

Penetrating wounds of the heart and great vessels

A report of 30 patients

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In this series of 30 consecutively operated patients, two were probably dead from their cardiac wounds on arrival at hospital and two suffered extrapericardial large vessel injury. These four patients died. Among the remaining 26 patients who arrived alive in the emergency room with intrapericardial wounds, 23 (89%) survived during the four-and-a-half years covered by this report. These included five survivors in a subgroup of six patients with serious left ventricular wounds.

The use of initial pericardiocentesis in 13, sternotomy in 10, and extracorporeal circulation in 7 of these 30 patients is emphasized.

Modern surgery of the pericardial cavity was initiated in Chicago by Williams in 1889 (Meade, 1961). Rehn (Ballance, 1920) reported the first cardiac wound suture in 1896. Survival from penetrating wounds to the intrapericardial contents and great vessels has slowly risen to 90% of patients reaching the emergency room alive (Naclerio, 1964). Controversy developed as to the role of pericardiocentesis (Hewitt, Smith, Weichert, and Drapanas, 1970; Ravitch and Blalock, 1949). As injuries of the heart have become more severe and operating safer, pericardiocentesis has become the primary preparation rather than the definitive operation.

In this report we analyse the treatment, mainly by residents under supervision, of 30 consecutive patients with penetrating wounds of the pericardium, heart, and great vessels occurring between 1 January 1966 and 30 June 1970. Twenty-three of these patients survived (77% overall survived). If one excludes two patients who may originally have been dead on arrival but were resuscitated, and two with a predominant extrapericardial descending aortic and innominate artery injury, then the survival rate for the remaining treated patients is 89% (23 of 26) for those reaching the emergency room alive with intrapericardial wounds. The increasing use of sternotomy (10 of the last 16 cases) and of extracorporeal circulation (7 of the last 16 cases) has increased exposure of all cardiac chambers and safety of manipulation. We also report that only one patient died out of six with left ventricular wounds, mostly gunshot.

ANALYSIS OF RESULTS

YEARLY INCIDENCE Six patients were treated in 1966, two in 1967, seven in 1968, nine in 1969, and six in the first half of 1970 (Table I).

CAUSE Eleven of the 30 wounded were caused by gunshot, 18 by knife, and one by a screwdriver (Table II).

ANATOMICAL INJURY The superior vena cava was involved in one patient, the right atrium in three, the right ventricle in 16, the pulmonary artery in four, the left atrium in two, the left ventricle in six, the ventricular septum in three, the aorta and

TABLE I
YEARLY INCIDENCE

Year	No. of Patients	No. Survived
1966	6	5
1967	2	2
1968	7	5
1969	9	6
1970 (to April 1970)	6	6

TABLE II
CAUSE OF INJURY

Cause	No. of Cases
Gunshot	11
Knife	18
Screwdriver	1

TABLE III
ANATOMICAL INJURY

Anatomical site	No. of Cases
Superior vena cava	1
Right atrium	3
Right ventricle	16
Pulmonary artery	4
Left atrium	2
Left ventricle	6
Ventricular septum	3
Aorta and branch	4
Pericardium (only)	1

More than one structure involved in 10 cases

TABLE IV
INCIDENCE OF SHOCK AND ARREST

	No. of Patients	No. Survived	% Survival
No shock	5	4	80
Shock	25	19	76
Shock + arrest	10	6	60
Shock + arrest + coma ..	4	1	25

its branches in four, and the pericardium (only) in one (Table III).

INITIAL PERICARDIOCENTESIS This was utilized in 13 patients. In three instances where the amount was recorded, 75 ml, 150 ml, and more than 500 ml of pure blood were aspirated.

SHOCK AND COMA There was only one death among five patients who were not in shock on admission. Among the 25 patients who were in shock on admission to the emergency room, 10 had cardiac arrest and four of these died (Table IV). In four of these 10 patients, coma was also present and only one survived. Patients considered in shock were those whose blood pressure was unobtainable in the emergency room but always had a palpable femoral pulse, except for the four in coma. Thoracotomy was performed six times in the emergency room and two patients died.

INITIAL INCISIONS Left thoracotomy was used in 14 patients, right in four, bilateral in two, and sternotomy in 10 (Table V). The operations performed consisted of suturing the stab wounds or gunshot wounds in the structures involved. Extracorporeal circulation was required five times initially and in two additional patients subsequently.

Additional operations included (Table VI) one of each of the following: hepatic lobectomy, suture of lung wound, suturing of knife wounds to the patella and face, left pneumonectomy, placement of pacemaker, and splenectomy. Three of these six patients died.

TABLE V
TYPE OF INCISION

Incision	No. of Patients	Structures Approached	% Survival
Bilateral thoracotomy	2	Right ventricle, ascending aorta	100 (2/2)
Right thoracotomy	4	Superior vena cava, right atrium, right ventricle, pulmonary artery	100 (4/4)
Midline sternotomy	10	Pericardium, right atrium, right ventricle, tricuspid valve, pulmonary artery, left atrium, left ventricle, ascending aorta, innominate artery	80 (8/10)
Left thoracotomy	14	Inferior vena cava, right atrium, right ventricle, left atrium, left ventricle, descending aorta	64 (9/14)

TABLE VI
OPERATIONS IN ADDITION TO REPAIR OF HEART WOUNDS

Procedure	Survived
Left segmental hepatic lobectomy	Yes
Suture lung wound	Yes
Suture patella and face	Yes
Left pneumonectomy	No
Pacemaker	No
Splenectomy	No

TABLE VII
POSTOPERATIVE COMPLICATIONS WITH RECOVERY

Complication	No. of Patients
Pneumonia	2
Arrhythmia	1
Ileus	1
Wound infection	1

Postoperative complications included ileus, pneumonia, wound infection, and arrhythmias (Table VII). Ileus occurred in patient 1 (Table IX), who underwent hepatic lobectomy in addition to suture of a left ventricular knife wound.

Pneumonia developed in patient 8 following bilateral thoracotomy and transverse sternotomy for repair of a through and through right ventricular gunshot wound, and in patient 13 following suture of knife wounds to the right ventricle, patella, and face.

Wound infection developed in patient 9, also following bilateral thoracotomy and transverse sternotomy for repair of ascending aortic knife wounds. Arrhythmias occurred in patient 18 after repair of right and left ventricular gunshot wounds. All these patients survived and were discharged without sequelae. Follow-up for from one to eight

TABLE VIII
SEVEN POSTOPERATIVE DEATHS

Additional Complicating Feature	No. of Patients
Preoperative coma (? dead on arrival) ..	3
Operation in addition to repair of cardiac wound ..	3
None ..	1

months showed these patients to be completely recovered.

There were seven postoperative deaths (Table VIII). In three patients (5, 16, and 20) coma was present preoperatively as well as cardiac arrest and shock. In patient 20 resuscitation in the operating room was not possible, while the two others died from cerebral oedema within three days.

In three other patients (11, 21, and 24) additional surgery (pneumonectomy, pacemaker, splenectomy) was required immediately following primary repair of cardiovascular wounds which consisted of gunshot wounds of the left ventricle and pulmonary artery (11), the descending aorta and pulmonary aorta (21), and a gunshot wound ventricular septal defect (24).

In only one patient who died was there neither coma nor the need for additional surgery. Patient 14 was explored the day after he sustained a gun-

shot wound of the extrapericardial innominate artery. An increasing murmur from an innominate artery to vein fistula could be heard on auscultation. With the aid of extracorporeal circulation, hypothermia of 20° C, and 20 minutes of circulatory arrest a graft was placed from the ascending aorta to the innominate artery bifurcation. In addition, the left innominate vein was ligated. The patient died from cerebral oedema three days postoperatively (a technical error must be presumed).

It should be pointed out that there was only one death among six patients (1, 6, 11, 18, 22, and 30) with wounds of the left ventricle. In four of these patients there were, in addition to the left ventricular gunshot wounds, other wounds of the right ventricle in one, of the pulmonary artery in another, of the lung in two, of the liver in two, and of the spleen in one. The only death was that of patient 11, who also required splenectomy and re-bled from the sutured left ventricular wound when he recovered from shock in the intensive care unit. Re-exploration and attempts at resuscitation proved fruitless.

Table IX summarizes the 30 consecutive patients seen in a four-and-a-half-year period at the University of Chicago Hospitals.

TABLE IX
CLINICAL SUMMARY

Case/ Admission	Weapon	Site of Injury	Initial Aspiration	Preop. Shock	Preop. Arrest	Operation	Postoperative Complications	Cause of Death
1 20 Mar. '66	Knife	LV	No	Yes	No	Suture LV; left segmental hepatic lobectomy; No pump	Ileus	
2 25 July '66	Knife	RV	Yes	Yes	No	Suture RV stab, no pump	None	
3 23 Aug. '66	Knife	RV	Yes	Yes	At operation	Suture RV stab; no pump	None	
4 27 Aug. '66	Knife	RV	Yes	Yes	At operation	Suture RV and lingula; no pump	None	
5 23 Sept. '66	Gunshot ? Dead on arrival	IVC, RA, RV	—	Yes Coma ? Dead on arrival	Yes	Suture IVC, RA, RV; no pump	—	Cerebral ? Dead on arrival
6 31 Dec. '66	Knife	LV	Yes	Yes	Yes	Suture heart, probably LV; no pump	None	
7 4 June '67	Screwdriver	RV and ventricular septum	No	Yes	No	RV wound, no pump; VSD closure no. 1, pump; VSD closure no. 2, pump; pacer, no pump	Temporary heart block after 3rd operation	
8 16 July, '67	Gunshot	RV through and through	Yes	Yes	No	Suture through and through RV wound; no pump	Pneumonia	
9 26 Feb. '68	Knife	Ascending aorta	Yes	Yes	No	Exploration of sealed ascending aorta wound of 3 mm; no pump	Wound infection	

cont.

TABLE IX

(Continued)

Case/ Admission	Weapon	Site of Injury	Initial Aspiration	Preop. Shock	Preop. Arrest	Operation	Postoperative Complications	Cause of Death
10 4 May '68	Knife	LA	No	Yes	No	Suture LA appendage; no pump	None	
11 9 June '68	Gunshot	LV and PA	Yes	Yes	No	Suture LV and splenectomy; no pump	—	Died from haemor- rhage LV wound
12 23 June '68	Gunshot	PA and SVC	No	Yes	No	Suture SVC and PA; no pump	None	
13 11 Aug. '68	Knife	RV	No	Yes	No	Suture RV, patella, and face; no pump	Pneumonia	
14 5 Nov. '68	Gunshot	Innominate artery and vein	No	No	No	Aorta-innominate graft, Ligation of innominate vein; pump		CNS death
15 30 Nov. '68	Gunshot	RA, LA, RV	No	Yes	In operating room	Suture RA, LA, RV; no pump	None	
16 23 Jan. '69	Knife ? Dead on arrival	RV	No	Yes Coma	Yes	Suture RV; no pump	Unconscious, died	CNS death
17 14 Apr. '69	Knife	RV	No	Yes Coma	Yes	Suture RV, ¹ untie coronary; no pump	Slow brain recovery	
18 11 May '69	Gunshot	RV anterior and LV posterior	No	Yes	No	Suture RV and LV wounds; no pump	Arrhythmia	
19 13 Aug. '69	Knife	RV	Yes	Yes	No	Suture RV stab; no pump	None	
20 5 Sept. '69	Knife	RV	Yes	Yes Coma	At operation	Suture RV stab; no pump	—	Died from ventricu- lar fibril- lation
21 16 Sept. '69	Gunshot	Left PA and descending aorta	No	Yes	No	Left pneumonectomy, descending aorta graft; pump	—	Died 2 hr postop.; clotting problem
22 29 Oct. '69	Gunshot	LV through and through	No	Yes	Yes	Suture anterior and posterior wounds; no pump	None	
23 8 Nov. '69	Knife	Right atrio- ventricular junction	Yes	Yes	No	Suture A-V groove, retract right coronary; no pump	None	
24 4 Dec. '69	Gunshot	RV and ventricular septum	Yes	Yes	Yes Complete heart block	VSD repair, pacemaker and closure RV wound; pump	—	Anuria and ventricu- lar arrhyth- mia
25 30 Jan. '70	Knife	Aorta and PA	No	No	—	Aorta and PA wound closure; pump	None	
26 3 Feb. '70	Gunshot self- inflicted	Pericardium	No	No	No	Pericardial exploration; no pump	None	
27 4 Apr. '70	Knife	RV	Yes	Yes	No	Suture RV; no pump	None	
28 7 Apr. '70	Knife	RV and septum	Yes	Yes	No	Suture RV, VSD repair; pump	None	
29 15 May '70	Knife	RA	No	No	No	Suture RA; no pump	None	
30 22 June '70	Gunshot	LV	No	No	No	Bullet from LV; no pump	None	

¹ Open cardiac massage and suturing of ventricular wound in the emergency room resulted in one of the coronary arteries being tied off. This was released in the operating theatre.

CNS=central nervous system; IVC=inferior vena cava; LA, RA=left, right atrium; PA=pulmonary artery; LV, RV=left, right ventricle; SVC=superior vena cava; VSD=ventricular septal defect.

DISCUSSION

The management of these 30 patients with heart and great vessel injuries was directed to the immediate establishment of airway, control of cardiac tamponade, and suture repair of the cardiovascular and associated injuries. The wounds were serious and pericardiocentesis alone did not suffice. This did not preclude its preliminary use in 13 of the 30 patients which greatly contributed to the ultimate survival of ten.

The presence of shock, cardiac arrest or coma increased the risk of death, which was only 20% without any of these factors, 24% if shock alone was present, 40% if shock and arrest existed preoperatively, and 75% if shock, arrest, and coma preceded surgery.

Surgery required for associated injuries in six patients increased the death rate to 50%. However, contrary to the reports in the recent literature (Sugg *et al.*, 1968) and more in line with Rehn's remarks in 1907 reported by Ballance in 1920, we found that in six patients with wounds of the left ventricle five survived despite the severity of the primary and associated injuries. This approaches the results with pure stab wounds reported in the literature (Borja, Lansing, and Ransdell, 1970).

The use of sternotomy in 10 of the last 16 patients allowed for a wider range of structures to be repaired safely. The primary use of extracorporeal circulation in five of these last 16 patients facilitated complete manipulation. However, only two of these patients survived. In addition, the pump was used after the primary repair in two patients, one surviving.

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