THE SURGICAL TREATMENT OF PECTUS EXCAVATUM (FUNNEL CHEST)

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Pectus excavatum is a depression deformity of the anterior chest wall that has been recognized under a number of names: funnel chest, trichterbrust, chonchondrosternon, koilosternia, and others. Despite the considerable literature on this well-known entity many differences exist concerning its development and management. A brief review of the current concepts and the results of surgical treatment used in this unit are presented.

Aetiology

The exact aetiology is still uncertain. Of the many theories advanced none could serve as a fit basis of treatment until Brown (1939) demonstrated that the deformity was due to a short central tendon of the diaphragm. Brodtkin (1951) observed a diminished inspiratory sternal retraction on the homolateral side following procaine injection of the phrenic nerve. We have noticed an almost complete disappearance of inspiratory sternal retraction when the diaphragm has been paralysed by curare. It does seem likely that some congenital abnormality of the diaphragm is primarily responsible for the condition.

The deformity is noticed shortly after birth, but in some individuals it may not become apparent until later years, and it may be observed by the parents for the first time in early adolescence. That there is a strong genetic factor is well shown by the commonly reported occurrence of multiple cases within a single family and in lineal descent through several generations (Sainsbury, 1947). This has been confirmed in our series. It is characterized by a progressive posterior sternal depression and distortion of the adjacent costal cartilages that begins near the sterno-manubrial junction and reaches its deepest point at the xiphoid. In infancy this retraction may be apparent only with deep inspiration and is best seen when the child is crying, a severe degree of deformity then being produced which immediately corrects itself after the inspiratory effort is over. Unfortunately it often tends to progress to a permanent bony deformity, and there is no way of knowing in which individual this will occur. In one of our cases it progressed from a mobile deformity seen only on deep inspiration to a fixed deformity in a period of six months. The deformity is often symmetrical but not always so. In time a characteristic posture develops. The ribs acquire a lateral flare and the chest becomes flattened and pulled down upon the abdomen, a dorsal kyphosis develops, and the head tends to protrude forward. The appearance is that of a thin round-shouldered, hollow-chested, pot-bellied individual. The costal cartilages dip into the sternum at a steep angle and the xiphoid is often impalpable from the overcrowding of the sixth and seventh cartilages. The depression, which is often extreme, usually deepens on inspiration.

The thoracic viscera may be affected by compression and distortion. Although there is interference with respiration this is seldom at a critical level, and in many instances the commonly used clinical tests of respiratory function may fail to show any serious alterations. There is adequate evidence in the literature to show that symptomatic cardiac disturbances are not uncommon. Electrocardiograms, angiocardiograms, and cardiac catheterization have pro-

vided convincing evidence of disturbed cardiac function. Symptoms of tachycardia, palpitation, arrhythmia, and dyspnoea can occur at an early age. A systolic murmur may be heard, and on the basis of this some of these children have been labelled "heart disease" and precluded from many activities at school.

The purpose of surgical treatment is to correct the sternal and costal cartilage deformity. This is of no value unless persistent post-operative supervision is carried out to see that the patient corrects the kyphosis, which is, of course, secondary to the diaphragmatic and sternal abnormality. The younger the patient the easier this is, and we are reluctant to operate on patients over 20 unless they have symptoms. There is no doubt that these symptoms will be relieved in this older age group, but the bad posture will probably persist.

Infants under the age of 6 months should not have treatment, as inspiratory sucking-in of the sternum may be present in the newborn and gradually disappear during the first few months of life. Delay in treatment is to be condemned, because in the early stage, when the chest wall is still mobile and deformity is produced only on deep inspiration, the operation is a relatively minor one. When the sternum has become detracted down and the costal cartilages are permanently deformed then a more extensive procedure is necessary. Excluding those who are too old and too young, we feel that all cases should have surgery.

It is striking how the patients' and their parents' concern over this disability is masked. When first seen in the out-patient department and accepted for operation their true feelings become more apparent, though restrained. It is only after operation that their real feelings are manifest. There is a reluctance on their part to believe that surgery can offer anything because they have been repeatedly told that nothing can be done. Many of them have had prolonged treatment in physiotherapy out-patient departments with little or no improvement, and an attitude of *laissez faire* exists. These children are often very conscious of their defect. They are shy of their complaint; boys frequently undergo teasing at school and girls feel handicapped, particularly as they reach adolescence. It has impressed us in their first follow-up how they volunteer a sense of well-being and an improved exercise tolerance. This latter is very constant. The patient often states that he can now do far more than he did before and that he can keep up with boys of his age effortlessly, whereas prior to the correction of his pectus he had found difficulty in keeping up. Thus surgery is undertaken: (1) for cosmetic reasons; the penalty for this is a scar which can be hidden, but it is impossible to hide the bad posture in a well-established case; and (2) to alleviate symptoms; these may be severe. It is true that the percentage of cases with symptoms in our series is not representative, as we are more inclined to see cases who have symptoms.

Brown (1939) and Ochsner and De Bakey (1939) put surgical treatment of pectus excavatum on a sound basis. Many modifications and variations have appeared since that time (Sweet, 1944, 1950; Ravitch, 1949; Wahren, 1950; Brodtkin, 1951; Woods *et al.*, 1952; Johnson and Kirby, 1952). Techniques involving the use of plaster casts, various forms of external traction and fixation, grafts of bone and cartilage internally to support the sternum, and plastic operations upon the deformed costal cartilages are in current practice. It is understandable that such a state of confusion should exist, since the exact aetiology of the condition is not completely settled and no one method of treatment has been 100% successful.

Most present-day operations are based upon the principles of Brown. It is mainly in the method of maintaining sternal elevation and in dealing with the deformed costal cartilages that the various techniques differ. We have been impressed with the modification described by Ravitch (1949), and our present technique is based essentially upon this method. It requires no traction or added supports externally or internally.

Technique of the Operation

The anaesthetic consists of nitrous oxide, thiopentone, curare, and oxygen with an endotracheal tube. A midline incision is made from above the upper limit of the deformity to the epigastrium. The pectoral muscles are dissected laterally to expose the full length of the deformed costal cartilages. Because of the crowding and depression, the lowermost two costal cartilages on each side usually need to be resected to expose the xiphisternal junction. After dividing this a tough fibrous band may be seen running from the posterior rectus sheath to the back of the sternum. This is not always present. When this so-called substernal ligament is divided the xiphoid and rectus retract, sometimes with an audible snap. It is now possible to palpate the entire posterior surface of the sternum and to free all adhesions and remaining diaphragmatic attachments.

If the costal cartilages are deformed they must be completely removed to the level where the posterior angulation of the sternum begins (Fig. 1). The remaining intercostal

structures are severed from the sternum, leaving it completely free except for its junction with the manubrium. At the site of angulation a transverse cuneiform osteotomy is made through the anterior cortical lamella of the sternum. In children an ordinary gouge is adequate; adults may require an osteotome. The sternum now may be bent sharply anteriorly to fracture the posterior cortical table. By means of two or three vertical mattress sutures the sternum can be maintained in a

FIG. 1.—Diagram showing the third, fourth, fifth, sixth, and seventh cartilages removed on the left, and the fifth being enucleated on the right, leaving the posterior perichondrial layer intact. The xiphoid has been detached with the rectus after division of the substernal ligament. The upper line shows the usual site of the transverse osteotomy.

position of slight over-correction. The pectoral muscles are sutured to the periosteum of the anterior surface of the sternum near the midline and the wound is closed without drainage. A simple gauze dressing is used to cover the incision, and the patient is got up and dressed the following day. There has been no fixation in any case.

If the operation is done in infancy, before there is any fixed deformity of the sternum or the costal cartilages, only a small transverse incision is needed over the xiphisternum. The xiphisternum joint and the substernal ligament are divided and the sternum and the lowest costal cartilages are freed of any diaphragmatic attachments. We have abandoned subperichondrial resection of the costal cartilages, since it can be tedious and is felt to be unnecessary. A section of each side of the cartilage is freed from the intercostal insertions and a curved blunt periosteal elevator is inserted beneath the cartilage and elevated. This elevated cartilage is then easily divided with a knife and each end picked up in turn with a towel clip, stripped free, and removed. A narrow strip of posterior perichondrium is usually left. The chest becomes firm in two weeks.

In a case with fixed deformity it is essential to be radical. If the deformity of the third costal cartilage is present but not marked it is wrong to spare it. This mistake was made in Case 2; the cosmetic result has been spoilt by the overgrowth of this third cartilage and the patient has a mild degree of pectus carinatum.

The extent of the deformity in each individual must be carefully assessed clinically and at operation to ensure complete removal of all deformed costal cartilages. No harm follows accidental opening of the pleura with an endotracheal tube in place. The lung is kept inflated, the pleura is closed, and any small remaining pneumothorax is allowed to absorb. Occasionally fullness beneath the lower end of the incision will require aspiration, but routine drainage of this space has not been found to be necessary. Respiratory paradox of the anterior chest wall has not been a problem. It was seen in only one patient; she developed a lung infection two days after the operation and the paradox was rapidly brought under control by giving her four million units of penicillin a day. Diligent pre-operative and post-operative physiotherapy is most important in achieving a smooth convalescence and a good result.

The early results in this series of 10 patients is very satisfactory, the longest follow-up being 11 months. Concerning the question of later recurrence, we gain solace from the report of Ravitch (1951), whose patients, treated in this way, have been followed up for five and six years with no evidence of recurrence.

Case Reports

Full reports on all these cases are not given, as in many this would be repetitive; only cases with features of interest are discussed.

The age range of the patients was 2 to 17 years. There were seven males and three females.

Case 1.—A girl aged 15 had had severe symptoms for two years. She was afflicted by frequent attacks of giddiness, which were quite unrelated to any particular posture or

FIG. 2

FIG. 3

FIG. 2.—Case 1. This patient presented with symptoms of pain, dyspnoea, giddiness, and palpitation. Severe degree of deformity and paradoxical movement on inspiration. FIG. 3.—Case 1. Follow-up 11 months post-operatively. Correction maintained and symptoms alleviated.

movement. For 18 months she had noticed a persistent sense of constriction in the chest and on exercise experienced incapacitating discomfort along the subcostal margin, this being always associated with severe palpitations. At the end of a day at school her ankles were swollen. She had ceased all sporting activities because of pain and dyspnoea. On examination the typical deformity of a well-established funnel chest was seen (Fig. 2). Her kyphosis was not fixed,

and there was marked paradoxical movement of the sternum on inspiration. X-ray examination showed a rotation of the heart into the left chest. Angiocardiogram revealed no filling defect. E.C.G. was normal and the circulation time using dehydrocholic acid was seven seconds. In July, 1952, the deformity was repaired. The result is shown in Fig. 3. At her last follow-up, 10 months after operation, there was no recurrence of deformity, her posture was excellent, and she had no disability.

Case 2.—A boy aged 5 had been subject to "bronchitis" all his life. The deformity was first noticed when he was 2½, and it had progressed since. In all respects he seemed a healthy boy except for his recurrent chest infections. On examination a well-marked deformity was seen. On inspiration there was a severe degree of paradoxical movement of the sternum. Repair was carried out. He had a well-formed substernal ligament, and when this was divided the xiphoid and recti sprang away. The mistake was made of not being radical enough; the third costal cartilage should have been removed on either side. His follow-up from the cosmetic point of view was disappointing in that there was some overgrowth of the third costal cartilage. There was no paradox, and since his operation nine months previously he had had no further attacks of bronchitis; this was the longest period he had been free of chest infection.

Case 3.—A boy aged 10½ was completely symptomless. His parents requested the operation because they were a Service family and were anxious for the boy to go ultimately into the Services. Also, they lived in a families camp and

FIG. 4

FIG. 5

FIG. 4.—Case 3. This patient had no symptoms. FIG. 5.—Case 3. Photograph taken just before discharge.

had seen a previous case returned from the unit. Fig. 4 shows the degree of deformity. This boy had a marked paradox. Fig. 5 was taken immediately before his discharge and well illustrates the need for close supervision over the next three to five months.

Case 4.—A girl aged 13 complained of pain in the xiphisternal region associated with exercise. It was a sharp non-radiating pain. It had been present for one year. She became more breathless than her friends and at times found it difficult to keep up with them. Because of a murmur in her heart the school doctor had years previously told her that she had heart trouble. Examination showed typical funnel-chest deformity. There was a systolic murmur over the mitral area. The deformity was repaired; the murmur has now disappeared, and she indulges in full activities without any discomfort.

[Since this paper was submitted five additional cases have been repaired. They have all done well and no complications have arisen.]

Summary

The current concepts of pectus excavatum are briefly reviewed.

A prophylactic operation is advised at an early age to prevent a progressive and permanent deformity. The two main indications for surgery are cosmetic and symptomatic. The technique employed requires no external traction or added internal support. In infancy the dividing of the xiphisternal joint and freeing of the sternum from the diaphragm correct the deformity. Older subjects require the added resection of all deformed costal cartilages and a transverse wedge osteotomy of the sternum.

Ten patients treated by this method are presented. There were no deaths or complications. The early results are satisfactory and encouraging. It is necessary to be radical and to excise all the deformed cartilages.

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ANTIHISTAMINE THERAPY

WITH SPECIAL REFERENCE TO SKIN DISORDERS

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During the past five years a separate out-patient clinic has been held twice a month for the purpose of studying the administration and overall value of the antihistamine group of drugs. Most of the patients attending the clinic have had urticaria. The main problems connected with the use of these drugs can be dealt with under headings of administration, ill-effects, and skin disorders affected.

The Drugs Available

The following drugs of the group are available for oral use in this country.

Official Name	Proprietary Name
Antazoline	Antistin (Ciba)
"	Histotab (Boots)
"	Ben-a-Hist (Bencard)
Bromazine	Ambodryl (Parke, Davis)
Chlorcyclizine hydrochloride	Histantin (Burroughs Wellcome)
"	Di-paralene (Abbott)
Diphenhydramine hydrochloride	Benadryl (Parke, Davis)
Mepyramine maleate	Anthisan (May & Baker)
Methaphenilene hydrochloride	Diatrin (Warner)
Phenindamine hydrogen tartrate	Theophorin (Roche)
Promethazine hydrochloride	Phenergan (May & Baker)
Tripeleannamine hydrochloride	Pyribenzamine (Ciba)
Meclozine dihydrochloride	Ancolan (B.D.H.)
None	Aetidil (Burroughs Wellcome)
None	Synopen (Geigy)

"Dibistin" (Ciba) is a mixture of antazoline and tripeleannamine.

"Avomine" (M. & B.) and dimenhydrinate ("dramamine," Searle) contain antihistamines but are primarily used for travel sickness.