This report presents the case of a 14-year-old, Caucasian girl who was diagnosed with pectus excavatum (PE) and who underwent an open Ravitch surgical procedure for correction of her chest wall deformity. The Institutional Review Board and patient’s parents granted permission to present this case report. Athletic trainers and therapists who treat adolescent athletes should have a fundamental understanding of the physical manifestations and psychosocial effects of PE. Better understanding may facilitate early identification, prompt referral, and improved care, which may limit adverse psychosocial consequences and optimize outcomes for patients who experience this condition.

Pectus excavatum, also known as “funnel chest,” is a congenital defect of the anterior thoracic wall. The lower costal cartilage undergoes rapid, misdirected growth, which results in a depressed or posteriorly displaced sternum. The severity of PE is represented by the “Haller Index” (HI), which is also known as the “Pectus Index” (Table 1). Computed tomography (CT) of the thoracic cavity is performed before and after surgery. The HI is determined by dividing the widest point of the thorax by the shortest anterior/posterior distance from sternum to thoracic vertebra. The larger the HI, the greater the severity of the PE deformity and patient dissatisfaction with body appearance. The results of corrective surgery are immediately identified with CT scans that demonstrate a decrease in HI. Long-term patient satisfaction is good to excellent.

Patients who suffer from PE often have a history of exercise intolerance, dyspnea with exertion, decreased exercise capacity (exercise time, VO2 max, power output, maximum heart rate, anaerobic index), shortness of breath, chest pain or palpitations, low spirometry values, and fatigue. In addition to physical signs and symptoms,

<table>
<thead>
<tr>
<th>Grade</th>
<th>Haller Index (cm)</th>
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<tr>
<td>I</td>
<td>3.0–3.9</td>
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<tr>
<td>II</td>
<td>4.0 – 4.9</td>
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<tr>
<td>III</td>
<td>5.0 – 5.9</td>
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<tr>
<td>IV</td>
<td>≥ 6.0</td>
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Note. Haller Index is determined by dividing the maximum internal transverse diameter of the chest by the minimum anteroposterior diameter.
these patients may also exhibit psychosocial maladjustments, such as anxiety, depression, disturbed body perception, poor body image, low self-confidence, increased interpersonal difficulties, or lack of autonomy.\textsuperscript{2,5,8,11-13} The reported prevalence of PE at birth varies from 1/400\textsuperscript{4} to 1/1000,\textsuperscript{12} but experts agree that it is the most common surgically treated chest condition.\textsuperscript{2,5,5,7,8,11,12} More boys than girls are born with PE (roughly 3:1).\textsuperscript{2,5} Although present at birth, PE becomes more evident with rapid skeletal growth at the onset of puberty.\textsuperscript{4,7}

Pectus excavatum has been identified in skeletal remains of people dating back to the 10th century A.D. The first surgical treatment for the condition was reported in 1911.\textsuperscript{5} A course of external traction for 6 weeks was attempted in 1920 with little success. In the 1950s, Dr. Mark M. Ravitch developed a surgical procedure that involved complete detachment and reattachment of the sternum to the costal cartilage.\textsuperscript{4,5} This procedure was performed on children who were 3–5 years of age from 1953 until the 1990s, but the incidence of restrictive thoracic dystrophy (i.e., failure of the chest to enlarge with general body growth) was troublesome.\textsuperscript{3,8,14} In 1997, Dr. Donald Nuss reported his experience in using a stainless steel strut brace that was inserted into the chest wall, posterior to the malformed sternum, in patients who were 12–18 years of age. Today, the Ravitch or Nuss procedures (also known as the minimally invasive repair of PE, MIRPE)\textsuperscript{4} are commonly accepted surgical methods for treatment of adolescent patients with PE. Although both procedures involve insertion of a stainless steel strut brace into the anterior thoracic cavity, the Nuss procedure is less invasive, because it does not require cartilage resection or sternal osteotomy.\textsuperscript{2,5,7,10} Flexible cartilage and elasticity of the thoracic wall make teenage patients good candidates for repair of PE deformity.\textsuperscript{15,14}

Postsurgical recommendations include a 3- to 5-day hospital stay,\textsuperscript{12,14} followed by 3 weeks of recovery at home. Light exercise or lifting may begin 1 month after surgery,\textsuperscript{12} light lifting after 2 months,\textsuperscript{8} and return to noncontact activities after 3 months.\textsuperscript{12,15} The length of time for the stainless steel strut brace to remain in place ranges from 2 to 4 years.\textsuperscript{4,12,14}

Although PE is present from birth, many patients do not notice or express concern about the deformity until their early teenage years. Many pediatricians consider corrective surgery as cosmetic in nature,\textsuperscript{4,10} however, as the patient develops, a number of factors should be considered. An adolescent growth spurt that exacerbates the condition is a common reason for development of concern, but some attribute it to psychosocial factors, i.e., development of identity, independence, self-confidence, positive body image, and the need to be accepted by peers.\textsuperscript{2,4,5,7,10,12} Positive physical and psychosocial results of the corrective surgery include improved pulmonary function,\textsuperscript{4,5} increased exercise capacity,\textsuperscript{4} and improvements in body image, self-esteem, quality of life, and ability to deal with social problems.\textsuperscript{7,8,12}

**Case Review**

A healthy 14-year-old Caucasian female who had been diagnosed with PE as an infant underwent a Ravitch procedure to correct her chest wall deformity. She was born with a mild PE, which increased in severity as a result of a rapid growth spurt at puberty. Prior to surgery, the patient participated in a variety of physical activities, but was often fatigued or short of breath shortly after initiation of activity. The patient and her mother consulted a pediatrician who referred them to a pediatric cardiothoracic surgeon to discuss options for PE corrective surgery. After the surgeon described the surgery and follow-up procedures, the patient and her parents elected to have the surgery performed. A week prior to the surgery, anterior-posterior and lateral view radiographs were obtained to rule out underlying conditions that could complicate the surgery. A radiologist confirmed the PE deformity with no other abnormalities of the ribs, lungs, heart, or abdomen.

The surgeon performed a modified Ravitch procedure with an infra-mammary incision, through which he inserted a 7-inch Lorenz stainless steel strut brace. Prior to inserting the Lorenz brace, he elevated the pectoralis major muscles and detached the rectus abdominis from its origin on the xiphoid process. The xiphoid process and bilateral costal cartilage from ribs 4-8 were then removed, and an anterior sternal osteotomy was performed. The Lorenz brace was inserted into the thoracic cavity and was secured with two stainless steel wires. The pectoralis major and rectus abdominis muscles were reattached and the subcutaneous tissue was sutured in layers. Standard postsurgical radiographs confirmed that the Lorenz bar and stabilizing wires were properly positioned, but they also identified a small (6mm) right apical pneumothorax. Photographs taken before and after surgery (Figures 1
and 2) demonstrate remarkable improvement in the appearance of the chest wall.

The patient spent two nights in a pediatric intensive care unit, with administration of epidural pain management. When the patient was alert, she was instructed to roll to her side, then to push up with her arm into a seated position. In this manner, the force imposed on the rectus abdominis was minimal. The epidural pain medication was discontinued on the third day after surgery, which was followed by administration of oral narcotics and non-steroidal anti-inflammatory drugs. She was released from the hospital 4 days after surgery. Follow-up lateral and AP radiographs were obtained at 9 days after surgery, and again at 40 days after surgery, which confirmed that the pneumothorax had resolved and that the Lorenz brace and wires were secure.

The surgeon informed the patient and her parents that rigorous activity would not be permissible for 2–3 months, which would be necessary for stabilization of the surgical repair and recovery of muscle function. The surgeon granted the patient permission to try out for her high school volleyball team, with the instruction that diving to the floor must be avoided. The patient subsequently participated on the “C squad” of the high school volleyball team.

Approximately 6 months after surgery, lateral and AP radiographs were obtained to prepare for surgical removal of the Lorenz bar (18 months earlier than cited in the literature4, 8, 10, 15). An acute cardiopulmonary abnormality (cardiomegaly) was identified. One week later, the bar was removed through a small incision that was lateral to the previous surgical incision.

No changes in pulmonary function or hemodynamic status were noted at the time of surgery; however, the patient complained of shortness of breath while in surgical recovery. Radiographs revealed decreased lung volume, with opacification in the left lower lobe. No pleural effusion or pneumothorax was identified. Radiographs obtained 2 hours later demonstrated improved lung volume, with resolution of the left lower lobe opacity, and the heart and pulmonary vascularity were deemed to be within normal limits.

A limited echocardiogram was performed at one week after the Lorenz brace removal for follow-up evaluation of the cardiopulmonary abnormality noted earlier. The cardiac chambers were determined to be normal in size, the biventricular contractility was very good, no pericardial effusion was evident, and all four cardiac valves appeared to be normal. The patient had her final follow-up evaluation with the surgeon 11 months after surgery. She denied any respiratory distress, and the chest shape was normal. The mother reported her daughter’s disposition to be normal for a 15-year-old. The surgeon released the patient to full participation.

**Discussion**

The patient and her parents planned the surgery so that she could complete her middle school volleyball career and have maximum time to recover prior to the date of high school volleyball tryouts. The surgeon did not recommend physical therapy nor any specific therapeutic exercises for recovery but did encourage

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**Figure 1** Pectus Excavatum before Ravitch procedure.

**Figure 2** Pectus Excavatum after Ravitch procedure.
the patient to gradually increase physical activity. Following surgery, the patient experienced some of the complications that are indicated in the literature (e.g., pneumothorax and shortness of breath), but they resolved in a relatively short amount of time. The surgery proved to be a catalyst for the young woman to develop her full potential, without the impediments of a poor body image or lack of exercise tolerance. Prior to the high school volleyball tryouts, the patient and her parents informed the coaching staff about the corrective surgery and the presence of the Lorenz brace. The parents assured the coaching staff that the patient was cleared for full participation by the surgeon with the caveat of “no diving for the ball until the Lorenz brace is removed.” Neither the patient nor her parents informed the high school athletic trainer about the history of PE surgery or the presence of the Lorenz brace, which deprived her of the opportunity for physical care and psychological support.

Although the surgeon did not prescribe any therapeutic exercises, conservative postsurgical management for such a procedure is appropriate. The athlete completed her freshman volleyball season without any complications.

In the 4 years that have passed since the athlete underwent the PE corrective surgery, she has participated in numerous high school social activities. Her parents have noted an increase in her self-esteem and confidence, which were evidenced by her involvement in student government participation in volleyball for four years (Figure 3), participation in lacrosse during her senior year, and involvement in social activities.

This case review provides information about PE to support an athlete through the decision-making and recovery processes related to surgical correction of the condition.

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