

Penetrating Cardiac Wounds:

A Comparison of Different Therapeutic Methods

P. N. SYMBAS, M.D., N. HARLAFTIS, M.D., W. J. WALDO, M.D.

The management of penetrating wounds of the heart has been controversial. During the last 10 years we have used 3 different therapeutic approaches for the treatment of these wounds and the obtained results comprise this report. From 1964 to 1974 we treated 102 patients, four of whom expired immediately after their arrival to the clinic. The remaining 98 patients were divided into five groups according to their clinical presentation and treatment. Group I, 17 patients (14 with stab and 3 with bullet wound) seen with cardiac tamponade from 1964 to 1967 were treated first with pericardiocentesis and then were operated upon if pericardiocentesis yielded no results or if cardiac tamponade recurred. Fourteen patients recovered and three died, with an overall mortality of 17.5%. Group II, 34 patients (23 with stab and 11 with bullet wound) were seen with cardiac tamponade from 1968 to 1971. The patients with stab wound were managed the same as group I patients and those with bullet wound were operated upon immediately. Twenty-nine recovered and 5 died, with an overall mortality of 14.7%. Group III, 20 patients (12 with stab and 8 with bullet wound) were seen with cardiac tamponade from 1972 to 1974. All of them were operated upon immediately and pericardiocentesis was used in this group only to provide time for a safe operation. Nineteen recovered and one died, with an overall mortality of 5%. Group IV, 20 patients (5 with stab and 15 with bullet wound) with massive bleeding, were operated upon immediately. Ten (4 out of the 5 with stab and 6 out of the 15 with bullet wound) recovered, with a mortality rate of 50%. Group V, seven patients were seen throughout the study period without bleeding or cardiac tamponade. Some of them were operated upon electively and others are being followed and all have done well. This study suggests (1) that patients with penetrating wound of the heart and cardiac tamponade or bleeding will derive better results if they are operated upon as soon as possible and if pericardiocentesis is used to provide time for a safe operation and (2) that those with other manifestations should be evaluated and if their lesion is significant, they should be operated upon electively.

IN THE PAST there has been considerable controversy regarding the management of penetrating cardiac

*From the Joseph B. Whitehead Department of Surgery,
Thoracic and Cardiovascular Surgery Division,
Emory University School of Medicine
and Grady Memorial Hospital, Atlanta, Georgia*

wounds.^{1,3,6,7,11,14,16} During the last 10 years we have used 3 different therapeutic approaches for the management of these wounds. The cases seen during this period at our institution were reviewed and the obtained results comprise the basis for this report.

Material

Between January 1964 and December 1974, 102 patients, 88 males and 14 females with the age ranging from 15 to 63 (mean 33.5) with penetrating wound of the heart were diagnosed and managed at Grady Memorial Hospital. Four patients, two with stab and two with gunshot wounds, expired immediately after their arrival in the emergency clinic. The remaining 98 patients, 54 with stab and 44 with gunshot wounds, who are the subject of this report, were divided according to their clinical presentation and treatment into 5 groups (Table I).

Group I is comprised of 17 patients (14 with stab and 3 with gunshot wound) who were seen with cardiac tamponade from 1964 through 1967 and were treated first with pericardiocentesis. In 4 patients (3 with stab wound and one with gunshot wound) the pericardiocentesis yielded no improvement and they were operated upon. One of them with a stab wound did well and 3 (two with stab wound and one with gunshot wound) died. Two of the death occurred in the operating room (one from cardiac arrest and one from intra-abdominal injuries) and one on the day of operation from pulmonary insufficiency. The remaining 13 patients (11 with stab and 2 with gunshot wound) improved clinically after the first pericardiocentesis and 10 went on to recover but in 3 (2 with stab and one with gunshot wound) cardiac

Submitted for publication September 26, 1975.

Correspondence: Dr. P. N. Symbas, 69 Butler Street, S.E., Atlanta, Georgia 30303.

TABLE 1. Patients with Penetrating Cardiac Wounds

Groups	Stab Wound	Bullet Wound
I	14	3
II	23	11
III	12	8
IV	5	15
V	—	7
Total	54	44

tamponade recurred and they were operated upon after a second pericardiocentesis. All 13 patients did well. From the 17 patients of this group treated initially with pericardiocentesis, 10 recovered from their injury after the first pericardiocentesis and from the remaining 7 patients who were operated upon, 4 did well and 3 died (overall mortality in this group, 17.6%) (Table 2).

Group II is formed of 34 patients (23 with stab and 11 with gunshot wound) seen with cardiac tamponade from 1968 through 1971. The patients with stab wound were managed in a similar manner as group I patients whereas those with gunshot wound were operated upon as soon as possible after the first pericardiocentesis, invariably whether they did or did not derive improvement from it. Of the 23 patients with stab wound, 9 yielded no clinical benefit from pericardiocentesis and were operated upon immediately. Eight of the 9 recovered and one died from cardiac arrest on the first postoperative day. The remaining 14 patients improved after the first pericardiocentesis and two of them went on to recover but 12 had recurrence of cardiac tamponade and were operated upon after a second pericardiocentesis. Ten of the 12 recovered from their injury and 2 had cardiac arrest in the operating room and died (Table 3). Nine of the 11 patients with gunshot wound recovered from their injury. The overall mortality in this group was 14.7%.

Group III is composed of 20 patients (12 with stab wound and 8 with gunshot wound) with cardiac tamponade who were seen from 1972 through 1974. All of them except one were operated upon as soon as possible. Pericardiocentesis was used in this group only to provide time to transfer the patients safely to the operating room. Eleven of the 12 patients with stab wound recovered from their injury and one died 45 days after surgery from intra-abdominal problems not related to the injury, whereas all 8 patients with gunshot wound did well. The only patient in this group who was not operated upon had a stab wound with cardiac tamponade and he improved after the first pericardiocentesis. Because of his clinical improvement and of other emergency cases, his thoracotomy was delayed. He continued to do well and recovered from the injury without surgery. The overall mortality in this group was 5%.

Group IV is formed of 20 patients (5 with stab and 15

with gunshot wound) who were seen throughout the period of this study and who had predominantly massive or unrelenting intrathoracic bleeding. All of them were operated upon immediately, 10 (4 out of 5 with stab wound and 6 out of 15 with gunshot wound) recovered from their injury, with a mortality rate of 20% for the patients with stab wound, and 60% for the gunshot wounds, and an overall mortality for this group of 50%. The causes of death in the remaining 10 patients are cardiac arrest in the operating room in 5, postoperative pulmonary insufficiency in one, sepsis in two, stress ulcer in one, and renal failure in one patient.

Group V is composed of seven patients (all with gunshot wounds) who again were seen throughout all the study period and who presented with the following problems but no evidence of cardiac tamponade and no massive or unrelenting bleeding: one had a bullet lodged in the left ventricle; one in the interventricular septum; two had a bullet in the pericardial cavity; one had a bullet embolized into the right pulmonary artery; and one had biventricular traumatic aneurysm and interventricular traumatic septal defect. All these patients were operated upon electively and did well. Another patient with a through-and-through injury of the left ventricle and intra-abdominal injuries had an exploratory laparotomy and thoracotomy and did well. The only death in this group was secondary to complications from intra-abdominal disease not related to the injury.

Of the 76 patients in whom the site of injury found at operation was recorded, the right ventricle alone was injured in 27 (35.4%) patients [in 24 (31.5%) from stab and in 3 (3.9%) from bullet wound], the left ventricle alone in 18 (23.6%) [in 7 (9.2%) from stab and in 11 (14.4%) from bullet wound], the right atrium alone in 7 (9.1%) [in 4 (5.2%) from stab and in 3 (3.9%) from bullet wound], and the left atrium alone in 2 (2.6%) from bullet wound (Table 4).

More than one cardiac wound was found in 22 (28.9%) patients, 4 with stab and 18 with bullet wound (Table 5). Two patients had stab wound of the right ventricle, one through and through and in one the entry of the wound was

TABLE 2. Results of Treatment in Group I Patients*

Treatment	Stab Wound		Bullet Wound	
	Survived	Deceased	Survived	Deceased
Pericardiocentesis	9	0	1	0
Surgery after pericardiocentesis and recurrence of cardiac tamponade	2	0	1	0
Surgery after negative pericardiocentesis	1	2	0	1
Total	12	2	2	1

* Overall mortality 17.6%.

TABLE 3. Results of Treatment in Group II Patients with Stab Wound*

Treatment	Total	Survived
Pericardiocentesis alone	2	2
Surgery after pericardiocentesis and recurrence of cardiac tamponade	12	10
Surgery after negative pericardiocentesis	9	8

* Overall mortality 13.04%.

on the right ventricle and the exit on the left ventricle. Two patients had stab wound of the left ventricle, one through and through and in one the exit wound was on the right ventricle. Eight patients had gunshot wounds of the right ventricle. Three of them had a through-and-through wound; one also had a wound of the left ventricle from a second bullet; one had a second wound of the right atrium; in one the bullet exited through the left ventricle; in one the bullet exited through the left ventricle and this patient had, in addition, a through-and-through wound of the left atrial appendage from a second bullet, and one had an intraventricular septal defect. Eight patients had gunshot wounds of the left ventricle. Six of them had a through-and-through wound. In one patient the bullet exited through the right ventricle, and in another, the bullet lodged in the intraventricular septum. Two patients had gunshot wound of the right atrium, one through and through; and one had, in addition, wounds in both the right and left ventricles and in the left atrium.

From the 80 patients, 32 with gunshot wound and 48 with stab wound, who recovered from their initial trauma, 16 had residual or delayed sequelae from their injury, 5 had retained a projectile in the heart or pericardium, 3 had ventricular septal defect, two a mitral and one a pulmonary valve regurgitation, one had aorticopulmonary shunt, 5 a ventricular aneurysm (one had both ventricular septal defect and biventricular aneurysm).

Of the patients with residual sequelae, 11 were operated upon and have done well. The remaining 5 patients (one with retained projectile in the left ventricular wall, one with ventricular septal defect, two with mitral regurgitation, and one with ventricular aneurysm) are followed and have had no difficulty related to their lesion.

Discussion

Penetrating wounds of the heart are one of the major causes of morbidity and mortality in our society.^{2,5,12,20} Although in the past, the majority of civilian penetrating wounds were the result of stabbing,^{10,12,21,22} during the last few years gunshot wounds have increased significantly. This may be due to the more frequent use of guns rather than knives as weapons and perhaps to the more speedy transportation of the patient from the scene of injury to the medical facilities.

With the increase of the incidence of bullet wounds,

TABLE 4. Sites of the Single 54 Penetrating Wounds of the Heart

Wound	RV	LV	RA	LA
Stab	24	7	4	0
Bullet	3	11	3	2

although the relative frequency of penetrating wounds to the various cardiac structures still coincides with their relative area of exposure to the anterior chest wall¹³ (in order of decreasing frequency being the right ventricle, left ventricle, right atrium and left atrium) multiple cardiac structures are injured more often. Twenty-two or 28.9% of our patients had more than one cardiac structure injured, 18 of them being from a bullet wound.

The clinical manifestations of the cardiac wounds depend upon the mode, site, and size of injury and the state of the pericardial wound.¹⁷ In cases in which the wound of the pericardium remains open and allows free drainage of the pericardial blood, the cardiac wound manifests with symptoms and signs of hemorrhage and hemothorax, whereas when the pericardial wound is obliterated with blood clot or adjacent structures, the escaping blood from the cardiac chamber cannot drain into the pleural space and cardiac tamponade ensues. Seventy-one of our patients showed clinical manifestations of cardiac tamponade, 20 had massive or unrelenting bleeding, and 7 had no tamponade or bleeding but showed other manifestations.

Bullet wounds of the heart appear to present more frequently with bleeding. Thirty-four per cent of our patients with bullet wound and 9.4% with stab wounds had this clinical picture.

Penetrating wound of the heart should be suspected in any patient with penetrating wound of the chest, upper abdomen or neck and particularly of the precordium. The diagnosis of such injury in patients presenting with hemothorax is made at exploratory thoracotomy.

Agitation, lack of cooperation, air hunger, cool and clammy skin, neck vein distention, Kussmaul's sign, paradoxical pulse, muffled heart sounds, and elevated

TABLE 5. Sites of Multiple Cardiac Wounds

Sites	No. of Wounded Patients	
	from Bullet	from Knife
LV through and through	6	1
RV through and through	3	1
LV and RV	3	2
RV and RA	1	
RV with VSD	1	
RA through and through	1	
LV and VS	1	
LV and RV through and through	1	
LV, RV, LA and RA	1	
Total	18	4

central venous pressure in patients with penetrating wounds of the precordium, neck, chest and upper abdomen strongly suggest penetrating injury to the heart with tamponade. Although with these clinical findings, cardiac tamponade is relatively easy to diagnose, it may not be so in certain clinical settings. When ethanol intoxication, for example, is present, it may produce many of the signs of tamponade, particularly the neurological manifestations. Such patients should be thoroughly examined and cardiac tamponade excluded before the agitation and the lack of cooperation, etc., are attributed to the intoxication. In patients with hemothorax and cardiac tamponade, the clinical picture may be attributed to just blood loss when volume expansion markedly improves the hemodynamic parameters. In such patients however, cardiac tamponade should be strongly suspected and searched for since volume expansion, which increases the filling pressure, will result in clinical improvement of patients with hemothorax and tamponade or tamponade alone.^{8,9} Neck vein distention and/or a central venous pressure of 12 cm saline or greater, in such instances, strongly suggest cardiac tamponade rather than hypotension due to blood loss, although these signs may be misleading, particularly when other conditions which may produce elevation of the central venous pressure are present.

Roentgenographic studies are of limited value for the diagnosis of a penetrating wound of the heart.

Fluoroscopy of the chest, showing decreased cardiac motion, is of slight value in diagnosing acute traumatic cardiac tamponade, and chest roentgenography, which has almost no value in the diagnosis; they should be used only for diagnosing injury to other organs. Either of these procedures may be performed only under close observation and in stable patients.

Thus, when signs of cardiac tamponade are present in a patient with an external wound that might result in cardiac perforation, pericardiocentesis should be performed at once. If nonclotting blood is obtained, the diagnosis is established and the decompression of the pericardial sac provides the initial effective treatment of the injury.

The pericardiocentesis should be done with a thin-wall metal needle or preferably a plastic #17 or #18 gauge catheter or needle through the left substernal paraxiphoid route. When a metal needle is used, the pericardiocentesis should be done preferably under constant electrocardiographic monitoring, if monitoring will not result in the delay of the pericardiocentesis. If a plastic catheter or needle is used for the pericardiocentesis, it should be left in place for continuous drainage of the intrapericardial blood until the cardiac wound is surgically repaired.

After the introduction of cardiorrhaphy, the management of the cardiac wounds manifesting with massive or unrelenting blood loss has been well established. The definitive treatment, however, of the cardiac wounds

presenting with cardiac tamponade, has varied. Multiple pericardiocenteses alone or multiple pericardiocenteses with surgery, or surgery as soon as possible have been used with various results.^{1,2,6,7,11,14,16} Our study is a retrospective one and various modes of therapy have been used during different chronological periods, thus the better results obtained in the recent years could be due to the overall improvement in the management of injured patients. Still, it strongly suggests that the treatment of choice for penetrating wounds of the heart is surgery as soon as possible and that pericardiocentesis should be used only to provide safe time for surgery. This is because the longevity of an initial favorable response to pericardiocentesis is unpredictable and when tamponade recurs, the patient's downhill course may be rapid. Also, the advancement in the fields of resuscitation, anesthesia, and cardiac surgery have made surgical intervention safe.

In addition, the progressive improvement of transportation has and will result in prompt arrival of the more severe cardiac wounds which can only be handled successfully with immediate surgery.

At the time of operation, small wounds are closed with interrupted sutures placed below the wound occluding finger and wounds in the proximity of the coronary arteries by placing horizontal mattress sutures through the myocardium beneath the coronary artery to prevent occlusion or injury to the artery. In projectile injuries, where there is a surrounding area of damaged myocardium, mattress sutures and Teflon or pericardial bolsters should be used to prevent the sutures cutting through the damaged myocardium. Rarely projectiles may create a defect in the cardiac wall which is difficult or impossible to repair by suture approximation of the wound edges. Under these circumstances, the wound is best managed with or without a prosthesis after establishing cardiopulmonary bypass.¹⁹ Likewise, some posterior cardiac wounds may be best treated after institution of cardiopulmonary bypass since major lifting of the apex of the heart, necessary for exposure of such wounds, is poorly tolerated.

The postoperative management in these patients is similar to that of any other critically ill patient with frequent determinations of hemodynamic parameters and strict attention to intake and output being the hallmarks of good care. In addition, the patient should be closely observed through out his hospital stay, and later for the development of signs or symptoms of residual or delayed sequelae from the penetrating cardiac wound, such as posttraumatic or postoperative pericarditis, ventricular septal defect, valvular defects, ventricular aneurysm, aortocardiac and aortopulmonary or coronary artery to coronary vein or to cardiac chamber communication.¹⁷ When such sequela is found and it appears that the defect endangers the patient's life, cardiac catheterization should be performed as soon as possible and then fol-

lowed by surgical repair. If the patient, however, tolerates his lesion postoperatively, cardiac catheterization should be performed electively and the hemodynamically significant defects should be repaired.¹⁸

References

1. Baue, A. E.: Immediate Thoracotomy for a Stab Wound of the Heart. *JAMA*, 186:521, 1963.
2. Beall, A. C., Jr., Ochsner, J. L., Morris, G. C., Jr., et al.: Penetrating Wounds of the Heart. *J. Trauma*, 1:195, 1961.
3. Beall, A. C., Patrick, T. A., Okies, J. E., et al.: Penetrating Wounds of the Heart: Changing Patterns of Surgical Management. *J. Trauma* 12:468, 1972.
4. Bishop, L. H., Jr., Estes, F. H., Jr., and McIntosh, H. O.: Electrocardiogram as a Safeguard in Pericardiocentesis. *JAMA*, 162: 264, 1956.
5. Blalock, A., and Ravitch, M. M.: A Consideration of the Non-operative Treatment of Cardiac Tamponade Resulting from Wounds of the Heart. *Surgery*, 52:330, 1962.
6. Blalock, A., and Ravitch, M. M.: A Consideration of the Non-operative Treatment of Cardiac Tamponade Resulting from Wounds of the Heart. *Surgery*, 14:157, 1943.
7. Boyd, T. F., Strieder, J. W., and Scarpato, R. A.: Immediate Surgery for Traumatic Heart Disease. *J. Thorac. Cardiovasc. Surg.*, 50:305, 1965.
8. Cooper, F. W., Jr., Stead, E. A., Jr., and Warren, J. V.: The Beneficial Effect of Intravenous Infusions in Acute Pericardial Tamponade. *Ann. Surg.*, 120:822, 1944.
9. Cooley, D. A., Dunn, J. R., Brockman, H. L., and DeBaKey, M. E.: Treatment of Penetrating Wounds of the Heart. Experimental and Clinical Observations. *Surgery*, 37:882, 1955.
10. Elkin, D. C.: The Diagnosis and Treatment of Cardiac Trauma. *Ann. Surg.*, 114:169, 1941.
11. Elkin, D. C., and Campbell, R. E.: Cardiac Tamponade: Treatment by Aspiration. *Ann. Surg.*, 133:623, 1951.
12. Isaacs, J. P.: Sixty Penetrating Wounds of the Heart. Clinical and Experimental Observations. *Surgery*, 45:696, 1959.
13. Jones, E. W., and Helmsworth, J.: Penetrating Wounds of the Heart. Thirty Years' Experience. *Arch. Surg.*, (Chicago) 96: 671, 1968.
14. Ravitch, M. M., and Blalock, A.: Aspiration of Blood From the Pericardium in Treatment of Acute Cardiac Tamponade after Injury. *Arch. Surg.*, (Chicago) 58:463, 1949.
15. Rehn, L.: Ueber Penetrierende Herzwunden und Herznaht. *Arch. Klin. Chir.*, 55:315, 1897.
16. Sanger, P., Tavana, M., Taylor, F. H., and Robicsek, F.: The Merit of Emergency Thoracotomy in the Management of Stab Wounds of the Heart. *North Carolina Med. J.*, 25:1, 1964.
17. Symbas, P. N.: Traumatic Injuries of the Heart and Great Vessels. Springfield, Charles C Thomas, 1972.
18. Symbas, P. N., DiOrio, D. A., Tyras, D. H., et al.: Penetrating Cardiac Wounds. Significant Residual and Delayed Sequelae. *J. Thorac. Cardiovasc. Surgery* 66:526, 1973.
19. Symbas, P. N., Tyras, D. H., and McCraw, D.: Repair of a Left Ventricular Traumatic Defect with a Dacron Prosthesis. *J. Thorac. Cardiovasc. Surg.*, 63:608, 1972.
20. Sugg, W. L., Rea, W. J., Ecker, R. R., et al.: Penetrating Wounds of the Heart: An Analysis of 459 Cases. *J. Thorac. Cardiovasc. Surg.*, 56:531, 1968.
21. Von Berg, V. J., Moggi, L., Jacobson, L. F., et al.: Ten Years' Experience with Penetrating Injuries of the Heart. *J. Trauma*, 1:186, 1961.
22. Wilkinson, A. H., Jr., Buttram, T. L., Reid, W. A., and Howard, J. M.: Cardiac Injuries: An Evaluation of the Immediate and Long-range Results of Treatment. *Ann. Surg.*, 147:347, 1958.