THE DIAGNOSIS AND TREATMENT OF CARDIAC TRAUMA*

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ALTHOUGH the suture of heart wounds is classed as an attainment of modern surgery, a knowledge of their fatal outcome, if untreated, has been recognized from the earliest times. For the student interested in the history of cardiac surgery, an interesting point of departure would be the Iliad and the Odyssey, for the Homeric stories abound with reference to cardiac wounds. Hippocrates[1] realized their fatal nature, as did Paré,[2] who described them, but made no suggestions regarding their treatment.

Boerhaave[3] stated that all wounds of the heart were mortal. Hunter made no mention of the subject, and John Bell,[4] in his "Discourses on the Nature and Cure of Wounds," devoted only two paragraphs to the subject, although he recognized the signs and symptoms of the condition and cited two patients who lived several hours, who might well have been saved by operation. He thus discussed the subject: "There is so little to be done . . . and the signs and consequences are so clear, that it were a waste of time to speak longer of wounds of the heart." Billroth,[5] who dominated the surgery of his day, wrote (in 1875): "Paracentesis of the pericardium is an operation which, in my opinion, approaches very closely to that kind of intervention which some surgeons would term a prostitution of the surgical art and other madness." He did add, prophetically, "Perhaps another generation will think otherwise about it." As late as 1896, Stephen Paget[6] wrote: "The surgery of the heart has probably reached the limits set by nature to all surgery; no new method and no new discovery can overcome the natural difficulties that attend a wound of the heart."

Two figures stand out because of their disagreement with these pessimistic pronouncements; Morgagni[7] who, in 1761, showed that blood in the pericardium compressed the heart and embarrassed its movements, and Baron Larrey[8] (Napoleon's great surgeon) who decompressed a wounded heart by drainage, and who demonstrated by experiments on dogs that these injuries were not necessarily fatal.

Modern surgery of the central circulatory system began with Roberts[9] (1881), who suggested that wounds of the heart be sutured. Block[10] (1882) successfully sutured the hearts of rabbits, but de Vecchio [11] (1895) deserves greater credit for demonstrating to the Eleventh International Medical Congress, at Rome, the healed wound in a dog's heart. Within a year the human heart was sutured by Cappelen[12] (September, 1895), by Farina[13] (March, 1896), and Rehn[14] (September, 1896). Rehn's patient survived. By 1909,

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Peck[15] was able to collect 161 cases treated surgically, with a mortality of 63 per cent. Pool[16] (1912) added 79 cases, with a mortality of 49 per cent; Smith[17] (1923) collected 25 cases, with a mortality of 36 per cent; and Bigger[19] (1932–1933) added 70 instances, with a mortality of approximately 30 per cent.

The percentage of reported recoveries is unquestionably too high, because of the fact that many single, favorable cases have been reported, whereas those ending fatally are not so likely to be recorded. At any rate, the percentage of recoveries is at the present time at least 50 per cent, whereas only 10 per cent of the untreated cases reported by Fischer[20] (1868) recovered.

Incidence.—Wounds of the heart are relatively rare. In southern hospitals they comprise about 0.1 of 1 per cent of patients. At Emory University, 2 per cent of the penetrating wounds of the chest injured the heart. Considering its size and exposed position, it is surprising that it is not more frequently injured. If those patients were considered who die of homicide, suicide, and accident, but never reach the operating room or the autopsy table, it is probable that the percentage would be much higher. Moreover, the diagnosis is frequently overlooked, and patients may die without surgical intervention who might otherwise have been saved had early diagnosis been made and prompt surgical intervention undertaken. That cardiac wounds are more frequent than is generally supposed is evidenced by the ever-increasing number that are reported. At Emory University, the number of patients treated for wounds of the heart has increased steadily each year since 1930. This is merely another evidence of a better ability to diagnose the condition, since the number of chest injuries has decreased.

Mode of Injury.—For the most part, penetrating wounds of the heart are produced with homicidal or suicidal intent, and, therefore, knives, ice-picks, and pistols are the most frequent weapons with which the injury is inflicted. In addition, the heart may be wounded in crushing injuries or by its accidental penetration by glass and splinters as a result of automobile accidents. Aside from penetrating wounds, contusions of the heart, fatal or nonfatal, may occur. In any event, early diagnosis and treatment is necessary since delay is rapidly fatal.

Cardiac Tamponade.—Rapid changes in pressure relationships, particularly within the pericardium, affect the filling and emptying of the heart and, if unrelieved, will quickly bring about a standstill of the cardiac mechanism. The diagnosis of acute cardiac compression, the removal of its cause, and the prevention of its recurrence, is the basis for the treatment of cardiac injuries.

Normally, the intrapericardial pressure is less than that of the atmosphere, and the pressure in the intrathoracic portions of the venae cavae is probably negative. With the rapid accumulation of fluid in the pericardium, as from pus or blood, the venous pressure rises, and after it reaches a height sufficient to overcome the increased intrapericardial resistance, blood enters the heart, and the circulation continues. Normally, the venous pressure ranges between

75 and 120 Mm. of water. In rapidly increasing accumulations of fluid, the pericardium cannot distend sufficiently nor can the venous pressure rise to such a level as to allow the filling of the heart for any length of time. However, I have noted a venous pressure as high as 400 Mm. of water in acute compression of the heart, and have seen this pressure maintained for as long as 30 minutes without a fatal result. Where the tamponade of the heart is gradually produced (serous effusion), the pericardium is slowly distended and a high venous pressure will maintain the circulation for days.

Acute tamponade leads to cerebral anemia, for the heart can no longer fill. Release of tamponade is, therefore, a matter of first importance, and demands immediate treatment. The symptoms are a low or unobtainable arterial pressure, a high or rising venous pressure, and a quiet heart. The pulse is weak or absent, and the veins, particularly those of the neck, are prominent and strutted. Because of the venous stasis there is a marked cyanosis of the lips and tongue.

Diagnosis.—Because of its position in relation to the anterior chest wall, a wound of the right ventricle is more frequent, but wounds of all four chambers as well as those of the intrapericardial portions of the great vessels may be encountered. The exact location of the wound can only be surmised before operation, since symptoms from bleeding or tamponade will be the same, regardless of the location. Death may occur from rapid loss of blood either into the chest or to the outside, but death is more likely to occur as a result of tamponade.

The history is usually characteristic. There is freedom from symptoms for several minutes after the injury, followed by exhaustion, and then loss of consciousness. Either stupor or wild delirium may follow. Patients have been known to walk several blocks or to continue fighting for as long as five minutes after a wound of the heart. Bleeding is profuse at first, but soon stops. This train of symptoms is due to a rapidly increasing tamponade. When the heart is wounded, it bleeds freely to the outside and usually into the pleural cavity as well. At the same time, some blood collects in the pericardium and when 100 to 200 cc. have so collected, the heart becomes compressed. Contractions become weak, and bleeding to the outside stops. With the rise in intrapericardial pressure, the venae cavae can no longer convey normal quantities of blood to the heart, and cerebral anemia, as evidenced by unconsciousness, results.

The position and direction of the wound may aid in diagnosis, but the course of a bullet, or even a knife thrust, is notoriously misleading, although those near the left of the sternum from the second to the fifth interspaces are most apt to injure the heart.

Accurate diagnosis, above all, will depend to a large extent upon the Resident Staff, who must be trained to be ever on the alert not only to recognize symptoms of cardiac trauma, but to suspect every chest injury as a potential heart wound. All too frequently, wounds considered inconsequential

may later prove to be fatal. This is particularly true in a case where an ice-pick has caused the wound.

The skin is usually cold and moist, and because of the venous congestion there is a cyanosis of the lips and tongue. The heart sounds are weak, often irregular, and the pulse is weak or imperceptible.

The arterial pressure is lowered, even unobtainable, and the venous pressure is raised as evidenced by prominent, strutted veins, particularly those of the neck. By direct measurement, this pressure is frequently above 200 Mm. of water, and a rise to 300 Mm. of water is not unusual. Such a pressure is consistent with life if not maintained for too long a period. Venous pressure readings should be obtained by the direct method of inserting a needle into a basilic vein and noting on an attached manometer the height at which a column of physiologic salt solution is maintained. The patient's body should be horizontal, and the vein should be on a level with the heart.

Roentgenograms are of no value, since death may occur from an amount of blood in the pericardial sac too small to cause a noticeable change in the size and contour of the heart shadow. Fluoroscopic examination, as shown by Bigger[19] is of great value, since the normal pulsations are prevented by a small accumulation of blood in the pericardial sac. Of all the diagnostic aids, this is the most accurate in proving or disproving one's suspicions of cardiac tamponade. It had best be undertaken with the portable fluoroscope, for with this unit the patient need only be turned on his side for examination.

To summarize:

(1) There is usually a history of freedom from symptoms for several minutes after the wound has been received, followed by rapid collapse and unconsciousness.

(2) Heart sounds are weak, as is the pulse.

(3) The arterial pressure is lowered.

(4) The venous pressure is raised.

(5) Fluoroscopic examination shows a quiet heart.

Operation should be carried out as soon as the diagnosis is established. To hasten and facilitate this, all necessary instruments should be kept ready in a separate container. Since infection of the pericardium and pleura is a frequent complication, meticulous care in preparation and technic should not be sacrificed for speed and haste. While preparations are being made, sufficient morphine should be administered to insure rest and quiet. The head should be lowered and the body kept warm. Theoretically, intravenous infusions are of little value so long as tamponade is present, but where excessive hemorrhage has occurred, it is indicated. The administration of a 6 per cent solution of acacia may be life-saving, and autotransfusion of the blood removed during the operation should be citrated and administered when possible. Blood transfusion should be undertaken as soon as possible after the release of the tamponade. For this purpose the "blood bank" is an invaluable aid.

Anesthesia.—Inhalation anesthesia is preferable to local anesthesia for

several reasons. The pleura may have been opened by the wound, or may be accidentally opened during the operation, and nitrous oxide and oxygen under positive pressure is necessary for the inflation of the lung. The difficulties of heart suture require that the patient be quiet, but these patients are usually wildly excited or are apt to become so with release of the tamponade, and unless completely anesthetized their struggles may interfere with the operation at a most inopportune time.

Suture of the Heart.—The incision should be so planned as to give the best exposure with the least trauma. It must also be made with some consideration as to the position of the external wound. Although the pleura is usually injured when the heart is wounded, further tearing of this membrane should be avoided if possible, for it adds greatly to the shock of the patient. For that reason dissection of the pleura from the pericardium is best begun in the fourth or fifth left interspace because of its lateral reflection at that point. It is this reflection to the left which leaves the pericardium uncovered by pleura at that point and so facilitates an extrapleural approach to the pericardium. It is of importance to remember that the costomediastinal lines of pleural reflection vary greatly; thus, either the left or right pleura may cross the middle of the sternum (Fig. 1). In a composite study of anterior pleural margins, Vosnitch was able to outline a small triangle of safety where the pericardium was uncovered by pleura. This lies behind the sixth left costal cartilage and sixth interspace (Fig. 2).

Unless the skin wound is well to the right of the sternum, the approach to the heart should always be made on the left, and the incision should be so planned that it can be readily enlarged if the heart wound is not easily located. With these factors in mind, experience has shown that a long transverse incision extending well across the sternum gives the best exposure (Figs. 3 and 4). By this approach one or two ribs can be removed, and, if necessary, the adjacent costal cartilages cut and a portion of the sternum removed. The pectoralis major muscle is separated in the direction of its fibers and can easily be retracted from the surface of three ribs. Dissection should begin well out on the rib, which can be easily lifted from its periosteal bed and cut without injuring the pleura. By lifting the rib, the cartilage can then be removed with less danger of injury to the pleura than if the cartilaginous portion is removed first. The internal mammary vessels are ligated and cut, the triangularis muscle is divided, and the pleura is displaced outward by careful gauze and finger dissection.

A second incision, and one giving excellent exposure, consists of turning a musculocutaneous flap laterally and removing two or more costal cartilages and ribs (Fig. 5). It requires more time to open and close the chest wall and is more likely to induce shock.

The incision should be planned to secure the best exposure in the quickest time and with the least shock. The median sternotomy (Duval-Barasty) (Fig. 6) gives excellent exposure to all the heart and the great vessels, but splitting the sternum requires a great deal of time, as does the closure of

the wound, and is productive of shock. It is mentioned only to condemn it, since in cases of severe hemorrhage or increasing tamponade the patient would not likely survive such a procedure.

The intercostochondral thoracotomy (Spangaro) offers a rapid approach to the heart but not a particularly good exposure. It can be enlarged by cutting or removing the cartilages above and below the incision and by removing a portion of the sternum.

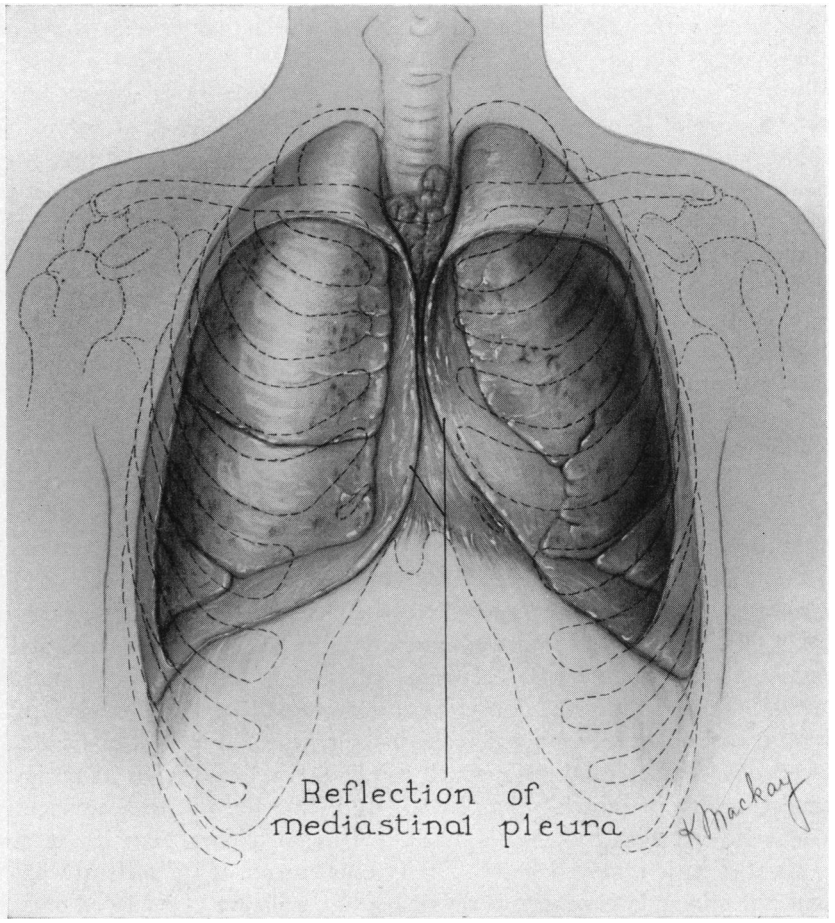

FIG. 1.—The usual anatomic relations in the anterior mediastinum.

The pericardium will be tense, bulging, and blue, and its pulsations will be weak and imperceptible. If the wound in the pericardium is seen, it should be enlarged, or, if not readily found, it is opened between stay-sutures of silk (Fig. 7). Occasionally, the heart wound can be located before the blood and clots are removed and before the heart starts bleeding profusely. If it is not immediately seen, the blood and clots are removed by suction. When the intrapericardial pressure is relieved, the bleeding becomes marked,

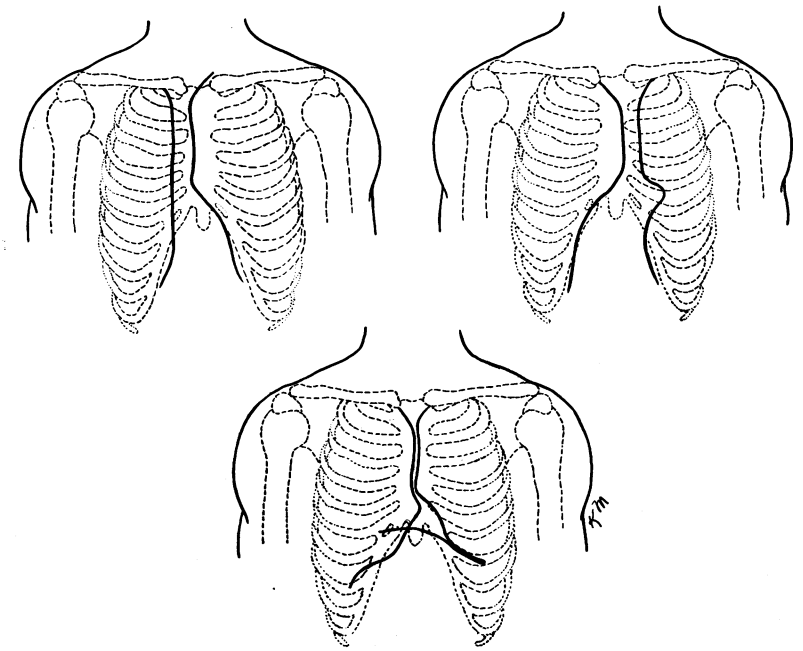

FIG. 2.—Diagrammatic representation of the lines of pleural reflection. Lower figure shows the triangle of safety (Matas).

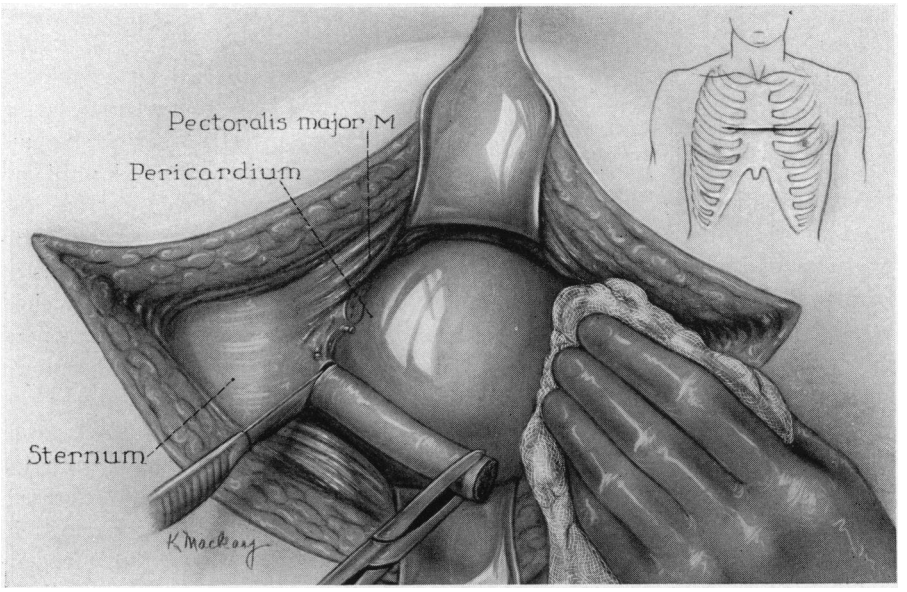

FIG. 3.—Showing the transverse incision, the removal of two ribs, and exposure of the pericardium.

as the contractions of the heart increase in force. When the wound is located, and it is most often found in the right ventricle, its closure is facilitated by placing the left index finger over it. In this way the bleeding will be impeded sufficiently to allow the passage of a suture directly under the finger. This is left untied for the moment and is held in the left hand for traction and hemostasis while other sutures are placed and tied. They should pass well into the substance of the muscle, but not into the chamber of the heart. Fine black silk on curved calix-eye needles is the material of choice. Heart muscle is extremely friable, and for this reason, the finger should not be placed *in* the wound, and sutures should be tied with only enough tension to approximate the edges (Fig. 8).

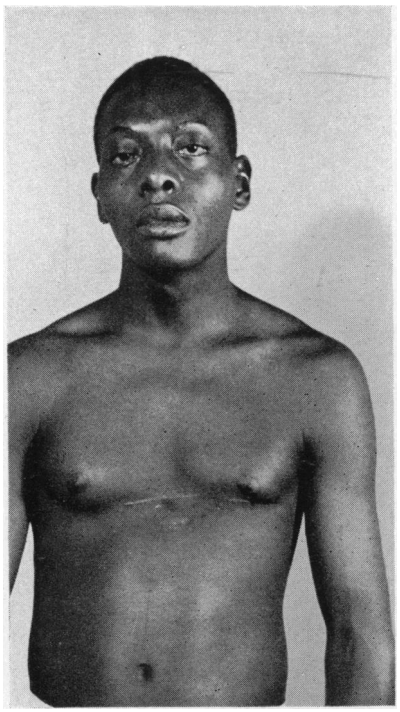

FIG. 4.—Patient showing a healed transverse incision.

Should the wound be behind the sternum or on the posterior surface of the heart, a stay-suture passed through the apex, as advocated by Ballance and by Beck, may be of great value, for by this means the heart may be rotated into such a position that the wound may be more easily sutured (Fig. 9).

Wounds in Special Positions.—Wounds of the auricle bleed with great rapidity and are more difficult to close because of the thinness and friability of the musculature in this location. Occasionally, a clamp, such as that used by Trendelenburg in closing the pulmonary artery, may be applied directly over the wound and the hemorrhage controlled until sutures can be taken (Fig. 10). If possible, sutures should not be carried into the chamber of the auricle because of the danger of an intra-auricular clot. Intrapericardial wounds of the great vessels will produce the same symptoms of tamponade as wounds in the heart muscle itself. They, too, are difficult to close because of the thinness of the structures. If the wound is in the pulmonary artery or aorta, the hemorrhage may be checked by passing the Trendelenburg probe behind them and thus impeding the flow of blood until the sutures can be placed (Fig. 10). Injuries to the coronary vessels may require ligature but are not necessarily fatal. I have found it necessary to ligate a major coronary vessel in three instances. All three of these patients survived, showing that this is not necessarily fatal. Electrocardiographic tracings in these patients show the typical findings of myocardial infarction. Where bleeding is so profuse that the wound cannot be located, it is sometimes necessary to resort to the procedure of Sauerbruch. In this, the venae cavae

are grasped between the middle and ring fingers of the left hand, and the first finger and thumb are left free to compress the cardiac muscle (Figs. 11 and 12). Needless to say, such a compression can be carried out for only a few minutes. During the course of any cardiac operation the heart may fibrillate or even stop beating, especially when traction is applied, or direct compression or kinking of the great vessels is employed. Should this occur,

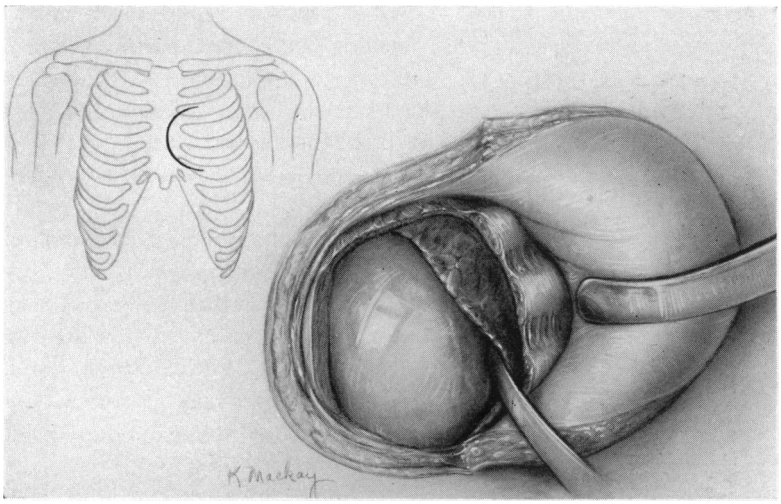

FIG. 5.—The approach to the pericardium through the musculocutaneous flap.

the operation should be momentarily stopped until normal contractions are resumed. The injection of one cubic centimeter of 1:1,000 solution of adrenalin directly into the heart muscle is frequently of value in restoring contractions. Gentle massage by pressure between the index finger and thumb will likewise often restore the heart beat.

After suture and control of the hemorrhage, the pericardial cavity is cleansed by suction and flushing with salt solution. The pericardium is loosely closed with interrupted sutures of silk, leaving sufficient space between the sutures for the escape of any fluid which may accumulate. Occasionally, the heart dilates to such an extent that complete closure of the pericardium is impossible. The muscle, fascia, and skin are then closed without drainage.

After operation the patient should be placed in an oxygen tent. Fowler's position will usually facilitate breathing. Morphine should be administered in sufficient amounts to insure rest and quiet.

Since the pleura and lung are often injured at the time of the heart injury, hemopneumothorax is frequently present. If its extent is such as to cause embarrassment of respiration, aspiration of the chest should be done, but in the absence of symptoms it is better to allow absorption of the air and blood.

Prognosis.—Immediate prognosis depends largely on the interval between

the injury and the operation. Delay may cause death from hemorrhage or tamponade or both. It likewise depends upon the character and extent of the injury; a bullet usually causes two wounds, with greater hemorrhage and tissue loss, and is rapidly fatal. Postoperative prognosis is largely dependent upon infection. Purulent pericarditis is apt to follow these wounds, which are necessarily contaminated and which may carry with them bits of clothing or other foreign material. Pneumonia resulting from lung injury, or as a part of the generalized infection, may likewise follow.

Thirty-eight patients with heart wounds have been operated upon by me or my Resident Staff (Fig. 13). Of these, 22 recovered and none of them have any residual symptoms referable to the injury. All wounds were pro-

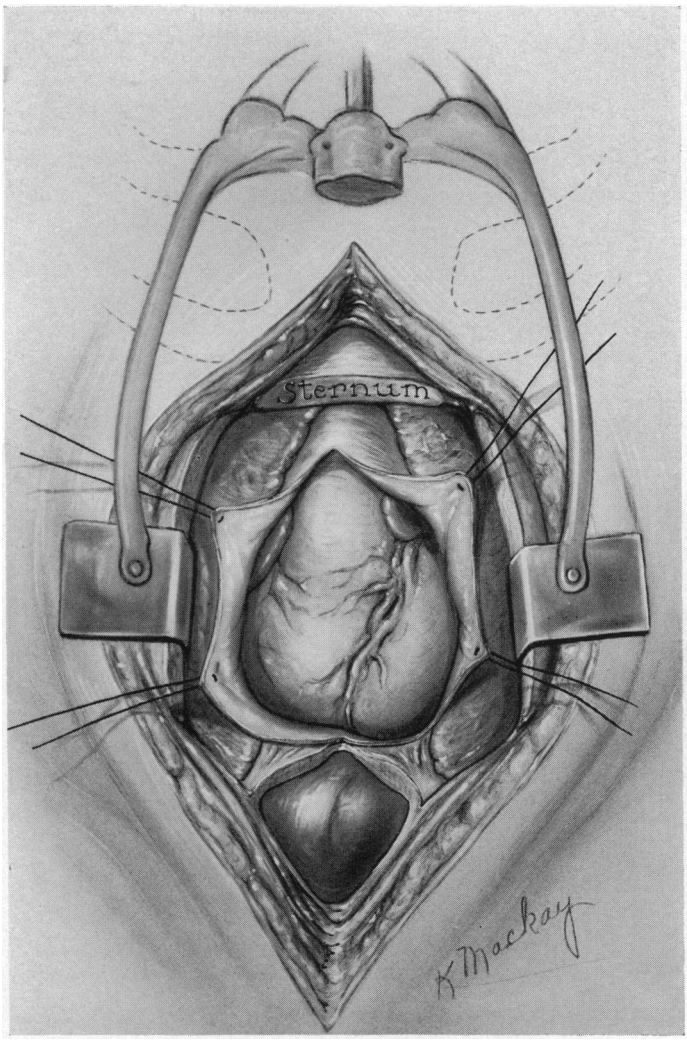

FIG. 6.—The Duval-Barasty median sternotomy (after Cutler).

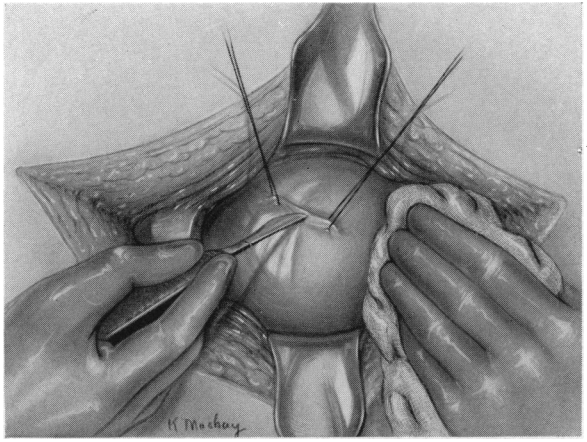

FIG. 7.—The opening of the pericardium between stay-sutures.

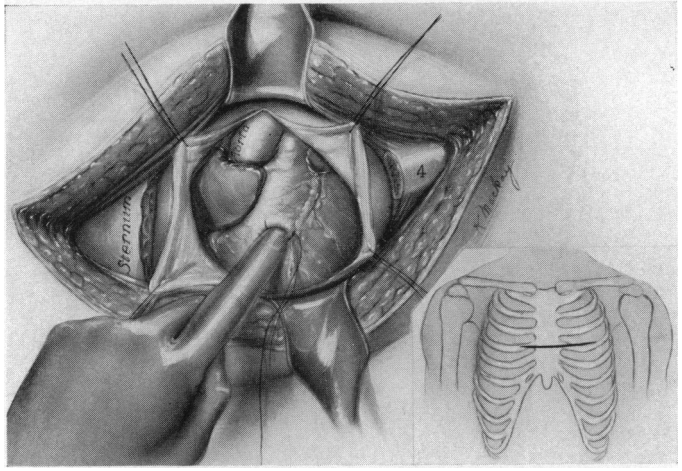

FIG. 8.—Method of controlling hemorrhage while suture is passed under finger.

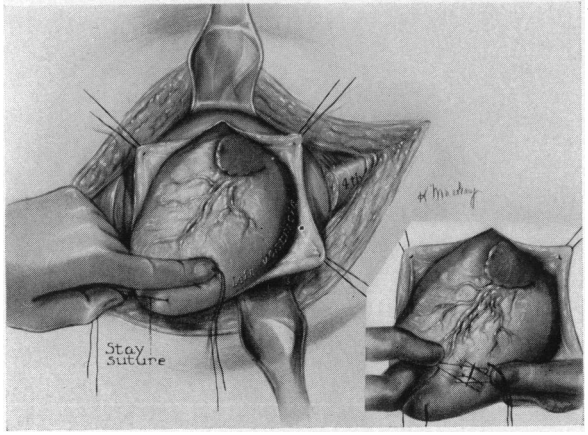

FIG. 9.—The use of the stay-suture in rotating the heart into position for suture (after Beck).

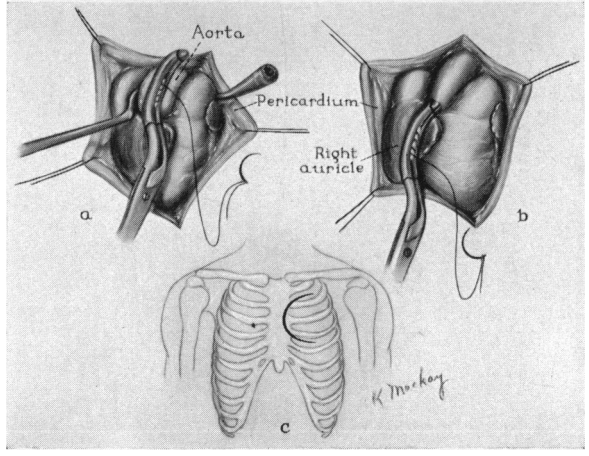

FIG. 10.—The use of the Trendelenberg probe and clamp in arresting hemorrhage in the auricles and great vessels.

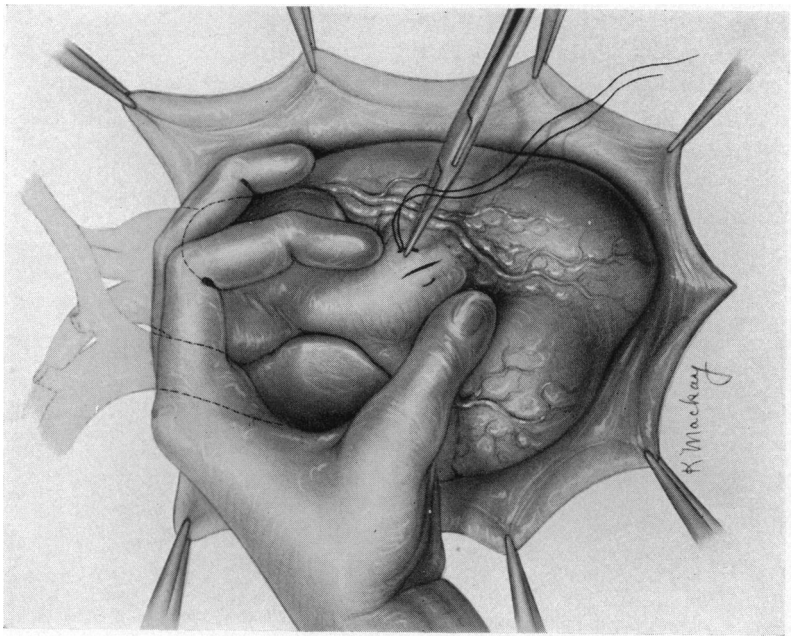

FIG. 12.

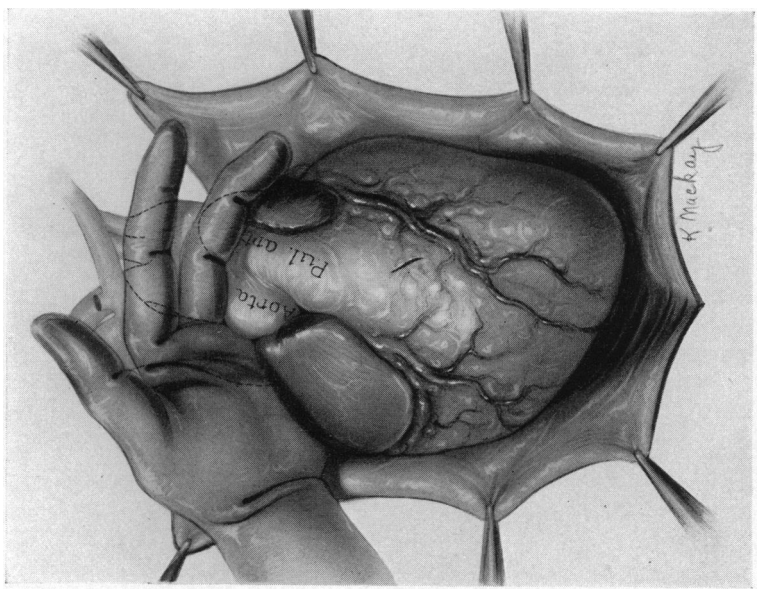

FIG. 11.

FIGS. 11 and 12.—"The Sauerbruch grip" illustrating the method of controlling hemorrhage by compression of the great vessels.

duced by knife or ice-pick except one (Case 37), which was caused by a bullet. In no instance was operation not undertaken because of the patient's condition. This means that in several instances the condition of the patient was so serious that there was practically no hope for recovery. No patients were operated upon in which the diagnosis was found to be incorrect, but

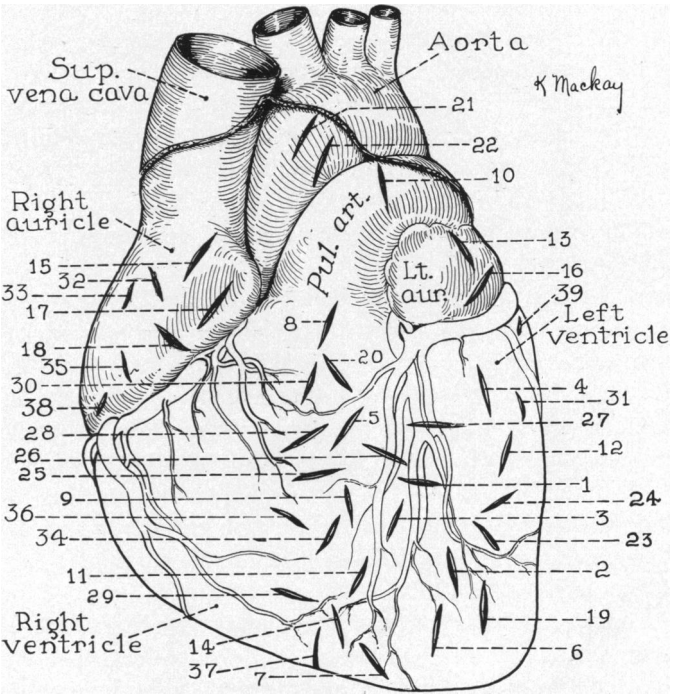

FIG. 13.—Composite picture showing the approximate location of the heart wounds reported in this paper.

it is only fair to say that some patients may have died with cardiac wounds upon whom operation was not performed. In two patients operated upon death occurred because of unnecessarily delayed operation, the result of failure of early diagnosis. There was one death from a postoperative hemorrhage due to the failure to ligate properly the internal mammary artery. The mortality rate in this series of 38 cases has gradually decreased, due, I believe, to the alertness of a Resident House Staff in establishing the diagnosis early and to better teamwork both at the operation and in post-operative care. The position of the right ventricle, occupying the greater part of the anterior portion of the heart, accounts for the fact that 14 of the 38 injuries were in that chamber. That ten of these patients survived is probably due to the fact that the right ventricle is easier to approach and suture. While pericardial adhesions undoubtedly form after these injuries, they are not of such a character as to produce symptoms either by constric-

tion or by increasing the work of the heart. That an already damaged heart can undergo considerable operative interference has been shown in those patients operated upon for coronary occlusion and for cardiac constriction. One of the patients in this series had been treated previously for myocardial failure. He recovered following the suture of a wound of his heart and is alive two years after the operation (see Tables I, II, and III).

Cardiac Rupture and Contusion.—Another type of cardiac injury which undoubtedly occurs with greater frequency than is generally supposed results from crushing wounds, usually from automobile accidents. Many are immediately fatal and are due to rupture of the heart, lungs, or great vessels as a result of compression of the thoracic viscera or penetration of the heart by broken ribs or sternum. Bright and Beck[21] collected 176 instances of injury to the heart following penetrating wounds of the chest, and have called attention to this type of injury as a common, though frequently overlooked, cause of death.

Certainly, there is no reason to believe that the heart, situated as it is between the sternum and the spine, is not subject to contusions of considerable severity; nor is there any reason to believe that recovery does not take place in the majority of instances. Other organs, notably the kidneys, are frequently the recipient of contusions from which they completely recover. The most common cause of such an injury is an automobile accident, in which an individual is suddenly thrown forward against the steering wheel. The sternum and ribs may be broken, and their ends directly injure the heart, or the sudden compression of the heart may injure it, although a break has not occurred (Fig. 14).

One can only speculate as to the exact nature of these injuries or as to the manner in which they are produced. In those patients who survive there is probably a contusion of the heart muscle with some hemorrhage into the myocardium, or gross hemorrhage into the pericardium.

Little attention has been paid to nonpenetrating heart lesions which are not fatal. Any patient who is struck in the chest must be suspected of such an injury, particularly if such symptoms as precordial pain, dyspnea, and tachycardia are present. Persistence of these symptoms, together with irregularity of the heart, cyanosis, and a peculiar "tick-tick" quality of the heart sounds, makes the diagnosis almost certain.

Cases of this kind give rise to speculation as to the eventual outcome, and raise many difficult medicolegal questions. Cardiac neuroses and malingering must always be considered, especially where the predominating symptoms develop following an injury to the chest in a patient previously well, it must be assumed that the symptoms are the result of that injury.

The treatment is entirely symptomatic. The chief reliance is to be placed on morphine and sedatives for quiet and rest, and on oxygen for dyspnea and cyanosis. Digitalis may be given but is of doubtful value. Above all, a patient with even a suspected cardiac lesion should be confined to bed until all symptoms have subsided.

TABLE I

SUMMARY OF 38 CASES OF CARDIAC WOUNDS

Case No.	Sex	Age	Instrument	Period from Duration to Admission	Location	Result	Cause of Death	Survival Period	Comment
1	M.	18	Knife	30 minutes	R. ventricle and coronary	Recovery	.....	.....	Well 8 years
2	M.	25	Knife	40 minutes	L. ventricle	Recovery	.....	.....	Well 9 years
3	M.	41	Knife	30 minutes	R. ventricle	Death	Pericarditis	3 days	Necropsy; wound healed
4	F.	25	Knife	"Few min."	L. ventricle	Death	Hemorrhage	None	Large wound; died on table
5	M.	30	Knife	?	R. ventricle	Recovery	.....	.....	Well 4 years
6	M.	30	Knife	"Few min."	L. ventricle	Death	Pneumonia	2 days	Necropsy; wound healed
7	M.	21	Knife	30 minutes	R. ventricle	Recovery	.....	.....	Well 3 years
8	M.	32	Knife	Not known	R. ventricle	Death	Emphysema	14 days	Mediastinal emphysema
9	F.	27	Knife	60 minutes	R. ventricle	Recovery	.....	.....	Well 3 years
10	M.	24	Ice-pick	Not known	Pul. artery	Death	Pneumonia	2 days	Necropsy not done
11	M.	34	Knife	Not known	R. ventricle?	Recovery	.....	.....	Well 5 years
12	M.	22	Ice-pick	Not known	L. ventricle	Death	Bacteremia	36 hours	Necropsy; wound healed
13	F.	36	Ice-pick	"Few min."	L. auricle	Recovery	.....	.....	Well 2 years
14	F.	30	Ice-pick	"Few min."	R. ventricle	Recovery	.....	.....	Well 2 years
15	M.	20	Knife	15 minutes	R. auricle	Recovery	.....	.....	Well 15 months
16	M.	43	Knife	Not known	L. auricle	Death	Hemorrhage	None	Died from hemorrhage at operation
17	M.	36	Knife	30 minutes	R. auricle	Death	Infection	3 days	Necropsy not done
18	M.	22	Knife	1 hour ?	R. auricle	Death	Hemorrhage	None	Died from hemorrhage at operation
19	M.	30	Ice-pick	Not known	L. ventricle	Death	Pneumonia	2 days	Necropsy; wound healed; pneumonia
20	M.	30	Knife	Not known	R. ventricle	Recovery	.....	.....	Well 11 months
21	F.	28	Ice-pick	"Few min."	Aorta	Recovery	.....	.....	Well 2 years
22	M.	..	Ice-pick	Not known	Aorta	Death	Pneumonia	2 days	Necropsy not done
23	M.	38	Ice-pick	Not known	L. ventricle	Recovery	.....	.....	Well 2 years
24	F.	..	Knife	1 hr. 20 min.	L. ventricle	Death	Tamponade	None	Died during operation
25	F.	19	Knife	1 hr. 30 min.	R. ventricle	Death	Hemorrhage	5 hours	Did not react
26	M.	29	Knife	Not known	R. ventricle and coronary	Recovery	.....	.....	Well 16 months
27	M.	24	Knife	Not known	R. ventricle and coronary	Recovery	.....	.....	Well 16 months
28	M.	..	Knife	30 minutes	R. ventricle	Death	Hemorrhage	None	Died on table
29	M.	39	Knife	Not known	R. ventricle	Recovery	.....	.....	Well 15 months
30	M.	40	Knife	30 minutes	R. ventricle	Recovery	.....	.....	Well 10 months
31	M.	39	Ice-pick	Not known	L. ventricle	Recovery	.....	.....	Well 11 months
32	M.	28	Knife	Not known	R. auricle	Recovery	.....	.....	Well 11 months
33	M.	35	Knife	Not known	R. auricle	Recovery	.....	.....	Well 10 months
34	M.	24	Knife	30 minutes	R. and L. auricle	Death	Hemorrhage	24 hours	Secondary hemorrhage; int. mammary artery
35	F.	38	Knife	Not known	R. auricle	Recovery	.....	.....	Well 3 months
36	M.	21	Knife	1 hr. 50 min.	R. ventricle	Death	Tamponade	2 hours	Respiratory death
37	M.	24	Pistol	50 minutes	R. ventricle	Recovery	.....	.....	Well 2 months
38	F.	19	Ice-pick	1 hour	L. auricle	Recovery	.....	.....	Well 3 months

TABLE II

CAUSE OF DEATH

	No. of Cases
Hemorrhage	6
Pericarditis, infection	3
Pneumonia	4
Emphysema	1
Tamponade	2
Total	16

TABLE III

LOCATION OF WOUND

	No. of Cases	Pat's. Recov.
Aorta (intrapericardial)	2	1
Pulmonary artery (intrapericardial)	1	0
Right auricle	6	4
Left auricle	3	2
Right and left auricle	1	0
Right ventricle	14	10
Left ventricle	8	3
Right ventricle and coronary	3	2
Totals	38	22

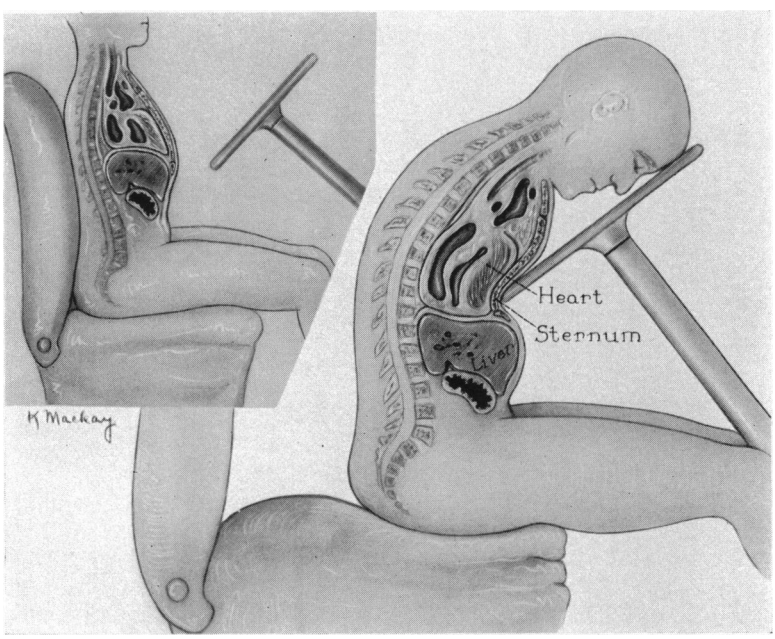

FIG. 14.—Diagrammatic representation of cardiac injury by the impact of a steering wheel.

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