PECTUS EXCAVATUM

REPORT OF TWO CASES SUCCESSFULLY OPERATED UPON

RICHARD H. SWEET, M.D.

BOSTON, MASS.

UNTIL Dr. A. Lincoln Brown[1] reported his operation, experiences with the correction of the deformity known as pectus excavatum were disappointing. The application of traction by various methods and the several plastic procedures, mostly of a minor and inadequate nature, were of necessity doomed to failure when considered in the light of an accurate understanding of the anatomic facts regarding the deformity. There were obvious objections to resection of a part of the sternum, although that radical procedure was of course better calculated than any others then available to relieve extreme degrees of pressure upon, or displacement of, the heart.

At the Massachusetts General Hospital our attempts to correct or relieve the condition in a few cases resulted in complete or partial failure, and the thought of operating upon such patients had been practically abandoned.

In 1943, the opportunity arose to apply the principles put forth by Doctor Brown. The success of the operation in these two cases prompts me to report them in considerable detail. It is desirable also to propose certain minor modifications of technic which may be worth the consideration of those who have occasion to perform this ingenious operation.

In May, 1943, Dr. Paul White referred to the Surgical Service two sisters, age 14 and 5 years, respectively, for consideration of the possibility of surgical correction of pectus excavatum. The elder child had suffered serious circulatory disturbances as a result of this deformity, which in her case was of extreme degree. But in addition she was much disturbed emotionally because of the anomaly. Her embarrassment because of the deformity was so extreme that she refused to wear a bathing suit, and was exceedingly shy about allowing anyone but her physicians to see her chest without clothing. She had grown rapidly and was taller than other girls of her age. She was so sensitive about her unusual height that she had accentuated her naturally stoop-shouldered posture so as to diminish her apparent tallness. The resulting poor posture tended to accentuate the chest wall deformity. Thus, she presented two cardinal indications for surgical correction of the pectus excavatum, namely, disturbances of the circulatory mechanism and the unfavorable effect of the deformity upon the psychology of the patient. In the hope that her appearance might be improved, this child was eager to be operated upon.

In the case of the younger sister no symptoms had been observed and she was too young to be disturbed about her appearance. But the deformity had become steadily more prominent as she had grown from infancy.

There was no clear-cut history of other examples of the deformity in the family. There were four siblings, all of whom were normal. The father, who was normal, had died. Their mother was of the impression that one paternal uncle had a pectus excavatum, but her knowledge of her husband's family was incomplete. The mother's family was free from any suggestion of the deformity for at least several generations.

ANATOMIC CHARACTERISTICS OF THE DEFORMITY

Without attempting to elaborate upon the possible causes of pectus excavatum or to improve upon the excellent description of the abnormal anatomy given by Brown,[1] several impressions resulting from the study of the two sisters referred to in this communication are presented. In each case the diaphragmatic attachments to the sternum, the importance of which is stressed by Brown, were found and cut as a part of the operative technic, but these structures were not abnormally large or strong. The substernal membrane or ligament did not appear to be a very important structure in these cases. The degree of depression of the gladiolus, however, was so severe in the older girl that the apex of the funnel-shaped deformity was actually about 1 cm. posterior to the plane of the anterior surface of the vertebral bodies and to the left of them. In the younger girl there was just room enough during expiration to insert a finger between the deepest portion of the sternum and the anterior surface of the vertebral bodies.

The skeletal deformity in both cases was characterized by what appears to be an anomaly of both the sternum and the costal cartilages, and of necessity the costochondro-sternal articulations of the lower three or four ribs. One is impressed in pectus excavatum by the fact that the gladiolus of the sternum, after being freed from its attachments within the mediastinum and liberated from the costal cartilages so as to bring it up from the bottom of the deep depression, is of essentially normal size and shape. Its upper portion near the manubrio-gladiolar junction has a posterior inclination, but once this has been corrected by a wedge-shaped transverse osteotomy the gladiolus appears to be normal. Its inferior end, actually at its junction with the xiphoid, represents the deepest point of the funnel deformity, the sides of which are made up of costal cartilages, upper abdominal wall, xiphoid, and gladiolus itself. When the deformity is well marked, no amount of release of pull by dividing the substernal attachments of the diaphragm, the ligaments, or the fasciae would appear to have much effect on improving the condition. In the cases with a deep depression it seems almost as though the sternum is pushed down against the spine by unusually long, inward-curving costal cartilages rather than that it is pulled down to the spine by the attachments beneath. Experience with the operation proposed originally by Brown, and described here, demonstrates that unless appreciable lengths of the lower costal cartilages are resected, it is impossible to correct the deformity even after releasing the pull of the substernal diaphragmatic and fascial attachments and the removal of a wedge of bone at the upper limits

of the gladiolus. One gets the impression, therefore, that the deformity may be primarily skeletal.

That there is, however, an inward motion of the lower end of the sternum during inspiration was well demonstrated in each of the two girls whose cases are under discussion. This was obvious from the measured decrease in the anteroposterior diameter of the chest on deep inspiration as compared with full expiration. It was also observed at operation most strikingly in

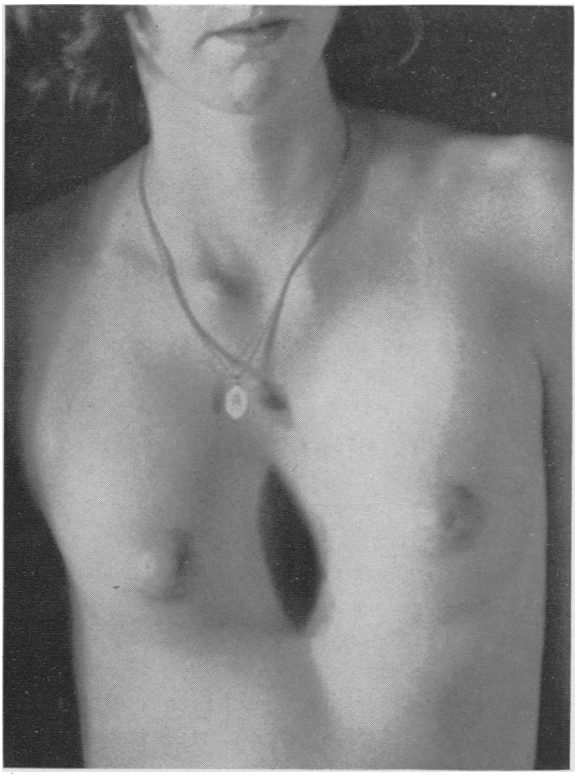

FIG. 1.—Case 1: Preoperative appearance of the chest, showing marked pectus excavatum. Note the locket hanging off the chest wall because of the funnel-shaped depression.

the younger child. In her case at operation during expiration there was just room enough to insert the index finger between the posterior surface of the sternum and the anterior surface of the spine. But during inspiration the sternum was depressed so firmly that the finger could not be withdrawn until released by the relaxation which occurred during expiration. This occurred even after the diaphragmatic attachments to the sternum itself had been severed.

CASE REPORTS

Case 1.—M. G. H. No. 343479: J. H., female, age 14, was admitted to the Massachusetts General Hospital, September 7, 1943, because of a marked funnel chest deformity,

which had been present since birth and which had become worse as the patient had grown older. About four years before admission she had begun to have attacks of palpitation coming on at irregular intervals and lasting from four to 24 hours. During these attacks the pulse had been regular, but the rate had gone up as high as 150 according to the patient's mother. She had had no dyspnea, chest pain, or pain in the arms associated with these attacks, but her mother said her lips had been blue during them. Following the attacks she had occasionally had slight pain in her chest lasting for an hour or two. There had never been any evidence of rheumatic fever or joint trouble.

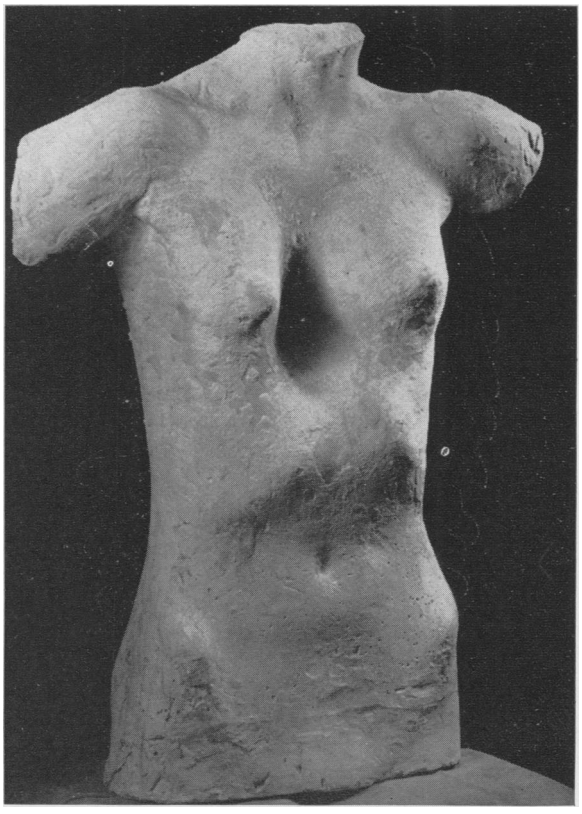

FIG. 2.—Case 1: Plaster model made directly from the patient by Dr. Carroll Larsen for the purpose of studying the deformity and as a permanent record for future comparison. This shows the extreme depth of the sternal depression somewhat more clearly than the photograph of the patient.

She had been studied in the Cardiac Clinic where a diagnosis of paroxysmal tachycardia had been made. On roentgenologic examination it was found that the lower extremity of the sternum touched the vertebral bodies. In the anteroposterior view the heart shadow was entirely in the left hemothorax extending to the left chest wall. The transverse diameter of the heart was 14.5 cm. The internal diameter of the thorax was 23.5 cm. In the right anterior oblique view the transverse diameter of the heart became 11.2 cm. and in the lateral view the depth of the heart measured about 8.4 cm. The heart appeared to be enlarged as well as flattened. An electrocardiogram showed rather marked right axis deviation with slight elevation of ST_1 and slight depression of ST_3, which was interpreted as evidence of quite marked right

ventricular strain and hypertrophy. These changes were believed to be dependent upon compression of the heart by the sternal deformity rather than on an associated cardiac defect, congenital or valvular. A consultation was, therefore, requested as to the possibility of surgical correction of the deformity.

There was no definite family history of funnel chest, but the patient's sister, five years old, had the same condition. Her father was known to have heart disease for a few months prior to his death from coronary thrombosis a year before her admission to the hospital and a paternal uncle and grandfather had some heart disease.

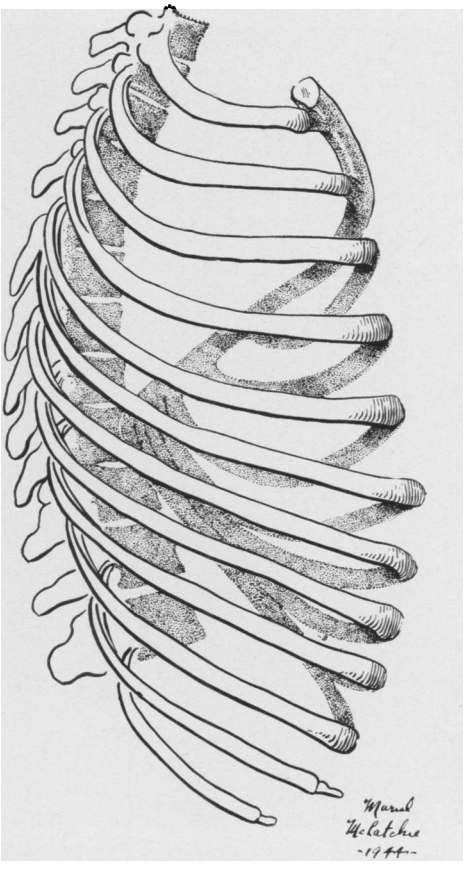

FIG. 3.—Case 1: Diagram of rib cage. Lateral view showing the relation of the sternal depression to the dorsal spine. Note the elongation and deep incurving of the lower costal cartilages.

Physical Examination.—This showed a tall, thin girl, age 14, with a long thin chest. There was some left middorsal scoliosis with a reverse dorsal curvature of the spine above this, but no kyphosis. There was marked depression of the sternum with a distance of only 9 cm. between the front of the sternum at the depth of the deformity and the back of the spine. The trachea was deviated to the left and the entire heart appeared to be pushed into the left chest. The pulse was regular at 80. Blood pressure 130/80. There was no edema and no evidence of arthritis. The lungs were clear and resonant. On examination of the heart the apex impulse was felt in the seventh interspace in the midaxillary line, 12 cm. from the midsternal line and 4 cm. beyond the midclavicular line. There was no dullness above the third rib, but the left border of cardiac dullness

agreed with the palpable impulse. The right border extended to the sternum. P2 was double. There was a moderate harsh systolic murmur at the apex, slight at the base. No diastolic murmurs were heard. The apical systolic murmur was loud at the left lung base in the back. Chest expansion at the upper thoracic level was 1 inch, at the lower thoracic level 1.5 inches, measured with the spine straight.

Laboratory examination of the urine was negative. The red blood cell count was 5,700,000, and the hemoglobin 90 per cent. Hinton test was negative.

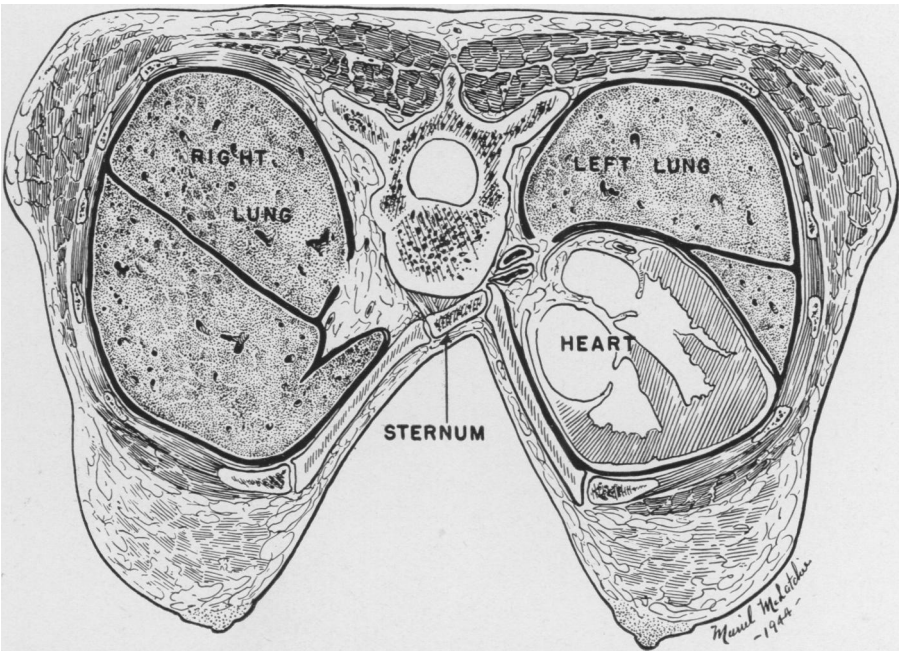

FIG. 4.—Case 1: Diagram showing the relations of the viscera and the chest wall deformity at the level of the apex of the funnel-shaped depression just above the junction of the xiphoid process with the gladiolus. Note the heart pushed completely into the left side of the chest with its apex against the left lateral wall of the thorax. The deepest point of the depression is actually posterior to the plane of the anterior surface of the vertebral bodies.

Operation was planned for October 1, but after the patient had reached the operating room, she had a sudden attack of paroxysmal tachycardia, with cyanosis and slight congestion of the neck veins. The pulse rate was over 160, and the blood pressure fell to 80 mg. of Hg. systolic. There was prompt relief after the intravenous injection of 6 cc. of cedilanid and on October 3, the patient was started on two grains of quinidine t. i. d. Her course was satisfactory and operation was finally performed on October 9, 1943.

Operation.—A vertical midline incision was made. The xiphoid process was removed, the rectus abdominis muscles were reflected from their attachments to the sternum and adjacent costal cartilages, and the diaphragmatic attachments were cut. The costal cartilages were then divided, but it was observed before this was done that the sternum was pulled in so deeply that it lay to the left and posterior to the anterior surface of the vertebral column. After cutting the costal cartilages all the way up to the second, it being necessary to divide the third in this patient, a transverse wedge-shaped piece of bone was removed from the sternum just below the articulations of the second cartilages. Three wire sutures were used to hold the trimmed lower portion of the sternum up in the proper position. Large segments of costal cartilage were

removed, fitting each one in turn so as to restore the chest to a reasonably normal contour. These were held in place by heavy silk sutures. Following this the muscle layers were reattached excepting the diaphragm. In closing the skin it was necessary to remove a redundant portion from one side because of the fact that after the deep funnel-shaped deformity had been corrected, there was too much skin.

The patient's postoperative course was complicated only by two attacks of paroxysmal tachycardia occurring one day and 12 days after operation, with improvement on administration of quinidine. An electrocardiogram taken on the 12th day showed the P waves more prominent than formerly. She was instructed in good posture and arm positions to assist in chest elevation and was discharged in good condition on the 17th postoperative day.

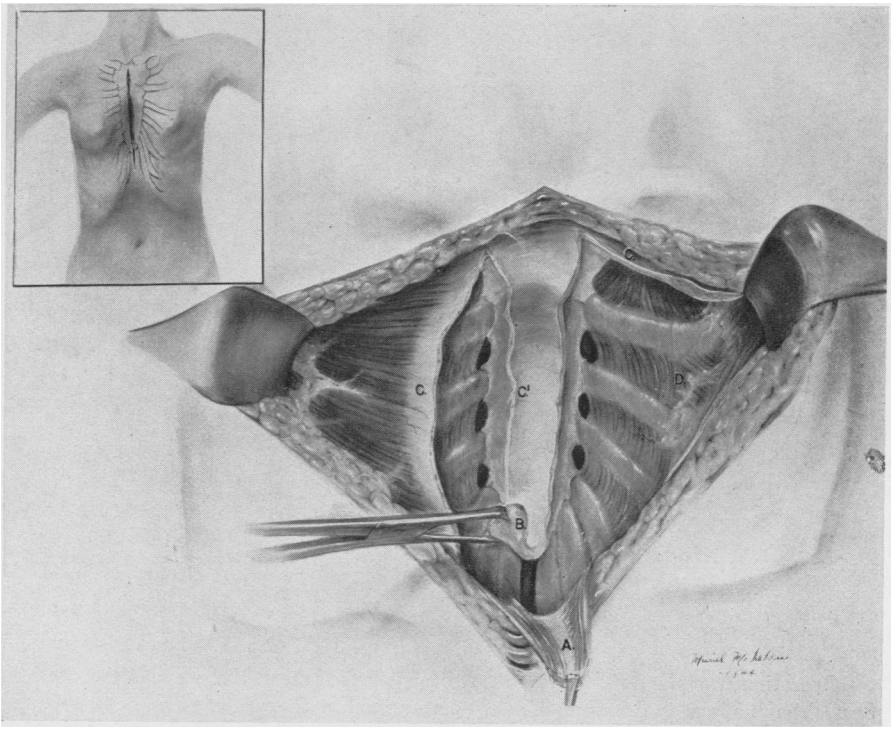

FIG. 5.—Case 1: Beginning of operation showing exposure. Insert gives line of incision. (A) Linea alba and a portion of each rectus abdominis muscle reflected after freeing from xiphoid and lower costal margin; (B) xiphoid process held up with tenaculum; (C) fascia of the pectoralis major muscle after separating it from the anterior surface of the sternum (C'); (D) pectoralis major muscle freed from underlying costal cartilages and retracted.

The patient reported for a postoperative check-up a month after discharge from the hospital. She had been fairly well except for a few short spells of paroxysmal tachycardia. The wound was well healed. The sternal depression was largely corrected so that the distance from the front of the sternum to the back of the spine was about 13 cm. The apex impulse was felt in the fifth interspace, 9 cm. to the left of the midsternal line. The systolic murmur was present in the left back as before. Fluoroscopy showed a large heart shadow, rather flattened anteroposteriorly and largely in the left thorax, but there was much more room in the mediastinal space. An electrocardiogram showed little change. T2 was less inverted, which was interpreted as possibly a sign of decreased right ventricular strain.

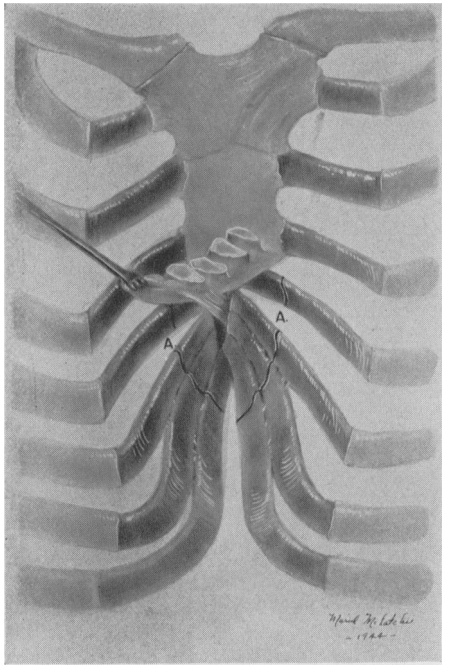

FIG. 6.—Case 1: Diagram to illustrate freeing of the sternum from the costal cartilages. The third cartilages have not yet been cut across. Note how the cartilages fall together after pulling sternum up. Line A indicates the location of the final divisions across the cartilages. All the cartilage between this line and the margin of the sternum is to be discarded.

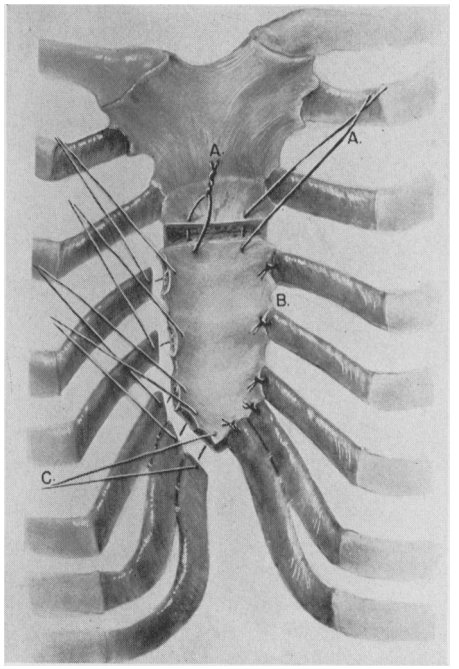

FIG. 7.—Case 1: Diagram to illustrate the method of fixing the sternum in its elevated position by wire sutures, (A) which approximate the edges of the defect left after removing a transverse wedge of the bone below the level of the second costal cartilages. Heavy silk sutures used to fasten the costal cartilages to the sternal edge shown tied on the left (B) and ready to be tied on the right (C).

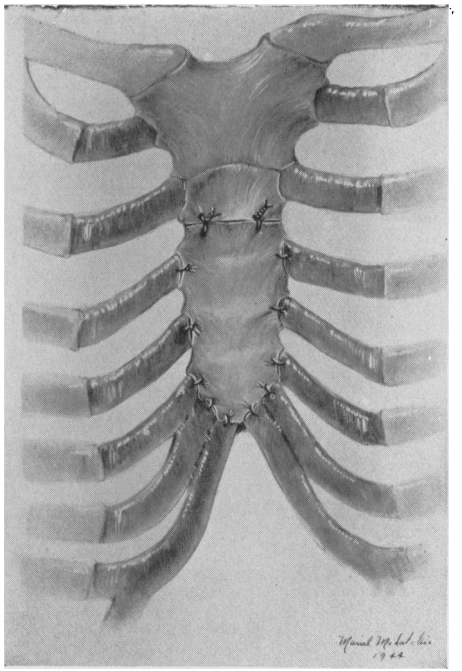

FIG. 8.—Case 1: Diagram showing all sutures in place after trimming the cartilages and removing a transverse wedge from the sternum, thus correcting the funnel-shaped depression.

Case 2.—M. G. H. No. 384900: P. H., female, age 5, sister of the patient described in Case 1, was admitted to the Massachusetts General Hospital, September 9, 1943, because of an apparently congenital funnel chest deformity. When the patient was six months old the mother had first noticed a depression of the anterior chest which had become more prominent as the patient became older. She had had no complaints and her activity had not been limited. There was no history of bone pain, fractures, swelling, or pain in the joints. She had been seen in the Cardiac Clinic ten months prior to admission, where a diagnosis of funnel chest, with displacement of the heart

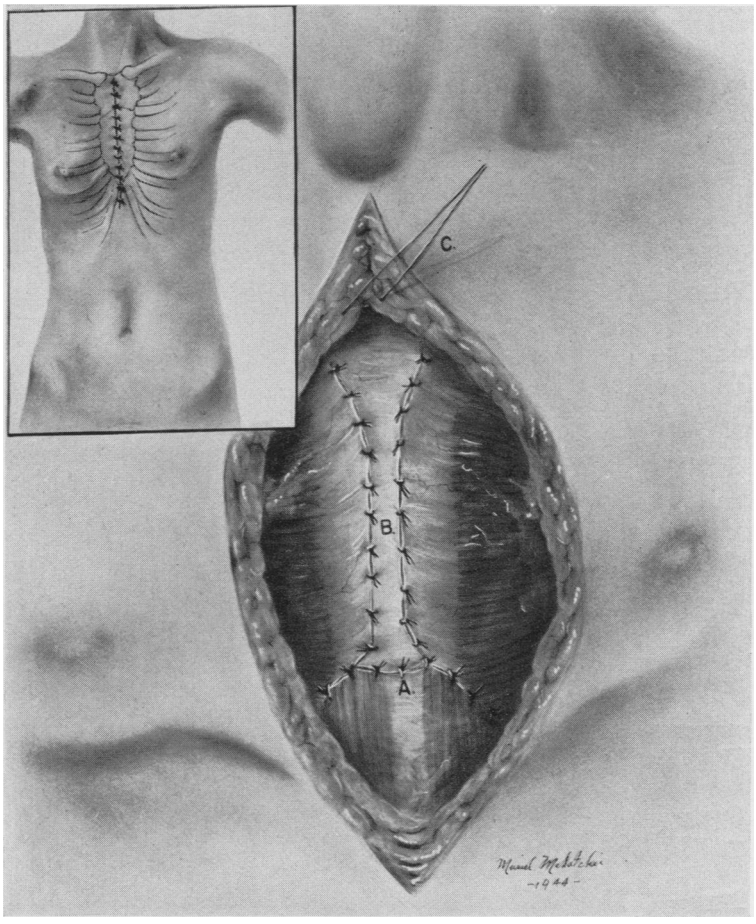

FIG. 9.—Case 1: Completion of the operation. Diagram showing suture of rectus muscles and linea alba to the lower costal cartilages and sternum (A); suture of pectoralis major muscle fascia to the sternum on each side (B); closure of the superficial fascia and fat begun (C). Insert shows completion of skin closure.

to the left and questionable cardiac compression had been made. Examination of the heart at that time by fluoroscope showed it to be almost entirely in the left chest and not much enlarged. An electrocardiogram was reported to be within normal limits.

Physical Examination.—This showed a well-developed and well-nourished girl, with good color. There was a large, hemispherical depression in the mid and lower sternum, about 3 x 3 cm., with characteristic sinking-in on deep inspiration. There was a moderate degree of scoliosis, apparently structural, with convexity to the left in the thorax and to the right in the lumbar region. Examination of the heart showed

the apex in the midaxillary line, impulse forceful, sounds of good quality. Rate was 100 and rhythm regular, with a rare extrasystole. There was a double mitral murmur of moderate intensity as well as a Grade III late apical systolic murmur heard all over the precordium, which became louder as one went to the left around the chest, becoming maximum, Grade IV, posteriorly just under the angle of the scapula on the left. There was a palpable thrill transmitted to the left axilla and pulmonic region. There was no diastolic murmur. The heart was apparently in the left chest, with the point of maximum impulse 4 cm. to the left of the midclavicular line. Vital capacity 870.66 cc. Blood pressure 90/65.

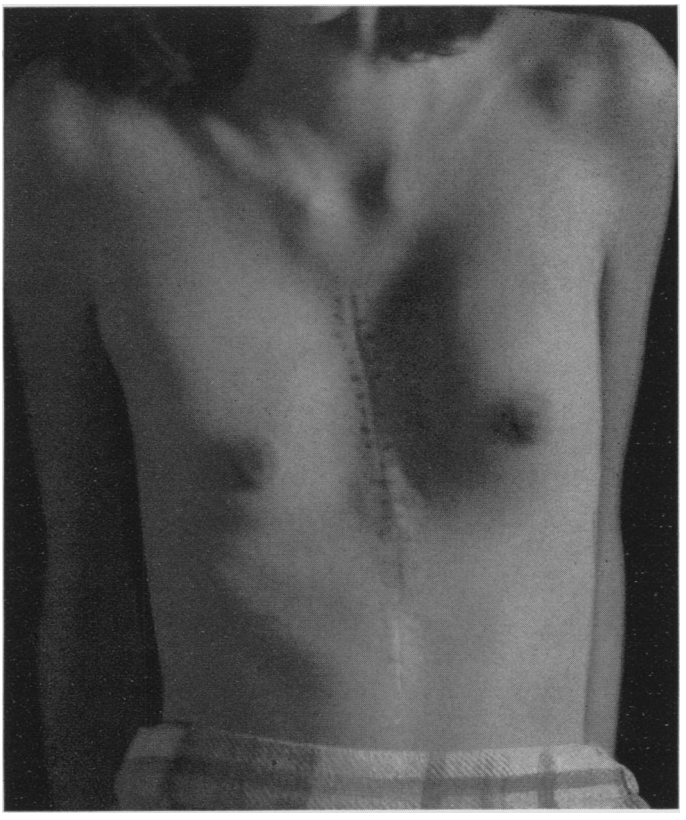

FIG. 10.—Case 1: View of chest two and one-half months after operation, showing correction of deformity.

Roentgenologic examination of the heart showed it displaced entirely into the left chest by the thoracic deformity, the apex reaching almost to the left lateral chest wall. It did not appear to be enlarged. An electrocardiogram revealed the axis shifted to the right with the P waves inverted and diphasic.

Examination of the urine showed it to be normal. The red blood cell count was 4.46; white cell count 9,600. The nonprotein nitrogen was 12 mg., and the serum protein 6.8 per cent.

Operation.—September 25, 1943: A vertical incision was made in the midline from the manubrium of the sternum to the upper abdominal wall. This was deepened down to the sternum. The xiphoid process was then freed-up and the attachments of the rectus muscle were freed from the costal margin and retracted. The sternal attachments

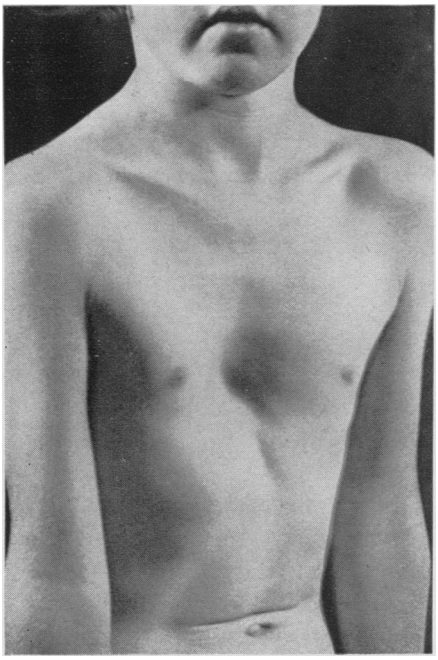

FIG. 11.—Case 2: Preoperative appearance of chest showing characteristic depression of lower portion of sternum.

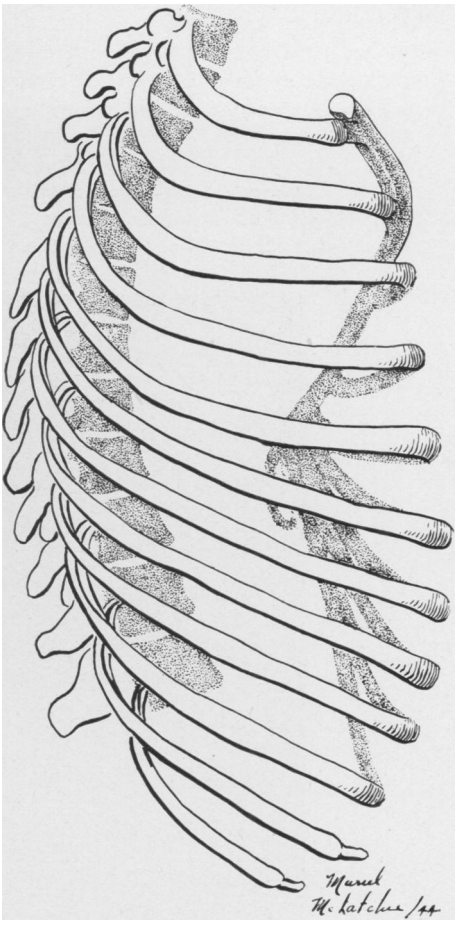

FIG. 12.—Case 2: Diagram of rib cage showing depth of sternal depression in this case.

of the pectoralis muscles were then severed and retracted. The costal cartilages, beginning from below and working upwards, were then cut across about 1 cm. from the sternum and division was carried up to the third cartilage on each side. The sternum was trimmed so as to free it of any costochondral attachments. A transverse osteotomy was performed with the rotary saw across the sternum just below the articulations of the third costal cartilages and a wedge-shaped piece of bone removed. The lower portion of the sternum was swung up and, using two wire sutures to close the gap where the wedge had been removed the lower portion of the sternum was held in a new position, thus correcting the funnel deformity. Segments of cartilage were removed on each side so as to make the rib cartilages fit the sternum again and these cartilages were held to the sternum in its new location by means of heavy silk sutures.

Except for a urinary tract infection the patient's postoperative course was uneventful. Roentgenologic examination of the chest showed the heart still placed somewhat to the left. She was started on postural exercises before leaving the hospital and was to be followed in the Posture Clinic.

She was seen for a follow-up visit on November 19, 1943. The functional and anatomic results were excellent. She was gaining weight, her color was good, and she looked better than before operation. She was cooperating very well with her exercises, and gave a good demonstration of her deep breathing and postural correction. The scar was smoothly healed. An electrocardiogram, November 24, showed little change from the preoperative tracing except with respect to the P waves (at first

diphasic to inverted in leads 1 and 2), with slight axis deviation in all records. Fluoroscopy showed the heart still somewhat displaced into the left chest, but there was ample mediastinal space.

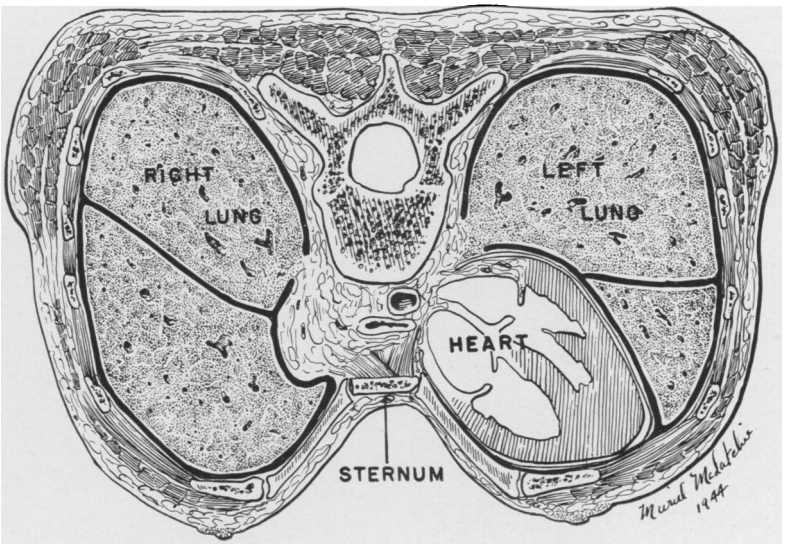

FIG. 13.—Case 2: Diagram showing relations of the viscera and the chest wall deformity at the apex of the funnel-shaped depression. Note the heart pushed to the left but not so far as in Case 1.

TECHNICAL CONSIDERATIONS

In general, the principles suggested by Doctor Brown were followed in the treatment of these two patients. The following minor departures from his method should be mentioned:

(1) A straight midline incision was used instead of the curved semicircular incision. This would seem to be preferable because it gives an exposure which is equally good on both sides of the sternum with a minimum of interference with the circulation to the skin edges.

(2) Excepting for the closure of the transverse osteotomy defect, heavy silk (No. 4 Deknatel) was used instead of wire to approximate the trimmed costal cartilages to the edges of the sternum. The silk gives adequate tensile strength and is more pliable.

(3) No external traction apparatus was employed to keep the sternum in place. Experience with these two cases demonstrates that this part of the procedure is not necessary.

(4) A light breast plate of plaster was made at the end of the operation in each case and moulded so as to fit the contour of the anterior chest wall over the gauze dressing. This was used to help stabilize the anterior chest wall during the first week after operation, during the time when there is such a great tendency to paradoxical motion of the chest wall during respiration. A plaster plaque such as was used in these cases has been found to be an invaluable assistance in the early convalescent-period after the opera-

tion of pericardiolysis and also after excision of a portion of the sternum for removal of tumors of that bone. It has been observed in such cases that the tissues assume enough rigidity of their own so that the plaster plaque can be abandoned after seven to ten days. In these two children the use of this

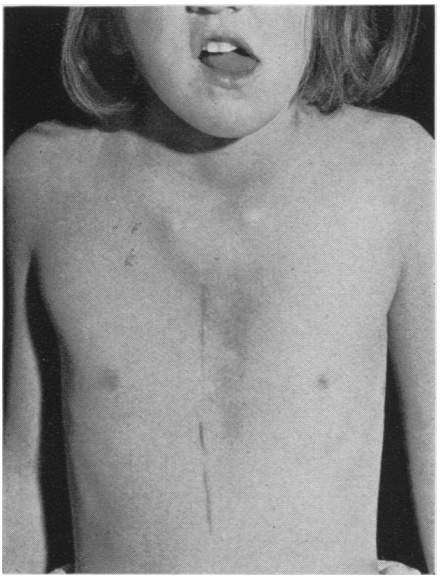

FIG. 14.—Case 2: View of chest three months after operation showing correction of deformity.

support was beneficial and appeared to eliminate the necessity for temporary external traction.

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