ORIGINAL ARTICLE

Child pectus excavatum: Correction by minimally invasive surgery

E. Felts, J.-L. Jouve, B. Blondel, F. Launay, F. Lacroix, G. Bollini

Department of Pediatric Orthopaedic Surgery, Children Timone Hospital, rue Saint-Pierre, boulevard Jean-Moulin, Marseille, cedex 513385 France

Intensive Care Unit and Anesthesiology Department, Children Timone Hospital, Marseille, France

Accepted: 9 March 2009

Summary

Introduction. — Pectus excavatum (PE) is a congenital deformity essentially responsible for an unattractive aspect, much more rarely for compression problems. The classical treatments consist either in filling the excavation or in open thoracic reconstruction (the Ravitch technique). Alternatively, the treatment described by Nuss raises the sternum with a retrosternal metallic bar placed under thoracoscopic guidance. We present the preliminary results of a series of 25 children operated on using this technique.

Hypothesis. — The minimally invasive procedure described by Nuss is a valid surgical strategy to treat PE.

Materials and methods. — Twenty-five patients were operated on between February 2004 and April 2007 by the same surgeon. Nineteen of these patients presented a purely cosmetic indication. The six other patients were considered to have a more severe form of PE, with cardiorespiratory repercussions. In this group, there were two cases of Marfan syndrome and two patients presenting a history of previous cardiothoracic surgery. The technique has always consisted in placing a retrosternal bar through two lateral incisions. The surgery was always performed with right lung exclusion and was guided by thoracoscopy in 21 cases. In four particularly severe cases, a subxiphoid approach was required, making endoscopic guidance unnecessary. The severity of the lesion was evaluated by the Haller Index. All the patients had regular clinical follow-up (at three weeks, three months, and then every six months); assessment of pain, satisfaction with the cosmetic results, and perceived improvement in respiratory function were the criteria used for this follow-up.

Results. — The cosmetic result was judged to be positive by 24 patients. One patient was dissatisfied (because of the asymmetrical shape resulting from the use of a single implant). Five patients presented minor complications with no repercussions on the cosmetic or functional
Pectus excavatum (PE) is the most frequently found congenital thoracic malformation, affecting one birth in 400, predominantly found in males, related to chondrocostal cartilage growth. This malformation is expressed as a more or less pronounced mediothoracic excavation. It can be symmetrical (involving the sternum in the frontal plane and symmetrical deformity on either side of the sagittal plane) or asymmetrical. The most relevant characteristics were defined by Cartoski et al. [1] as localized or diffused depressions, the length of the excavation, the symmetrical or asymmetrical aspect, and sternal torsion.

The etiologies of PE are multiple: they can be idiopathic (50% of cases), hereditary (40% of cases) [2], or be classified within the collagenoses such as Marfan syndrome (5% of cases) or Ehler-Danlos disease (1% of cases).

In children, the progression of the thoracic deformity is related to growth, with a tendency to worsen as the child ages. The progressive risk is considered potentially major at the time of pubertal growth because the thoracic circumference increases by 50% during puberty.

In the most frequent forms, the deformity only produces an unattractive aspect, particularly at puberty. The deformity is often the most pronounced in girls and can result in breast deviation. In severe forms, most often associated with collagenosis, modifications in the osteocartilaginous structure can be the source of compressions of the intrathoracic contents (the heart, lungs, primary bronchi), which can lead to a restrictive syndrome or promote the onset of recurrent pulmonary infections.

Currently, the paraclinical evaluation of the severity of PE is based on the Haller CT index [3]. This provides the ratio of the transversal diameter of the thorax to its anteroposterior diameter at the point where the deformity is the most pronounced.

Since the first descriptions of this condition, the treatment techniques for funnel chest have evolved significantly. Today many different techniques are used depending on the objectives for each patient. Some techniques produce only a cosmetic effect: they simply fill the excavation using a silicon prosthesis [4] or an injection of resorbable or non-resorbable products. These substitutive techniques have no effect on the actual anatomy of the thorax and are therefore not a treatment that is suitable for cases of intrathoracic compression.

Other surgical techniques attempt to achieve a long-lasting modification of the chondrocosternal morphology. Among the most classical of these techniques are the procedures described by Ravitch [5] and Bedouelle [6] during which several osteotomies of the sternum and the costal arcs are performed, maintained by placing one or several metallic bars. This technique has the disadvantage of substantial scarring, making it difficult to apply in cosmetic indications, and of being particularly invasive for fragile patients.

The technique described by Nuss is a minimally invasive surgical procedure that raises the sternum with a retrosternal metallic bar placed with thoracoscopic guidance. It is based on the flexibility of the thorax in young subjects, making effective correction possible. This surgical procedure presents the advantage of actually correcting the anatomy of the thorax by associating little scarring and relatively uncomplicated follow-up [7].

More recently, non-surgical techniques using a vacuum chest wall lifter have been described, but today they are still experimental and the results remain inconclusive [8], or these techniques have been used in addition to the minimally invasive thoracoscopic techniques to facilitate the insertion of the retrosternal implant [9–10].

This paper reports the results of a prospective and continuous series of 25 patients who were treated with placement of a retrosternal bar following the initial principle described by Nuss.
Materials and methods

Our series included 25 patients (15 males and 10 females). The mean age was 13.8 years (range, 5–18 years). All were operated by the same operator.

The patients were placed on general anesthesia, in the strict dorsal decubitus position after being intubated for right lung exclusion. In the older children, exclusion was achieved using a Carlen’s tube. In smaller children, a bronchial blocker was placed using endoscopic guidance. The arms were extended with less than 90° abduction, to prevent any risk of brachial plexus injury [11]. The first stage of the operation consisted in identifying the most depressed zone and preparing the metallic bar(s) to implant. The bars were originally rectilinear and their length and curve were moulded using flexible templates. The stem was then curved to the template’s shape. Two incisions were made at the right and left middle axillary lines. Next, skin flaps were raised and tunnelled up to the chondrosternal junction. A thoracoscope was inserted between two intercostal spaces below the right thoracic incision. Thoracoscopic guidance allowed us to observe the procedure from the thoracic entry point. A retrosternal-shaped guide approximating the implant was inserted with the concave side facing forward, thus dissecting the plane separating the sternum from the pericardium. The guide was then externalized via the left side at the chondrosternal junction and then through the skin lesion. A tie was attached to the trial bar. The trial bar was then removed under thoracoscopic guidance, which allowed the passage of the tie from left to right. The tie was then attached to the final bar, so it could be inserted with the concave side facing forward from right to left. The implant was then flipped 180° so that the concave side faced backward. The bar was stabilized with a stabilizer attached to the soft tissue of the chest wall, as described in the original technique. Wiring it to a rib with two subperiosteal cable wires was found to provide greater reliability. The implant thus presented a trajectory that was right extrathoracic subcutaneous, then intrathoracic and retrosternal, and finally left extrathoracic subcutaneous. In the best of cases, the left pleural cavity was not invaded. In practice, left pleural invasion is frequent with no consequences other than minor pneumothorax. At the end of the procedure, the thoracic cavity was explored, guided by the thoracoscope, to ensure that there was no organic lesion and evaluate bleeding. If there was no significant bleeding, the right lung was reventilated in the dorsal decubitus position, without systematic thoracic drainage.

The patients who had substantial depressions or a history of cardiothoracic surgery required a subxiphoid approach approximately 3 cm in length to verify that the sternum was lifted and the sternopericardial plane dissected safely, as reported by Huang et al. [12].

During our practice, we modified the implant shape to facilitate its insertion and the costal fixation with steel wires.

Similarly, the initial asymmetrical forms initially treated with a single implant were secondarily treated by placing two implants on either side of the deformity, which perfected the correction, as also described by Nuss [13] and Dzielicki et al. [14].

Follow-up was adapted to pain. Analgesia was most often ensured by a lever-operated morphine pump authorized starting the 4th day. In two cases, a thoracic epidural analgesia was installed at the end of surgery for a duration of three days.

Immediate postoperative x-rays were taken to verify that the implant was properly positioned and clinical evaluation included the patient’s evaluation of the result. Patients were then seen at one month, three months, and then every six months. During each consultation, patient satisfaction of the cosmetic result, residual pain (VAS), and respiratory function were evaluated. The result was considered positive if the patient was satisfied with the cosmetic result, had no residual pain in daily activities at three months, and perceived an improvement in respiratory function if there had been respiratory problems preoperatively (fewer episodes of superinfections or dyspnea).

Results

Twenty-five patients were included in this study between February 2004 and April 2007: 15 males and 10 females, with a mean age of 13.8 years (range, 5–18). The mean follow-up was 26 months (range, 14–52). Nineteen patients presented a purely cosmetic indication (Fig. 1a–b). The six other patients were considered to have a severe form of PE with cardiorespiratory repercussions and symptoms of dyspnea on exercise or recurrent atelectasis because of compression of the left bronchial tube (Fig. 2). In this second group, we noted two cases of Marfan syndrome (Fig. 3a–b) and two patients with a history of cardiothoracic surgery.

The PE was symmetrical for 21 patients and asymmetrical for four patients.

Most of the patients underwent surgery with thoracoscopic guidance, except for four who needed a complementary subxiphoid approach (two cases of Marfan syndrome with respiratory repercussions and two patients with a history of cardiothoracic surgery).

A single implant was used in 22 patients. In three cases, two bars were placed (Fig. 4) for asymmetrical forms of PE. A thoracic drain was necessary in 14 patients, the first cases in our series, with the drain removed on average on the third day. In two cases, a thoracic epidural analgesia was installed at the end of surgery for a duration of three days.

Follow-up was adapted to pain. Analgesia was most often ensured by a lever-operated morphine pump authorized starting the 4th day. In two cases, a thoracic epidural analgesia was installed at the end of surgery for a duration of three days.

Immediate postoperative x-rays were taken to verify that the implant was properly positioned and clinical evaluation included the patient’s evaluation of the result. Patients were then seen at one month, three months, and then every six months. During each consultation, patient satisfaction of the cosmetic result, residual pain (VAS), and respiratory function were evaluated. The result was considered positive if the patient was satisfied with the cosmetic result, had no residual pain in daily activities at three months, and perceived an improvement in respiratory function if there had been respiratory problems preoperatively (fewer episodes of superinfections or dyspnea).

Figure 1  a: Pectus excavatum (PE) with cosmetic surgical indication. Symmetrical deformity with breast deviation. b: Clinical results after seven days (same patient).

The PE was symmetrical for 21 patients and asymmetrical for four patients.

Most of the patients underwent surgery with thoracoscopic guidance, except for four who needed a complementary subxiphoid approach (two cases of Marfan syndrome with respiratory repercussions and two patients with a history of cardiothoracic surgery).

A single implant was used in 22 patients. In three cases, two bars were placed (Fig. 4) for asymmetrical forms of PE. A thoracic drain was necessary in 14 patients, the first cases in our series, with the drain removed on average on the third day. In two cases, a thoracic epidural analgesia was installed at the end of surgery for a duration of three days.
3rd postoperative day. Three patients presented postoperative minimal pneumothorax, which resolved spontaneously and did not require drainage. No cases of pericardial effusion were demonstrated. We found immediate postoperative pain to be substantial. All of the patients in this series were given analgesia by self-administered morphine for the first three days. In two cases, a thoracic epidural was installed.

Ambulation was allowed on average starting the 4th day after surgery, upon morphine cessation. They were discharged on the 7th postoperative day, on average, after effective analgesic control. Follow-up was uncomplicated for 21 patients. For two of them, an inflammatory reaction was observed in the bar area, a small aseptic fluid collection, with no bacteria found on bacteriological samples taken, which led to removal of the implant after one year. One case of secondary implant displacement required early surgical revision on the 15th postoperative day. The fixation of the lateral stabilizer to the soft tissues of the chest wall had failed. As a result, we changed the implant fixation technique for the rest of the series. One patient was hospitalized two days after discharge for fever; blood tests demonstrated *Staphylococcus aureus*. Although the patient had a normal CT scan and a clean scar, the infectious episode was treated medically with antibiotics without our having to remove the implant.

The children were allowed to return to school after three weeks and sports were allowed after three months.

During the postoperative evaluations, a single patient was dissatisfied with the cosmetic result because of persistence of thoracic asymmetry. Twenty-four patients presented positive results. Six patients demonstrated improvement in respiratory function. The bar was removed with no surgical or postoperative complications in 13 patients, with the results remaining constant and the implant remaining in place a mean 19 months [range, 12—26]. These patients were followed up for a mean 26 months [range, 14—52].

**Discussion**

Today, PE is managed increasingly with minimally invasive techniques such as the endoscopic treatment described by Nuss et al. with an uncomplicated follow-up period [15]. The results were satisfactory, with a low complication rate and minimal scarring, particularly important in a pediatric population [16]. With experience and the change in fixation technique, we have progressively been able to limit the risk of complications, as has also been described by other authors [17—18].

In our study, the only negative result was the case of an adolescent with asymmetrical PE treated with a single implant at the beginning of our experience.

Afterward, asymmetrical PE (whatever the etiology) were treated by placing two implants, which improved the cosmetic results with no postoperative repercussions.

Fixation to soft tissues on the right side using a stabilizer was abandoned in favor of fixation to an adjacent rib, on the...
right side, with subperiosteal steel wire. Since this type of fixation was adopted, we have observed no secondary displacement; this simpler fixation method seems more reliable and results in fewer cutaneous problems [19].

Evaluation of the postoperative cosmetic results was based on self-evaluation by the patient and family and showed very good results. Like Metzelder et al. [20], we believe that this warrants the use of this technique for cosmetic purposes, particularly since the results are stable over time after the implant is removed.

According to the data reported in the literature, pulmonary function is not objectively improved [21–22]. However, the patient’s well-being is greatly improved [23]. It would seem that this positive effect is related to improve cardiac function [24–25].

Cases of aseptic subcutaneous collections identical to what we report have also been described in the literature and attributed to a hypersensitive reaction to the implant material [26] apparently without having to remove the material.

One of the potential problems with this type of surgery remains, however, the removal of the intrathoracic implant. No complications were noted in our series, but a potential risk of serious complications exists from a lesion of the thoracic viscera. Nugochi and Fujita [27] proposed a new technique for implant removal, but it requires reopening the two initial incisions.

The results of our study and the review of the literature confirm the value of the Nuss technique for treating PE. The low level of scarring is also a point to consider in the choice of this treatment for cosmetic indications [28]. In addition, the uncomplicated follow-up compared to the Ravitch technique used previously means that this minimally invasive procedure can be used with patients who are reputed to be fragile. Moreover, the asymmetrical forms of the condition, which classically are a contraindication for this technique (because the results have not been shown to be sufficiently satisfactory) can be, in our opinion, treated effectively and satisfactorily with two implants shaped to fit the deformity, with stable results over time. When a patient presents with a major form or has a history of cardiorespiratory problems, we recommend a short subxiphoid incision to release the pleural and pericardial adherences. With this alternative, thoracoscopic guidance is not necessary and scarring remains slight compared to the Ravitch procedure.

With a few simple adjustments, this technique gains in reliability in cosmetic indications and can be extended to particular forms such as collagenosis and postoperative deformities.

Conflicts of interests

None.

References


