustained stab wounds.

Of the five patients who had multiple injuries to the heart, one had a through-and-through GSW to the right atrium, right ventricle, and abdomen. Of the other four, all of whom had stab wounds, three had through-and-through wounds to right atrium and ventricle and one patient had a through and through injury to the left ventricle. A single patient with the multiple cardiac GSW and two of four patients with multiple cardiac stab wounds died perioperatively. The risk of death was not different between patients sustaining single or multiple cardiac wounds ( $P = 0.11$ ).

**Table 1.**  
Mode of presentation in patients with stab wounds

| Mode of presentation | Operative approach | Number of patients | Mortality   | Overall mortality (%) |
|----------------------|--------------------|--------------------|-------------|-----------------------|
| Lifeless             | ERT                | 7                  | 4/7 (57%)   | 57                    |
| Critically unstable  | Sternotomy         | 23                 | 8/23 (35%)  | 35.5                  |
|                      | Thoracotomy        | 8                  | 3/8 (37.5%) |                       |
| Cardiac tamponade    | Sternotomy         | 47                 | 2/47 (4.3%) | 8                     |
|                      | Thoracotomy        | 4                  | 2/4 (50%)   |                       |
| Thoracoabdominal     | Sternotomy         | 5                  | 0/5 (0%)    | 0                     |
|                      | Thoracotomy        | 1                  | 0/1 (0%)    |                       |
| Benign               | Sternotomy         | 1                  | 0/1 (0%)    | 0                     |
| Total                |                    | 96                 | 19/96       | 19.8                  |

**Table 2.**  
Mode of presentation in patients with gunshot wounds

| Mode of presentation | Operative approach | Number of patients | Mortality  | Overall mortality (%) |
|----------------------|--------------------|--------------------|------------|-----------------------|
| Lifeless             | ERT                | 4                  | 4/4 (100%) | 100                   |
| Critically unstable  | Sternotomy         | 8                  | 6/8 (75%)  | 82                    |
|                      | Thoracotomy        | 3                  | 3/3 (100%) |                       |
| Cardiac tamponade    | Sternotomy         | 1                  | 1/1 (100%) | 100                   |
|                      | Thoracotomy        | 0                  |            |                       |
| Thoracoabdominal     | Sternotomy         | 5                  | 3/5 (60%)  | 60                    |
|                      | Thoracotomy        | 0                  |            |                       |
| Benign               |                    | 0                  |            | 0                     |
| Total                |                    | 21                 | 17 /21     | 81.5                  |

ERT: Emergency Room thoracotomy.

Of the four patients with intrapericardial aortic injury, one was critically unstable upon arrival at the hospital and died in the operating room. Three others presented with pericardial tamponade, and one died; of the two patients with intrapericardial superior vena cava injury one was critically unstable on arrival, and one had cardiac tamponade; both died. Of the seven patients with intrapericardial pulmonary artery injury, one was critically unstable and died, the other six presented with cardiac tamponade and all survived.

Eleven patients had concomitant laparotomy. Laparotomy was done first in eight cases. The most common intra-abdominal injuries were to the liver and diaphragm; injuries were also found to small bowel, pancreas, kidney, spleen, and stomach. The operative approach in the chest was by sternotomy in 10 cases and by thoracotomy in one case. There was no statistically significant difference in the risk of death between patients with or without abdominal injury ( $P = 1.0$ ).

Mortality for patients with stab wounds was 19/96 (19.8%), compared to 17/21 (81%) for patients with GSW ( $P \leq 0.0001$ ). Overall, 81 patients (69%) survived, and 17 of them sustained major complications, 3 with pneumonia, 1 with respiratory failure, 3 with retained hemo-

thorax requiring formal thoracic decortication, 7 with mild pericardial effusion, and 1 each with cardiac failure, apex thrombosis, and mitral valve regurgitation.

Of the 36 patients who died, 24 died in the ER or during the course of operation (66.6%), 12 died within 24 hours of admission, and another died of multiple organ failure 5 days post-injury.

Of the 51 patients with stab wounds who presented with cardiac tamponade, the mortality was only 8%. Compared to the other patients with stab wounds, cardiac tamponade conferred a significant survival advantage ( $P = 0.02$ ). In patients who survived isolated heart injury, the mean duration of hospitalization was 6 days (range: 4–15 days). Most patients in the study were initially seen by relatively junior medical staff who, following the management classification, immediately initiated appropriate management and alerted the senior staff. Once the patient had been classified and resuscitation and/or diagnostic procedures were initiated, no patients deteriorated sufficiently physiologically in the resuscitation room to require an ERT.

Postoperative echocardiograms were obtained prior to discharge, and one patient was found to have a hemodynamically insignificant mitral valve lesion. Echocardi-

ography was repeated at the 1-month and 3-month outpatient follow up examinations. and no further intracardiac defects were identified; compliance with follow-up was 71% at 1 month and 28% at 3 months.

## DISCUSSION

Chris Hani Baragwanath Hospital may still be the busiest trauma center in the world, with an average of 140 non-orthopedic trauma admissions per week. The distribution of admissions is skewed, with the majority presenting on weekends. As a result, it is common for the senior trauma unit staff to be operating in several operating rooms simultaneously, and for the junior staff to be running the resuscitation room without direct senior supervision. By applying the protocol for penetrating cardiac injuries, our junior staff have been able to identify patients with possible cardiac injury and start appropriate resuscitation and/or investigation while alerting senior staff to the need for urgent assessment. For the period of the study, we believe we have identified every patient with a penetrating injury to the heart, and there was only one negative exploration of the chest. The efficiency of our system is such that there are minimal delays, and therefore no patient deteriorated during transfer from the resuscitation room to the operating room. We believe this to be in direct contrast to previous years, when diagnosis was delayed in a significant number of cardiac injuries per year, leading to unsuccessful emergency department thoracotomies or late transfer to the operating room accompanied by significant physiological deterioration and the expected adverse results.

In this study, mortality for GSW was significantly higher than for stab injuries. We know that in South Africa < 10% of patients with penetrating cardiac injury are likely to arrive at hospital alive,<sup>1</sup> and we believe that there is likely to be an excess of GSW deaths pre-hospital; the overall ratio of stab to GSW wounds presenting at our hospital is 2:1, however, the ratio of patients with penetrating cardiac injury arriving at the hospital alive is approximately 5:1.

In this study, as in others,<sup>18</sup> patients were more likely to survive if they presented with cardiac tamponade than without. This apparent protective effect of tamponade is not present in every study,<sup>19</sup> and it is suggested that although tamponade may protect the individual from exsanguination, this effect is limited and time-dependent.

Sixty-five percent of GSW patients were critically unstable at presentation, compared to 35% of those with stab wounds; however, the mortality rate of the critically

unstable GSW patients was 82% compared to a 35.5% mortality rate for similarly classified patients with stab wounds. Only five patients sustained through-and-through cardiac injury, one of which was a GSW; therefore the higher mortality in GSW cannot be attributed to this mechanism of injury. The striking difference in mortality between GSW and stab wounds is likely to be due to the greater tissue damage from the GSW, a greater degree of exsanguination plus the existence of a degree of myocardial contusion.

Despite our high index of suspicion for cardiac injury, we have shown that when cardiac injury occurs from a stab wound located outside the precordium, the patient is more likely to die than after a precordial stab. We believe this is because the attending doctors are less likely to consider the possibility of cardiac injury when the initial wound is not in the precordium with consequent delay to surgery. Stab wound patients who presented with cardiac tamponade had only 8% mortality.

The operative approach in this series was by median sternotomy except when there was suspicion of severe coexisting thoracic extracardiac injury or the operation had to be expedited (in certain cases of the critically unstable group). Other centers advocate routine use of thoracotomy for knife injuries to the heart<sup>20</sup>; however, it is our experience that thoracotomy exposure usually needs to be extended across the sternum (especially for injuries to the right of the heart), sternotomy also facilitates lifting the heart for repair of posterior injuries and is the best approach if injuries to mediastinal vessels are encountered. It is our experience that patients recover better after a sternotomy compared to a thoracotomy. Sternotomy is a very fast approach to the heart, once the technique has been practiced.<sup>21</sup> There is always concern about pericardial contamination in the presence of bowel injury. This is managed by copious peritoneal lavage before performing the sternotomy. The sternotomy itself is always started from the manubrium, and special attention is paid to avoid entering the peritoneal cavity at the xiphoid end. In all cases but one this was successful in our series, giving good access to the pericardial sac. There were no intrathoracic complications directly related to bowel injury. This was probably not due only to the above technical precautions but also to the fact that all these patients were taken to the operating room soon after arrival at the hospital.

Mortality in our group of patients who had a laparotomy to address thoracoabdominal injury was 27%, which appears to be better than the results achieved by Asensio and co-workers in their recent series where they report a mortality of 59% for such injuries.<sup>22</sup> However, their series

had a higher proportion of GSW than ours (73% versus 45%), and this probably explains the apparent difference; the mortality of thoracoabdominal GSW in our series being 60%). The decision about which side of the diaphragm to address first is a difficult one. We try to address the “cavity of major blood loss” first, but we always prepare ourselves to change tack if the operative findings do not account for the patient’s condition.<sup>23</sup>

Follow-up is notoriously difficult in major trauma patients, and in our population this is compounded by the difficult socioeconomic circumstances that our patients often have to endure. We therefore cannot comment on the evolution of potential valvular or septal injury. In our 78 survivors, only one was discovered to have a valvular lesion at time of discharge. No further lesions were discovered at echocardiology review; however, our follow-up is poor and other workers have identified a valvular or septal lesion rate of up to 19% during a mean follow-up of 23 months post-injury, albeit that the majority of these lesions were found not to be hemodynamically significant.<sup>24</sup> Nevertheless, in agreement with other centers,<sup>25</sup> we recommend close follow-up of these patients when possible.

As the incidence of penetrating trauma increases in previously “immune” parts of the world, it is mandatory for surgeons to be prepared to tackle penetrating injury to the heart immediately, as delay is likely to lead to adverse outcomes. The two most common modes of presentation of cardiac injury are cardiac tamponade and excessive hemorrhage, depending on the size of the wound in the pericardium.<sup>26</sup> Armed with knowledge of the modes of presentation of these injuries and a high index of suspicion and a management protocol, rapid diagnosis can be made even by inexperienced junior staff. Such a structured approach to patients will enable early definitive management and acceptable results.

## ACKNOWLEDGMENTS

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## REFERENCES

- Campbell NC, Thomson SR, Muckart DJ, *et al.* Review of 1198 cases of penetrating cardiac trauma. *Br J Surg* 1997;84:1737–1740.
- Velmahos GC, Degiannis E, Souter I, *et al.* Penetrating trauma to the heart: a relatively innocent injury. *Surgery* 1994;115:694–697.
- Krug EG, Mercy JA, Dahlberg LL, *et al.* The world report on violence and health. *Lancet* 2002;360:1083–1088.
- Saadia R, Levy RD, Degiannis E, *et al.* Penetrating cardiac injuries: clinical classification and management strategy. *Br J Surg* 1994;81:1572–1575.
- Velmahos GC, Degiannis E, Souter I, *et al.* Outcome of a strict policy on emergency department thoracotomies. *Arch Surg* 1995;130:774–747.
- Rhee PM, Acosta J, Bridgeman A, *et al.* Survival after emergency department thoracotomy: review of published data from the past 25 years. *J Am Coll Surg* 2000;190:288–298.
- Hanpeter DE, Demetriades D, Asensio JA, *et al.* Helical computed tomographic scan in the evaluation of mediastinal gunshot wounds. *J Trauma* 2000;49:689–694.
- Porter JM, Ivatury RR. Unwillingness to lie supine? a sign of pericardial tamponade. *Am Surg* 1997;63:365–366.
- Rozycki GS, Feliciano DV, Ochsner MG, *et al.* The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multicenter study. *J Trauma* 1999;46:543–551.
- Rozycki GS, Ballard RB, Feliciano DV, *et al.* Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. *Ann Surg* 1998;228:557–567.
- Harris DG, Papagiannopoulos KA, Pretorius J, *et al.* Current evaluation of cardiac stab wounds. *Ann Thorac Surg* 1999;68:2119–2122.
- Degiannis E, Bowley DM, Westaby S. Management of penetrating cardiac injury. *Ann R Coll Surg Engl* 2005.
- Macho JR, Markison RE, Schechter WP. Cardiac stapling in the management of penetrating injuries of the heart: rapid control of hemorrhage and decreased risk of personal contamination. *J Trauma* 1993;34:711–715.
- Mayrose J, Jehle DV, Moscati R, *et al.* Comparison of staples versus sutures in the repair of penetrating cardiac wounds. *J Trauma* 1999;46:441–443.
- Bowley DM, Cherry R, Snyman T, *et al.* Seroprevalence of the human immunodeficiency virus in major trauma patients in Johannesburg. *S Afr Med J* 2002;92:792–793.
- Wall MJ Jr, Mattox KL, Chen CD, *et al.* Acute management of complex cardiac injuries. *J Trauma* 1997;42:905–912.
- Baker JM, Battistella FD, Kraut E, *et al.* Use of cardiopulmonary bypass to salvage patients with multiple-chamber heart wounds. *Arch Surg* 1998;133:855–860.
- Moreno C, Moore EE, Majure JA, *et al.* Pericardial tamponade: a critical determinant for survival following penetrating cardiac wounds. *J Trauma* 1986;26:821–825.
- Asensio JA, Murray J, Demetriades D, *et al.* Penetrating cardiac injuries: a prospective study of variables predicting outcomes. *J Am Coll Surg* 1998;186:24–34.
- Gao J, Gao YH, Wei GB. Penetrating cardiac wounds: principles for surgical management. *World J Surg* 2004;28:1025–1029.

21. Mitchell ME, Muakkassa FF, Poole GV, *et al.* Surgical approach of choice for penetrating cardiac wounds. *J Trauma* 1993;34:17–20.
22. Asensio JA, Arroyo H Jr, Veloz W. Penetrating thoracoabdominal injuries: ongoing dilemma-which cavity and when? *World J Surg* 2002;26:539–543.
23. Hirshberg A, Wall MJ Jr, Allen MK, *et al.* Double jeopardy: thoracoabdominal injuries requiring surgical intervention in both chest and abdomen. *J Trauma* 1995;39:225–229.
24. Demetriades D, Charalambides D, Sareli P, *et al.* Late sequelae of penetrating cardiac injuries. *Br J Surg* 1990;77:813–814.
25. Asensio JA, Murray J, Demetriades D, *et al.* Penetrating cardiac injuries. *Surg Clin North Am* 1996;76:685–724.
26. Kulshrestha P, Das B, Iyer KS, *et al.* Cardiac injuries—a clinical and autopsy profile. *J Trauma* 1990;30:203–207.