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Editorial Update

Current Management of Pectus Excavatum

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Abstract. Pectus excavatum (PE) is one of the most common anomalies of childhood. It occurs in approximately 1 in every 400 births, with males afflicted 5 times more often than females. PE is usually recognized in infancy, becomes much more severe during adolescent growth years, and remains constant throughout adult life. Symptoms are infrequent during early childhood, but become increasingly severe during adolescent years with easy fatigability, dyspnea with mild exertion, decreased endurance, pain in the anterior chest, and tachycardia. The heart is deviated into the left chest to varying degrees causing reduction in stroke volume and cardiac output. Pulmonary expansion is confined, causing a restrictive defect. Repair is recommended for patients who are symptomatic and who have a markedly elevated pectus severity index as determined by chest X-ray or computed tomography scan. Repair using the highly modified Ravitch technique is usually performed after the age of 8 years. The optimal age for repair is between 12 and 16 years. Repair can be performed on adults with similar good results. Recent modifications in the Ravitch technique remove minimal cartilage and routinely use a temporary internal support bar for 6 months. Operation rarely takes more than 3 hours, and hospitalization rarely exceeds 3 days. Pain is mild and complications are rare, with 97% of patients experiencing a good to excellent result. The new minimally invasive Nuss repair avoids cartilage resection and takes less operating time, but is associated with more severe pain, longer hospitalization and a higher complication rate, with the bar remaining for 2 or more years. This technique is less applicable to older patients and those with asymmetric deformities. Long-term follow-up will be necessary to determine which operation may be best for any specific patient.

Pectus excavatum (PE), or funnel chest, is one of the most common major congenital anomalies, occurring in approximately 1 in every 400 births [1]. The deformity is inherited through either parent, although not clearly as a recessive trait. Approximately 40% of PE patients are aware of one or more members of the family constellation who have pectus deformities. Pectus excavatum is first recognized in infancy in most cases, and it slowly becomes more pronounced during the ensuing years until the adolescent growth spurt, when almost all patients experience a marked increase in severity until full skeletal growth is achieved. For most patients, the deformity remains constant thereafter throughout adult life. Regression rarely occurs spontaneously or with exercises. Males are afflicted approximately 5 times more often than females [2]. The condition is uncommon in blacks and Latinos. Excavatum deformities are approximately 6 times more common than pectus carinatum. Other malformations may coexist, especially musculoskeletal anomalies, including scoliosis (65%), and occasionally, clubfoot, syndactylism, Marfan syndrome, or Klippel-Feil syndrome.

Most PE patients are tall, have an asthenic habitus, a slouching posture, and a relaxed and slightly protuberant abdomen. The chest wall characteristically has a decreased anteroposterior diameter. The deformity is asymmetric in almost 50% of PE patients, with the concavity usually being deeper on the right side, and the sternum rotated posteriorly slightly on the right. The most common configuration is a symmetric depression involving the lower three fourths of the sternum, extending laterally almost to the costochondral junctions. The lowermost costal cartilages often flare outward, giving younger patients a "pot belly" appearance. Deep inspiration commonly accentuates the severity of the deformity.

The pathogenesis of PE remains unclear, with the most prevalent theory being that the deformity results from unbalanced overgrowth in the costochondral regions, further explaining the frequent asymmetric appearance and the existence of the completely opposite deformity, pectus carinatum, in family members. The involved cartilages are often fused, bizarrely deformed, or rotated. The xiphoid may be bifid, twisted, elongated, or displaced to one side. Resected cartilage segments occasionally show a disorderly arrangement of cartilage cells.

Symptoms

Symptoms are infrequent during early childhood, apart from a shy awareness of the abnormality and a typical unwillingness to expose the chest while swimming or taking part in other social or athletic activities. Easy fatigability, shortness of breath with mild exercise, and decreased stamina and endurance often become apparent during early adolescence when children become involved in competitive sports. More than one half of PE patients experience occasional sharp pains or compression type of discomfort in the lower anterior chest during exercise, or occasionally at rest. Tachycardia, and/or palpitations are common. Many patients experience exercise-induced wheezing; approximately one fourth have an increased frequency of respiratory infections or asthma. Pectus excavatum patients commonly try hard to keep up with their peers physically, using wider diaphragmatic excursions to compensate for the diminished chest wall excursions caused by the deformity. When the deformity is moderate to severe, the sternum displaces the heart into the left chest. Pulmonary expansion during inspiration is moderately confined, resulting in a "restrictive defect" as noted on pulmonary function tests. The deformity clearly places physiologic restrictions on the patient and is not merely a cosmetic concern.

Evaluation

The severity of PE deformities can be calculated by dividing the inner width of the chest, at the widest point, by the distance between the posterior surface of the sternum and the anterior surface of the spine as determined on computed tomography (CT) scans or chest radiographs. The mean severity index for normal persons is 2.52, and the mean index of patients who underwent PE repair in the large series reported by Haller et al was 4.4 [3]. The index has ranged from 3.2 to 12.7 (mean = 4.8) in our experience [4]. Other methods for determining the severity of the PE deformity are more complex, less helpful, and often more expensive.

Despite the diminished volume of the thorax in patients with severe PE, standard pulmonary function tests at rest are often either within normal limits or show a mild restrictive defect. It is difficult to obtain reliable measurements in patients under 8 years of age. Most of the symptomatic PE patients will use more extensive phrenic excursions, which causes them to utilize more energy during exercise than do persons with a normal chest, which may explain in part the early fatigue and tiredness with physical activity. Many studies performed over the past 4 decades have failed to document consistent improvement in pulmonary function at rest after surgical repair of PE, despite considerable symptomatic improvement [5]. Studies performed under exercise conditions, however, have shown that the maximum voluntary ventilation, maximum oxygen utilization, total lung capacity, and total exercise time are improved significantly after repair of PE [6].

Electrocardiographic abnormalities are common in PE patients, consisting primarily of right-axis deviation and depressed ST segments, which reflect rotation of the heart within the thorax rather than an intrinsic abnormality. Compression of the right ventricular outflow tract may cause a functional systolic cardiac murmur along the upper left sternal border in approximately 18% of patients. Echocardiograms may demonstrate mitral valve prolapse in approximately 15%, particularly in patients with Marfan syndrome. Mitral valve prolapse is only occasionally of clinical concern, and then primarily in adults [4].

Measurements of cardiac output using right ventricular catheterization have demonstrated diminished stroke volume and cardiac output in preoperative patients during upright exercise [7, 8]. These findings are not demonstrable in patients tested supine without exercise and may account for some of the reports of no physiologic impairment in PE patients. Angiocardiograms may show compression of the right ventricular outflow tract and right ventricle. In occasional patients this compression is reflected physiologically in right ventricular catheterization measurements and pressure waves similar to those of constrictive pericarditis. Cardiac output and stroke volume have been demonstrated to be reduced in patients with PE deformities, and to be considerably improved after repair [9]. These observations support the hypothesis that both a restrictive cardiac stroke volume and the increased work of breathing described in several PE patients may be ameliorated by operative repair of the anomaly, thus improving exercise tolerance in most patients [10].

The majority of patients and their families are poorly informed by physicians about the limiting physiologic effects of the deformity, or the availability of safe and highly successful options for surgical correction. Although most patients express concern about having a poor body image, repair of the thoracic skeleton is rarely recommended for cosmetic improvement alone. The availability of several Web sites on the Internet regarding pectus deformities during the past few years has allowed patients to become better informed and to obtain advice from other patients as well as from knowledgeable physicians.

Treatment

In the past, many pediatric surgeons have recommended that children with moderate to severe depression of the sternum undergo repair of PE between the ages of 2 and 5 years, despite the fact that almost all young children were asymptomatic. This decision was based on the fact that the repair can be performed more easily at this age than in later years. Early repair of PE by techniques that resect a major portion of the deformed costal cartilages have been discouraged in the past few years because some authors have cautioned that removing large segments of costal cartilage in young children may interfere with the rib growth plates and produce a narrow chest [11]. Haller et al. [12] have also cautioned against extensive cartilage resection in young children because of the occasional later occurrence of constricting asphyxiating thoracic dystrophy. Occasional young children with localized deformity of the lower three or four costal cartilages who undergo repair may experience later deformity of one or two higher cartilages as they progress into adolescent growth, which may produce a recurrent deformity. Most surgeons who use a technique that involves resection of the costal cartilages will wait until the children are at least 8 years old or preferably in their early adolescent growth years, unless they have pectus-induced physiologic symptoms. The optimal age for repair appears to be in the range of 12 to 16 years, although adults with persistent PE deformities extending into the fourth and fifth decades have achieved excellent results following repair [4]. The use of autologous tissue, Silastic, or other prosthetic materials to fill a severe PE deformity provides no physiologic benefit to the patient, often migrates causing further cosmetic deformity, and has little place in the primary management of PE deformities.

Surgical repair for PE may be performed using extensive modifications of the original procedure described by Browne [13] and modified by Ravitch [14] and Welch [15], with minimal costal cartilage resection as described recently [4], or by a minimally invasive correction of the deformity without costal cartilage resection as described by Nuss and associates [16]. Maintenance of the elevated sternum in the corrected position by external traction using harnesses or other cumbersome devices has almost universally been abandoned in favor of various methods of internal fixation. Similarly, the use of autologous tissue or other supporting techniques have not been consistent in providing good long-term chest wall stability in the desired position. Internal sternal support with a temporary metal bar or prosthesis after repair of PE minimizes the occurrence of postoperative respiratory distress caused by paradoxical chest wall motion, reduces pain, permits early ambulation, permits deeper respirations, reduces hospitalization and cost, and maximizes the extent to which the defect is permanently corrected.

The operative technique for the highly modified Ravitch repair (HMRR) requires general endotracheal anesthesia. A transverse inframammary incision with upward curvature in the mid-portion provides adequate exposure to the lower four costal cartilages (Fig. 1). A vertical extension in the midline superiorly is helpful in exposing the second and third cartilages when they are deformed. Cutaneous, as well as pectoralis and abdominal muscle flaps are elevated with electrocautery just sufficient to expose the deformed costal cartilages. Many surgeons resect all the lower deformed car-

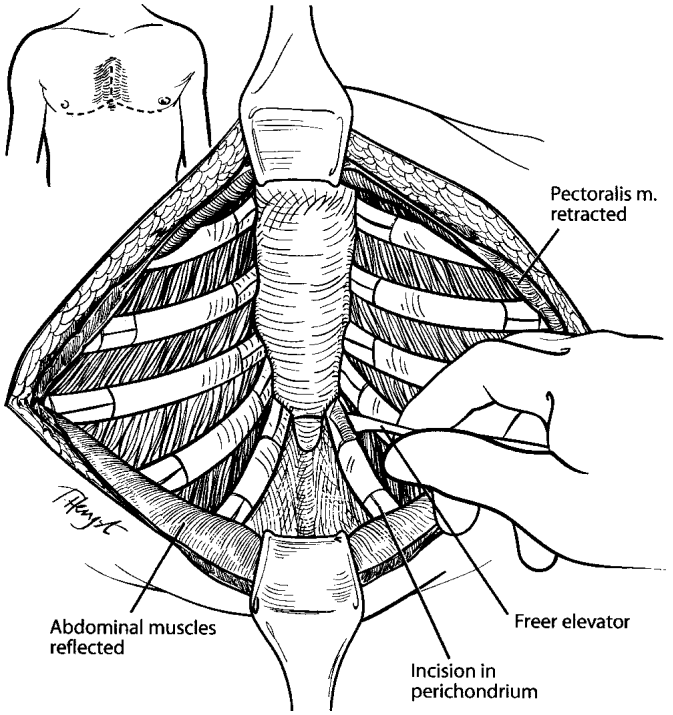

Fig. 1. A transverse inframammary incision with upward curvature in the mid-portion and a small vertical extension superiorly is commonly used. Cutaneous, as well as pectoralis and abdominal muscle flaps, are elevated just sufficient to expose the deformed costal cartilages. Incisions are made through the perichondrium on the medial and lateral ends of the deformed cartilages, and short segments of cartilage are removed. m.: muscle.

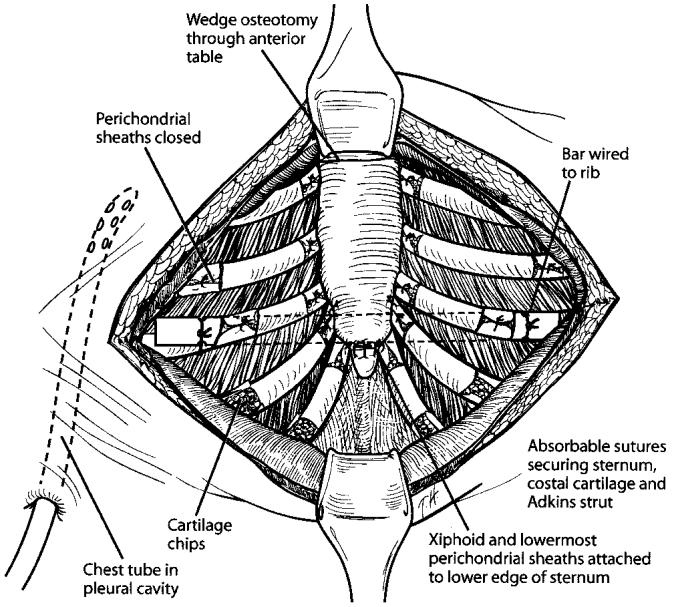

Fig. 2. A transverse wedge osteotomy is made across the anterior table of the sternum at the desired level. The posterior table of the sternum is fractured but not detached. The lower sternum is elevated to the desired level and an Adkins strut is placed across the lower anterior chest posterior to the sternum and costal cartilages, with the tip of the strut attached to the anterior surface of a rib on each side with wire. The xiphoid and lowermost perichondrial sheaths are reattached to the sternum. Finely minced fragments or autologous costal cartilages are placed into the open perichondrial sheaths.

tilages, with careful preservation of the entire perichondrial sheaths. Recent reports; however, indicate that only small segments of deformed costal cartilages medially and laterally need to be removed to permit elevation of the chest wall with minimal force [4]. Preservation of the major portion of the lower costal cartilages provides more stability to the chest postoperation, reduces operative time, and ensures that the costal cartilages will regenerate more quickly and have a tubular configuration. The xiphoid is divided from its attachment to the lower sternum because it is commonly angled anteriorly or posteriorly. The xiphoid should not be excised, because it fills the space caudad to the sternum and assists in reattaching the abdominal muscles to the thorax. In most cases the perichondrial sheaths and intercostal muscles should not be detached from the side of the sternum, as was recommended previously, except for the lowermost one or two, just sufficient to insert the retrosternal support bar. The retrosternal space is mobilized 2 to 4 cm. The right pleural space is often entered, in which case a small chest drainage tube is used for 24 hours.

A transverse wedge osteotomy is made through the anterior table of the sternum with an osteotome or oscillating saw at the cephalad transition from the normal to the depressed sternum, usually at the level of the insertion of the second or third costal cartilages (Fig. 2). The posterior table of the sternum is gently fractured but not displaced, and the lower sternum is then elevated to the desired position where it is secured. In the past, many surgeons used only sutures through the osteotomy site to hold the sternum anteriorly. Others favored the additional use of "tripod fixation," in which the most cephalad normal cartilages are divided obliquely such that when the sternum is elevated, the sternal ends of cartilage will rest on the costal ends [17]. During the past few years, most surgeons have used a retrosternal support bar together with sutures across the sternal osteotomy. The use of various wires, pins, or plates with screws has largely been abandoned. A thin stainless-steel bar (Adkins strut) [18] is placed across the anterior chest posterior to the sternum and perichondrial sheaths of the adjacent costal cartilages, and then attached to the anterior surface of the ribs laterally at the level where the chest has a near-normal contour. For preadolescent young children, securing the bar anterior to the sternum and costal cartilages with large absorbable sutures similar to the technique used for pectus carinatum provides stability without the need to mobilize the retrosternal space [19]. The use of more than one sternal support bar is rarely necessary. The support bar is removed approximately 6 months postoperatively under general anesthesia on an outpatient basis, rarely taking more than 20 minutes. Bars left in place more than 8 months often become surrounded with regenerating cartilage and may be more difficult to remove.

The xiphoid and lowermost perichondrial sheaths are reattached to the sternum. Finely minced fragments of autologous cartilage, which were removed earlier, are placed into the short segments of open perichondrial sheaths to enhance cartilage regeneration. The perichondrial sheaths are closed loosely to encourage tubular cartilage regeneration. The pectoralis and abdominal muscles are sutured together over the sternal repair (Fig. 3). For those patients without a chest tube, a small suction catheter is placed between the muscle layer and the cartilaginous repair.

Before performing the sternal osteotomy and resection of short segments of cartilages from the deformed ribs, a force of approxi-

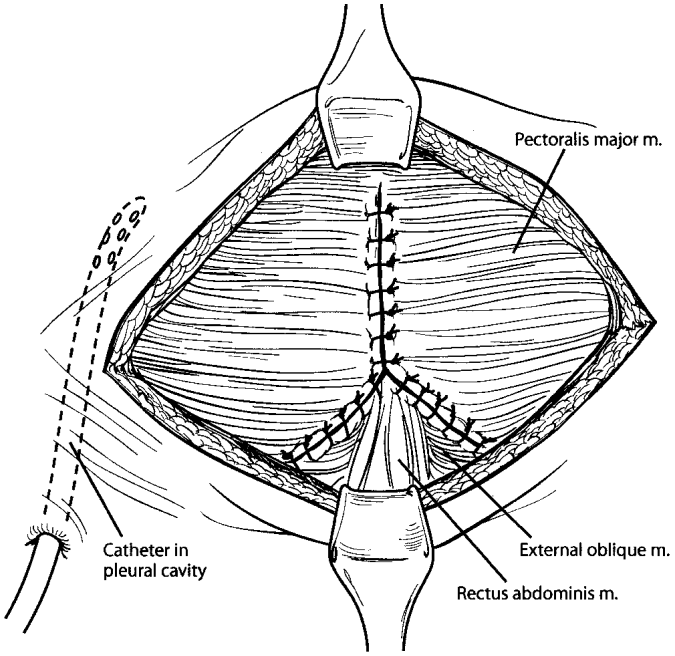

Fig. 3. A drainage catheter is placed into the right pleural cavity in the majority of patients. The pectoralis muscles are reapproximated over the cartilaginous repair. The abdominal muscles are attached to the pectoralis muscles across the lower anterior chest.

mately 15 lb is necessary to elevate the sternum to the desired level in children age 10 years and younger, whereas for adolescents the mean force required is approximately 32 lb, and for adults the mean force is 41 lb [20]. After the sternal osteotomy and costal cartilage excisions, the force necessary to elevate the sternum is less than 1½ lb in almost all patients. The technique of making an osteotomy through the posterior table of the sternum and placement of a wedge of cartilage in the osteotomy site to elevate the sternum as described by Ravitch [21] has been abandoned by most surgeons because of the lack of any benefit over the anterior osteotomy, and the very extensive mobilization of the sternum that is necessary. Similarly, resection of the lower sternum with turnover and placement of the posterior table anteriorly with reattachment of the lower and upper sternum and perichondrial sheaths has been discontinued because of the extensive dissection necessary, the occasional failure of revascularization with necrosis of the lower sternal segment, and the lack of any benefit compared to simpler operative techniques.

With the described HMRR operative technique, the average blood loss is under 100 ml and transfusion is very rarely necessary [4]. The mean duration of the operation is less than 3 hours. Operative pain is surprisingly mild and is controlled with intravenous analgesics for the first 2 days, and by oral nonnarcotic medications thereafter. Epidural analgesia is very rarely used. No patients are placed into an intensive care unit. Hospitalization is rarely more than 3 days. Over 90% of patients return to school or work within 2 weeks. The chest should be protected from direct trauma for 2 to 3 months, by which time periosteal regeneration of new cartilage is complete. Extensive physical activity using the pectoralis and upper abdominal muscles should be deferred for 3 months. Long-term follow-up (mean = 10.3 years) indicates that 97% of patients have experienced a good to excellent result [4, 22] (Figs. 4, 5, 6).

There is virtually no mortality associated with repair of PE using the described technique. Pneumothorax occurs in less than 6% and is usually so small that no treatment is necessary. Wound seromas or pleural effusion occur in less than 5%. The substernal support bar may migrate slightly and become visible in the subcutaneous

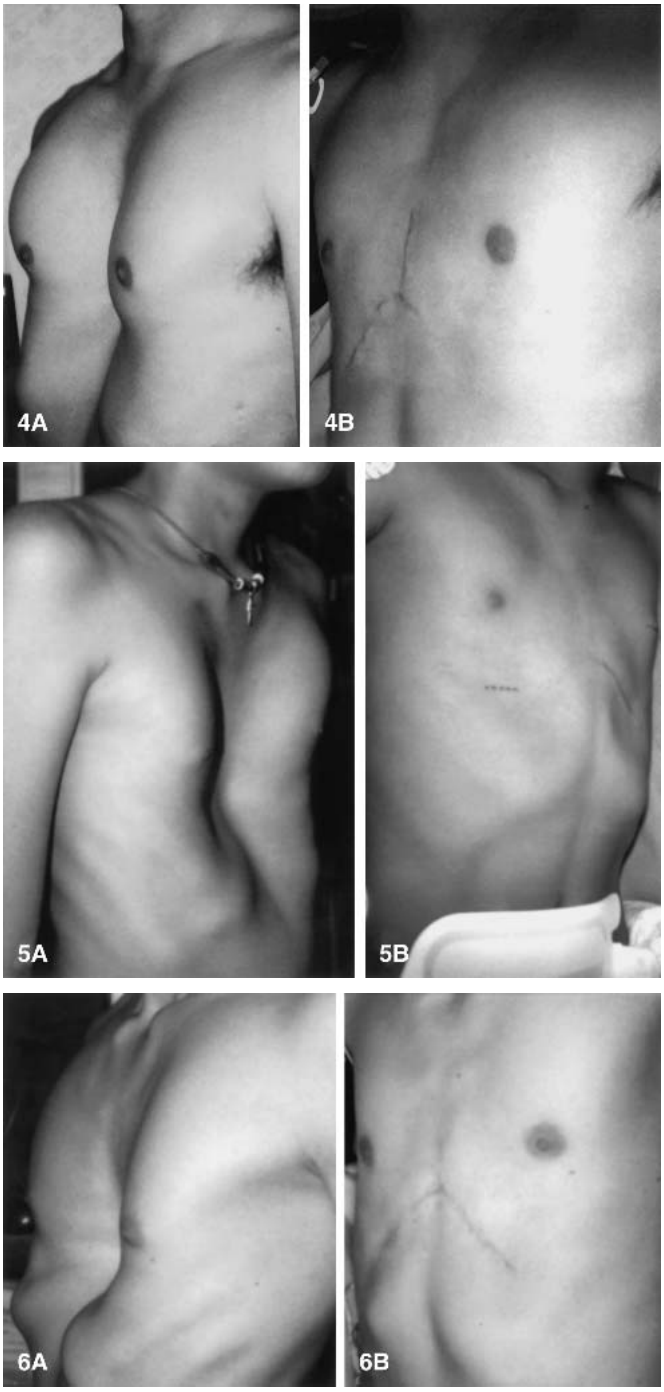

Fig. 4. A 21-year-old man with a pectus severity index of 7.4 **(A)**. Postoperative appearance 2 months after removal of the sternal bar **(B)**.

Fig. 5. A 12-year-old boy with a pectus severity index of 5.9 **(A)**. Chest appearance 6 months after operation **(B).** Dots on the right chest show where the sternal support is to be removed.

Fig. 6. A 17-year-old boy with a pectus severity index of 4.84 **(A)**. Postoperative appearance 7 months after repair **(B).**

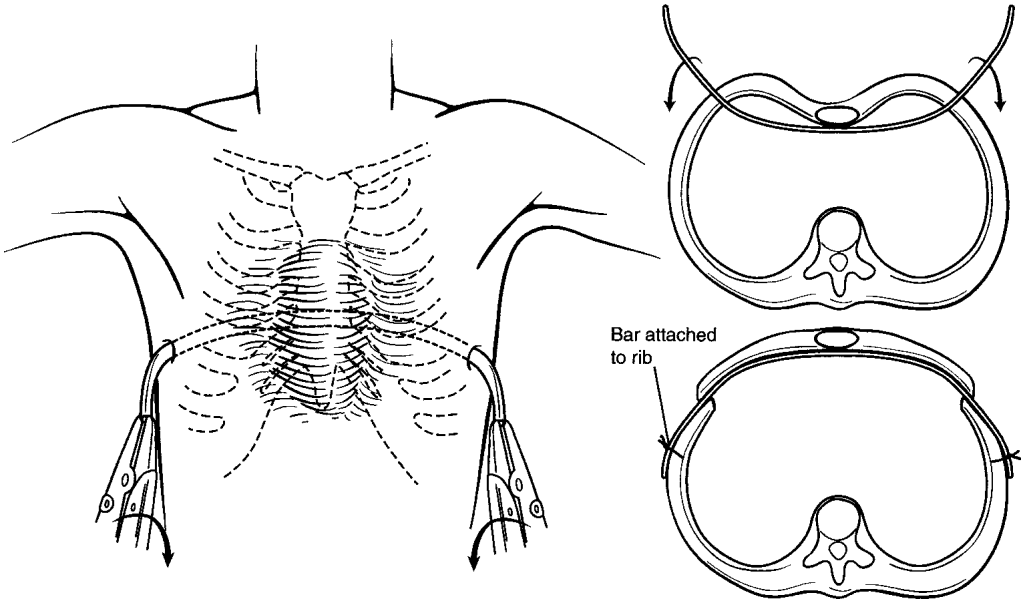

Fig. 7. Minimally invasive repair using a convex steel bar guided across the chest through a substernal tunnel and then twisted with a wrench to force the convex side anteriorly, which elevates the depressed sternum and deformed costal cartilages.

tissues, but is rarely problematic. There is a tendency for mild recurrence of PE in approximately 7% of patients who were repaired at an early age when they experience the adolescent growth spurt, although less than 2% undergo reoperation. Mild irregularity of the lower anterior chest from the regenerated costal cartilages or persistent protrusion of the lowermost floating cartilages may benefit from local minor revision on an outpatient basis. Adolescent patients have a propensity to develop mild hypertrophy of scars, which can be reduced by injecting triamcinolone.

A new minimally invasive technique for repair of PE (MIRPE) was reported by Nuss et al. in 1998 for young children (mean age under 5 years) [16]. The MIRPE avoids any cartilage resection and sternal osteotomy by placing a carefully preformed convex steel bar under the sternum through bilateral thoracic incisions and then forcibly turning the bar over to elevate the deformed sternum and costal cartilages to the desired position (Fig. 7). A long clamp is passed blindly immediately under the sternum and out the contralateral side, and two strands of umbilical tape are drawn through the track. The bar is then pulled across the chest beneath the sternum by the tape. The bar is placed with the concave side anteriorly and then it is turned over with a vice grip so that the concavity faces posteriorly, thereby raising the sternum and anterior chest wall to the desired position. A second bar is placed superiorly or inferiorly if needed. The bar is secured to the lateral chest wall muscles with heavy sutures. If the bar is unstable, a 2 to 4 cm stabilizing cross bar is attached to one or both ends of the sternal bar. The operation rarely takes more than 90 minutes and blood loss is rarely more than 80 ml. The bar is left in position for 2 or more years, depending on the age of the patient and the severity of the deformity, when re-modeling of the deformed cartilages and sternum has occurred. Removal of the bar is technically more complex and takes longer than removal of the Adkins strut used with the HMRR.

Recent modifications of the MIRPE adopted by many surgeons include the use of thoracoscopy to visualize passage of the clamp behind the sternum [23]. This change followed cardiac perforation in two or more patients during blind passage of the clamp [24]. Other surgeons elevate the sternum with a bone hook during passage of the clamp to widen the retrosternal space anterior to the heart. Fixation of the bar to the sternum has been used by many surgeons to minimize the occasional flipping of the bar onto the heart resulting from the downward pressure of the deformed sternum, particularly in adolescents.

Results following Repair

Reports of favorable clinical experience with the MIRPE have included primarily young children [25]. During recent years, the MIRPE has been extended to older patients including occasional adults, although the complications and postoperative pain are higher in older patients. The MIRPE is less likely to produce a good result in patients with asymmetric PE. Reports comparing the HMRR and the MIRPE indicate that although the operating time is shorter for the MIRPE, the length of hospitalization, severity of postoperative pain, complication rate, need for reoperations, and limitation in activity may be longer and more severe than with the HMRR [1, 26]. Long-term follow-up through adolescent years will be necessary in order to make a valid comparison between the two techniques because only a small percentage of the Nuss bars have been removed. The HMRR is very versatile and applicable to patients of all ages and with all types of deformities, including those with recurrent defects.

Patients with PE corrected by both the HMRR or the MIRPE experience moderate to marked improvement in exercise tolerance with much less dyspnea and increased stamina and endurance in the vast majority of cases. Almost all patients with activity-induced pain or discomfort in the anterior chest will note considerable improvement within 4 months. Tachycardia and/or palpitations are frequently reduced. Asthmatic patients often experience fewer episodes of wheezing and a decrease in requirement for bronchodilator medications. Physiologic evaluation of PE patients after operation unfortunately has rarely been performed. Almost all patients indicate a marked improvement in self-image and quality of life [27].

Many patients who do not undergo repair of severe PE deformities in childhood will experience worsening symptoms in adult life. Recent reports indicate that those adults who have symptoms and

activity limitations related to their PE deformity can undergo repair with low morbidity, short limitation of activity, and a high frequency of symptomatic improvement [4]. Repair of PE deformities is technically easier and is recommended during childhood; however, for symptomatic patients who did not undergo operation as children, repair during adult years should be considered as a recommended treatment option.

Recurrent Deformities

Until the past 6 years, few hospitals had compiled a large surgical experience with most surgeons performing only a few pectus operations each year using a variety of surgical techniques. With the limited individual surgical experience and the many variations in operative technique used in previous years, the recurrence rate has been relatively high. Reconstruction of recurrent PE deformities is technically more difficult than is the primary repair, and it should be undertaken for patients with severe deformities who have major symptoms. Factors associated with recurrence after repair using modifications of the Ravitch technique include failure to provide adequate support to the sternum and anterior chest with a metal strut, detachment of several perichondrial sheaths from the sternum without adequate reattachment, injury to the perichondrial sheaths while removing the disfigured costal cartilages, resection of large segments of costal cartilage in children while the growth plates are active, disrupting the vascularity to the lower sternum, excision of the xiphoid, and failure to approximate the pectoralis and abdominal muscles securely over the cartilaginous repair. Recurrence is much more frequent when repair is performed in children under the age of 10 years [28].

The technique for repair of recurrent PE will vary extensively depending on the operative findings. A HMRR with Adkins strut can be performed on more than 60% of patients with recurrent deformities. Others may require reattachment of mobile costal cartilages and/or xiphoid process to the sternum. A few may benefit from autologous bone or cartilage grafts, or muscular reconstruction. Approximately 15% cannot be reconstructed safely. The results after repair of recurrent deformities are often good, but less consistent than after primary repair. Repair of recurrent PE deformities using the MIRPE has also been helpful in occasional patients. Patients who experience recurrence after a primary MIRPE may anticipate an excellent result following reoperation using the HMRR.

Comments

To obtain optimal results, repair of PE requires attention to several technical details, with small alterations made on the basis of different anatomic features in a specific patient. As with other major operations, the number of repairs performed by a surgical team may have a close relation with lower complication rate and better outcome [29]. At present PE deformities can be repaired with a low rate of complications and a short hospital stay. The improvement in respiratory symptoms, exercise tolerance, and endurance, and the reduction in pain and improvement in body image of more than 96% of patients in large reported series support the view that symptomatic patients of all ages with severe deformities should undergo repair, preferably during the early adolescent years. Routine use of internal sternal support with minimal cartilage resection has provided excellent long-term clinical results at low cost with the HMRR. Very good results have also been reported by several surgeons using the MIRPE, although long-term results are not yet available.

Résumé. Le pectus excavatum (PE) ou thorax en entonnoir est une des plus fréquentes anomalies de l'enfance, affectant une naissance sur 400, cinq fois plus chez les enfants de sexe mâle que ceux de sexe féminin. Le PE est habituellement reconnu dès l'enfance, devient plus marqué lors de la croissance dans la période de l'adolescence et reste constant pendant la vie adulte. Les symptômes sont peu fréquents pendant l'enfance mais augmentent pendant l'adolescence: fatigabilité et dyspnée au moindre effort, endurance diminuée, douleur thoracique antérieure et tachycardie. Le coeur est dévié à gauche de façon variable, avec diminution du volume systolique et du débit cardiaque. L'expansion pulmonaire est gênée, résultant en un syndrome restrictif. La réparation est recommandée pour les patients symptomatiques et qui ont un indexe de sévérité élevé, déterminé par un cliché thoracique et la tomodensitométrie. La technique de Ravitch modifiée est habituellement réalisée entre l'âge de 12 à 16 ans. On peut également envisager la réparation chez l'adulte avec d'aussi bons résultats. Les modifications récentes de la technique de Ravitch comportent l'ablation du cartilage et font appel à une fixation interne temporaire par tige pendant 6 mois. L'intervention ne dépasse rarement trois heures et l'hospitalisation est habituellement de moins de trois jours. La douleur résiduelle est modérée, les complications sont rares avec 97% des enfants ayant un résultat qualifié de bon ou d'excellent. La réparation mini-invasive de Nuss ne comporte pas d'exérèse de cartilage et prends moins de temps, mais est caractérisée par plus de douleur, une hospitalisation plus longue et un taux de complications plus élevé, la tige de fixation devant rester en place au moins deux ans. Cette technique est moins facile à appliquer aux adultes et aux patients qui ont une déformation asymétrique. II faut un suivi à long terme pour déterminer quelle opération pourrait être la mielleure pour chaque patient individuel.

Resumen. El pectus excavatum (PE) es una de las malformaciones más frecuentes del niño, con una incidencia de 1 por cada 400 nacimientos; es 5 veces más frecuente en el sexo masculino que en el femenino. Normalmente el PE se diagnóstica en la infancia, se agrava con el crecimiento en la adolescencia y se estabiliza persistiendo durante toda la vida adulta. Durante la infancia suele cursar sin sintomatología, apareciendo ésta cuando el PE sea agrava en la adolescencia; cursa con fatigabilidad precoz, disnea al mínimo esfuerzo, disminución de la resistencia, dolor en la pared anterior del tórax y taquicardia. El corazón se desvía y rota hacia el hemitórax izquierdo produciéndose una disminución, más o menos intensa, del volumen de eyección y del gasto cardiaco. La expansión pulmonar está constriñida por lo que se restringe la función pulmonar. El tratamiento corrector está indicado en los casos sintomáticos que tienen una marcada reducción del diámetro antero-posterior del tórax en las radiografías y/o en el estudio con tomografía computerizada (CT). La intervención quirúrgica más utilizada es la de Ravitch modificada, que ha de efectuarse después que el niño cumpla 8 años y mejor cuando tenga de 12 a 16 años de edad. El proceder de Ravitch también proporciona buenos resultados en los adultos. La reciente modificación de la técnica de Ravitch consiste en la resección mínima de los cartílagos con colocación de un apoyo interno temporal durante 6 meses, con una barra o fleje metálico. La operación, rara vez dura más de 3 horas y la estancia hospitalaria, no suele exceder los 3 días. La operación es poco dolorosa y las complicaciones escasas, obteniéndose buenos o excelentes resultados en el 97% de los casos. La nueva técnica mínimamente invasiva de Nuss evita la resección de los cartílagos y acorta el tiempo operatorio, pero es más dolorosa, precisa un mayor tiempo de hospitalización, la tasa de complicaciones es más elevada y el apoyo interno metálico (barra) ha de mantenerse durante 2 o más años. En adultos o en casos de deformidad asimétrica la realización de la técnica de Nuss es difícil. El estudio de los resultados tardíos determinará cual es el mejor procedimiento quirúrgico para cada paciente.

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