PECTUS EXCAVATUM*

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Pectus excavatum or funnel chest is a depression deformity of the thorax. The exact aetiology of this deformity is not known, but the following factors appear to be of significance:

1. *Inspiratory obstruction.* The newborn or very young child shows a marked over-action of the muscles of inspiration, and depression or recession of the ribs as a result of obstruction to inspiration. The over-action of the diaphragm may lead to a funnel-chest type of deformity if the respiratory obstruction is severe and maintained. It is interesting to note that the deformity disappears immediately a tracheotomy is performed. Thus, in the early case, there is every hope of a complete restitution to normal if the obstruction is relieved.

2. *Hereditary factor.* Ample proof exists of the hereditary nature of this lesion. The same deformity may be seen in successive generations of a family, but it is not necessarily present in all the siblings.

3. *The central tendon of the diaphragm.* A number of cases show a definite short tendinous attachment between the central part of the diaphragm and the back of the sternum. Division of this tendon will allow the depressed sternum to spring back into its normal position. An equal number of cases, however, have no evidence of this additional attachment. A substernal ligament is sometimes discovered which is an extension of the linea alba and posterior rectus sheath, to the posterior periosteum of the sternum. This ligamentous attachment is felt as a taut band restraining the lower end of the sternum.

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4. *Abnormal growth of the rib cartilage.* In the condition of pectus excavatum the rib cartilages are longer than normal. This extra length bridges the increased space between the rib and the manubrium sterni. The excess of costal cartilage may be associated with a failure of the ossification of the lower portions of the sternum, which normally occurs at puberty. It is not possible to state, however, whether the overgrowth of these cartilages is the cause or the result of the pectus deformity.

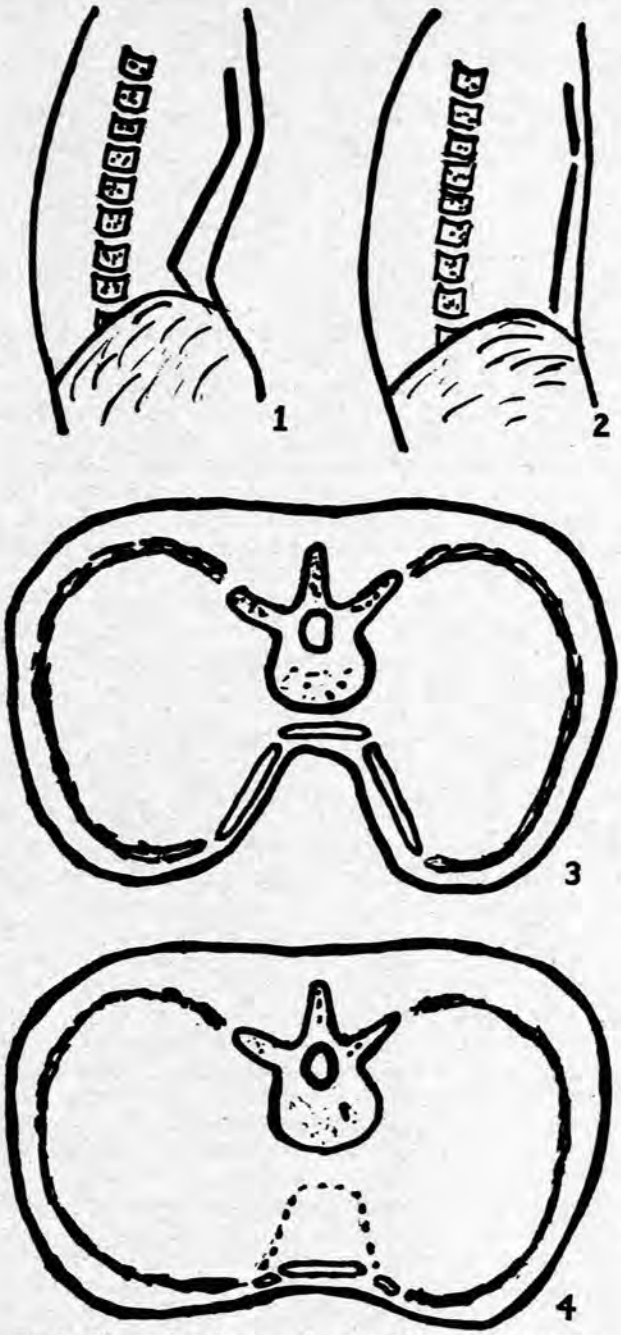


Fig. 1. Illustrating the posterior angulation of the sternum, occurring at the level of the 2nd costal cartilage. This distance between the vertebral column behind and the xiphoid process of the sternum in front may be considerably reduced.
Fig. 2. Illustrating the effect of the posterior osteotomy. The sternum comes forwards away from the vertebral column.
Fig. 3. Section illustrating the elongation of the costal cartilages and demonstrating the depression.
Fig. 4. Illustrating the technique of bringing the sternum forwards. The costal cartilages are made shorter.

SIGNS AND SYMPTOMS

Despite the diversity of aetiology, the clinical picture is the same in all cases, i.e. sternal depression is present. The depth of the depression may vary considerably. In an extreme case there may be only about a 2-inch space between the front of the vertebral column and the back of the sternum, and all the mediastinal structures, particularly the heart, must become adapted to this restricted space or be displaced (Figs. 1-4). In the majority of cases, however, the condition is referred in adolescence for surgery for cosmetic reasons, the patient showing only a sternal depression, without any symptoms.

In support of the theory of an abnormally short central tendon is the fact that the sternum is not only pulled inwards, but also downwards. This downward displacement is in some cases associated with a postural kyphosis, as reported by Lester.

The acute dyspnoea which accompanies pectus excavatum in infancy is invariably due to the respiratory obstruction which has caused the pectus deformity, and not to the deformity itself. The cause of the obstruction, which may be oedema of the glottis, laryngeal stridor, or enlarged tonsils and adenoids, must be dealt with as a matter of urgency. Relief of the obstruction results in the disappearance of the sternal recession.

Older children with pectus excavatum usually give a history of repeated attacks of bronchitis without severe respiratory difficulty. They show the typical deformity associated with a round-shouldered and pot-bellied posture. The deformity nearly always increases in severity as the child grows older, the eventual appearance in adolescence being that of a narrow 'funnel-chested' physique. Psychological problems now ensue, the patient becoming socially unsure and extremely self-conscious, particularly in a bathing costume.

The displacement of the mediastinal structures is usually asymptomatic. Occasionally cardiac flow murmurs develop.

SURGICAL TREATMENT

Time of Operation

Ideally, surgery should be postponed until the child is at least 18 months old. This is not always possible, and a severe degree of funnel chest, or the occurrence of frequent attacks of bronchitis, may necessitate surgical treatment when the infant is less than a year old. Naturally the presence of respiratory obstruction must first be excluded. Operation at this early age may be a relatively minor procedure and may also obviate the necessity for any future surgery when the child is older. Simple division of the tendonous attachment of the diaphragm to the sternum, and division of some of the lower costal cartilages when necessary, generally gives a lasting result.

A formal operation, on the lines to be described later becomes essential if the child is over 18 months old. If the surgical treatment does not conform with the 3 basic procedures mentioned below, re-operation at a later date becomes inevitable. Fortunately the prospects of obtaining good results are excellent, and the operative risks are negligible. The 3 basic procedures are as follows:

1. Taut tendonous attachments to the back of the sternum must be divided.

2. The costal cartilages must be restored to their normal position.

3. The sternum must be elevated.

Anaesthesia

Inhalational anaesthesia with an intratracheal tube must be used in case the pleural cavity is opened, when positive-pressure ventilation becomes necessary.

Operation

A vertical incision down the middle of the sternum, or alternatively a transthoracic incision curving across both sides of the chest and under the breast margins, are the methods of choice. The curved incision is particularly applicable to women patients because the incision falls under the mammary fold. The final result in such cases is excellent cosmetically, as the only evidence of the incision is the small area of scarring across the middle of the sternum. The incision is extended downwards through the subcutaneous tissues to the muscle layer. The sternum is then mobilized in a manner which ensures correction of the deformities without impairment of its blood supply.

As stated above, the costal cartilages of many of these patients are longer than normal. The costal cartilages from the 3rd rib downwards must be exposed on both sides. The 2nd costal cartilage is usually not involved in the chest deformity. The muscle fibres of the pectoralis major are stripped laterally as far as the bony part of each rib. Small perforating arteries are usually present, and these can be preserved if great care is taken. If they are damaged, the bleeding must be controlled by means of artery forceps and diathermy. The costal cartilages are thus exposed in their length from the sternal attachment out to the actual bony part of each rib. The perichondrium over each costal cartilage is then divided and elevated with rib elevators in order to expose the whole sheath enclosing each costal cartilage. The full length of the costal cartilage must be brought to view in this manner.

Difficulty may be encountered in exposing the cartilages of the lower ribs, as ribs 4, 5, 6, and 7 may be crowded together to fuse into a small, almost vestigial, part of the lowest piece of the sternum.

The xiphoid process should be mobilized in the same way. It is generally impossible to find any perichondrium, and consequently it is a waste of time to explore this process. It must, however, be completely freed from the attached rectus abdominus muscle with scissors. The muscle fibres of the rectus abdominus should be deliberately separated from the lower part of the sternum. The xiphoid process is frequently twisted or pulled posteriorly by the shortened tendons of the diaphragm, or it may be angled backwards in such a way that the shortened tendons of the diaphragm are attached only to a part of it, with resultant projection forwards of its lowest portion.

The maximum depression point in the funnel-chest deformity is usually at this site, and consequently a considerable degree of the deformity is relieved the moment the xiphoid process is freed from the underlying fibrous attachment. It may be simpler to separate the cartilaginous xiphoid process from the shortened tendon of the diaphragm rather than to separate the lower portion of the sternum from the xiphoid process, for the xiphoid process will then retract posteriorly with the cartilaginous tendon. The complete separation of the muscle fibres of the rectus abdominus from the lower part of the sternum, and the removal of any remaining posterior attachments of the diaphragm to the cartilaginous portions of the ribs and sternum, are of prime importance. All the cartilaginous parts of the sternum have now been freed from any shortened attachments to the posterior diaphragm, and the perichondria have been elevated from them.

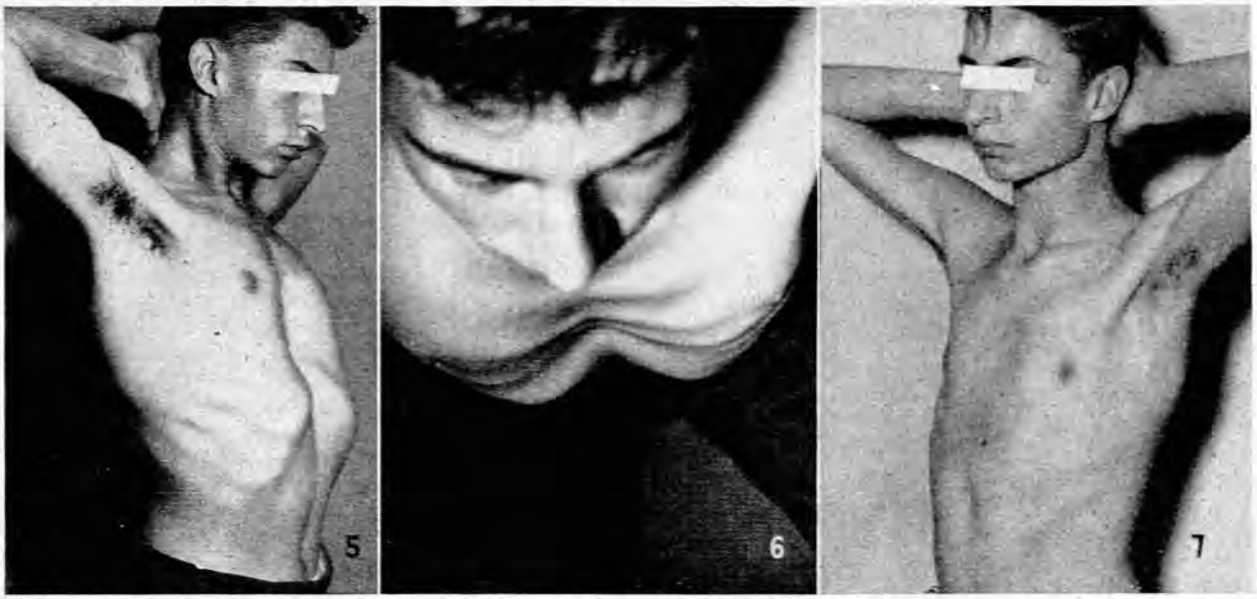
All articles on this subject report that the surgeons have employed the anterior sternal osteotomy. I have not been able to see the purpose of this method if the deformity is due to a posterior displacement of the sternum, usually at the site of the 2nd costal cartilage. In my opinion the important part of the operation lies in the performance of a posterior osteotomy.

Following on the elevation of the perichondrium, a Gigli saw should be passed from one side to the other behind the sternum at the highest possible level. This, in practice, usually proves to be at the level of the 3rd costal cartilage. Care must be taken to ascertain the position of the internal mammary vessels. The Gigli saw is then used to cut through the posterior half of the sternum, and when this has been completed the wire portion of the saw is removed. The sternum is then held with bone-holding forceps, and preparations for the total mobilization of the affected part are now complete.

The costal cartilages should now be divided in such a way that their division will allow of the subsequent fixation of the sternum in its new position. The method is the oblique division of each costal cartilage so that there is a wedge-shaped portion with the sharp edge of the wedge projecting posteriorly. All the costal cartilages should be divided at the site of the deformity, which can be easily seen, since the costal cartilages curve inwards owing to the pulling effect of the central portion of the diaphragm. This portion, of course, has already been divided, so that much of the deformity will have disappeared.

The fixed deformity which has occurred in the costal cartilages during the years of growth must now be corrected. The simple manœuvre of holding the sternum at its lower end with bone-holding forceps and levering it forwards will bring the entire sternum and costal cartilages into a position which is anterior to the rib ends. It may be necessary to assist each portion of rib forwards, and while this is being done the whole sternum will come forward, with the ends of each rib hitching anteriorly to the original sites of their attachment.

All that remains is the completion of the mobilization of the upper portion of the sternum at the site of the posterior osteotomy. The lower end of the sternum is still held with bone-holding forceps, while further leverage is put on it until the posterior portion begins to fracture. This must be done very carefully so that the sternum is not completely broken at the site of the osteotomy. Complete correction must nevertheless be obtained. This displacement is best described as a hinge movement at the site of osteotomy. The whole sternum is then brought forward and easily supported by the ribs ends. The attached intercostal bundles and perichondrial layers will keep the sternum in its new and correct position.



Figs. 5 and 6. Showing the funnel-chest deformity from two angles. *Fig.* 7. Showing the post-operative appearance. The sternum has been brought forwards and excess costal cartilages have been removed.

It will be seen that the sternum is now mobilized, and that its entire blood supply and fibrous attachments have been unimpaired. Rib cartilages showing excessive deformity may have to be trimmed. The important point, however, is that the oblique incision through the costal cartilages must be so maintained as to hold them in front of their original ribs. The original deformity can be seen to have occurred in the costal cartilages only, and not in the bony portions of each rib.

Furthermore, if the lower portion of the sternum is cleared of its perichondrium and periosteum, proof can be obtained in some cases that normal ossification has not taken place. One or even two pieces of the sternum may still be underdeveloped, with a persistence of cartilage in its substance.

The incision is closed by the insertion of absorbable catgut sutures in the deeper structures and subcuticular dermalon in the skin.

During the procedure, the pleural cavities may have been opened. This, however, is not important if the surgeon has controlled all bleeding points. If bleeding continues it will drain into the pleural cavities. As a safety measure the anaesthetist is asked to distend the lungs completely before the final closure. The blood from any hidden bleeding sites will thereby be evacuated from the pleural cavities. The surgeon must then search carefully for any deep bleeding points. If it is impossible to repair the openings into the pleural cavities, intercostal drainage tubes must be inserted to allow the free escape of any collecting blood. These will also aid the lungs in their complete re-expansion.

The subcutaneous tissues are now carefully approximated and the skin incision is closed by means of subcuticular stitching. The sternum is maintained in its new position by means of a stitch which is passed round it and then passed externally to a support on a slab of plaster of paris which has been placed over the chest.

The patient is then taken to the ward, where he is nursed on a bed equipped with fracture boards. Breathing and coughing exercises are started as soon as possible, and the patient is allowed up on the 7th day. Drainage tubes should be removed on the 2nd day.

Stress must be laid on the importance of adequate and frequent postural exercises in the early post-operative stages before the sternum has become fixed.

CONCLUSIONS

Deformities of the sternum are not unusual. The depression deformity, namely pectus excavatum or funnel chest is of fairly common occurrence, and by its very nature causes severe emotional problems. Secondary symptoms are frequent. Surgery is therefore symptomatically therapeutic as well as cosmetic.

All the cases which have been treated have shown improvement, some dramatically. The operation has been performed on 15 cases, 7 of whom were females. One case requried re-operation. There were no deaths and, apart from some slight keloid changes in a few cases, no post-operative complications.