New Endoscopic Minimal Access Pectus Carinatum Repair Using Subpectoral Carbon Dioxide

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Purpose. This study establishes a minimal access hybrid technique for pectus carinatum repair. Based on 132 conventional repairs (1984–2000) and our own endoscopic technique for correcting prominent costal arches, the conventional carinatum repair was adapted to an endoscopic-assisted technique.

Description. Inserting two submuscular trocars and inflating CO₂, the entire ventral thoracic wall was dissected endoscopically detaching pectoral muscles from ribs and sternum. February 2001 to February 2004, we repaired 37 patients (32 male) of 16.8 ± 4.3 years (12 to 36 years). Endoscopic-assisted rib resection and axial reanastomosis, transsternal struts, and sternotomies were performed semi-open from a 2.9 to 4.7 cm incision.

Evaluation. All were completed minimally invasively, one seroma was managed conservatively. Thirty-three patients rated their result as excellent, 4 as good with a follow-up of 29.1 ± 9.5 months (range, 18 to 55 months). Twenty-one struts were removed with no recurrence.

Conclusions. Minimal access pectus carinatum repair is safe, effective, and offers high comfort for the patient. The results are at least as good as conventional repairs, but hospital stays could be halved. Encouraging results of this early experience warrant further evaluation by other centers.

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Technology and Technique

Pectus carinatum is 5 to 10 times less common than funnel chest, and Fonkalsrud [1] termed pectus carinatum “the undertreated deformity,” because neither indications nor the preferred treatment are standardized at all. Although thoracoscopic funnel chest repair is established [2, 3], no minimal access repair had been devised for pectus carinatum so far [4]. Based on 132 pectus carinatum repairs from June 1984 to December 2000 [5], and our endoscopic method for correcting prominent costal arches in funnel chests [2, 3], we adapted the Hegeman-Willital repair for thoracic deformities [5, 6] to an endoscopic-assisted minimal access technique [4]. This prospective observation study on the first 37 patients intended to standardize, evaluate and establish this new technique.

Clinical Experience

Patients and Methods

From February 2001 to February 2004 we treated 37 adolescents and young adults by our new minimal access repair for severe pectus carinatum, who were not amenable to compressive orthotics. Thirty-two patients were male and 5 were female, and they ranged in age from 12 to 36 years (mean, 16.8 ± 4.3 years). Two males and one female had redos after 1 to 3 failed Ravitch repairs. All deformities were severe enough to cause significant complaints such as shortness of breath and decreased stamina (34 of 37 [92%]) chest pain on exertion (36 of 37 [97%]), backache (33 of 37 [89%]), and inability to sleep in the prone position (30 of 37 [81%]). All patients felt considerably impaired in sports, partner relations, and social activities, and many patients had stopped these activities years ago. All patients were recorded prospectively with preoperative and postoperative photographs, thoracic molds, and computed tomographic scans.

In accordance with the Helsinki Declaration and relevant guidelines, the study was approved by our Institutional Review Board on January 9, 2001. All patients gave informed consent to the procedure and prospective study, and consent to conversion to an open procedure if necessary.
They received patient-controlled analgesia by epidural catheter for 2 to 3 days, which kept most pain free and allowed respiratory training and early walking on the evening of the operative day. All patients were followed prospectively by outpatient visits at 6 weeks, 3 months, and 6 months, and then every 6 months thereafter until strut removal after 18 to 24 months. Final visits after strut removal were at 1 year and 5 years. Postoperative follow-up was 18 to 55 months (mean, 29.1 ± 9.5 months). During this period we had 296 Nuss funnel chest repairs with the same follow-up protocol (ie, a carinatum/excavatum ratio of 12.5% [37 of 296]).

For the endoscopic minimal access carinatum repair we used two high-definition television monitors, a high-definition television digital video camera, and a 30°, 5-mm lens for bilateral endoscopy of the subpectoral (epicostal) space. Although the basic procedure has been described elsewhere extensively [5, 6], adding endoscopic dissection has reduced access size dramatically. Under single-shot cephalosporin two 5-mm trocars were bluntly advanced from a cranial (axillary) and a caudal (costal arch) 5-mm access into the anterior axillary line until the ribs were touched. Then 15 mm of mercury CO2 was insufflated until the pectoral muscle lifted from the ribs establishing an epicostal space to work in. The pectoralis major and minor were entirely detached from the ribs under sight by blunt dissection and hook cautery through the second 5-mm trocar (Fig 1A). Near the parasternal region, perforating vessels were meticulously cauterized by monopolar hook or bipolar clamp until the sternum could be dissected free. Thus the dissection was performed nearly without blood loss, although cautery smoke had to be occasionally evacuated. Then the ports for lens and hook were changed to dissect the costal arch and separate the rectus abdominis muscle from the costal arch and xiphoid process. The same dissection was performed from the opposite side until the muscular-cutaneous layer was entirely detached from the ventral bony thorax between both anterior axillary lines and from the xiphoid to the manubrium. No complication of CO2-dissection was observed, but if dissection exceeded 1 hour of duration, reduction of insufflation pressure or occasional desufflation was required to prevent the moderate rise in systemic CO2, as we observed in 2 patients. Finally the scope was brought back into one of the caudal ports to visualize the substernal space and allow safe dissection of the sternum from the ventral mediastinum and to avoid injury of the internal thoracic vessels. At that point a 2.9 to 4.7 cm midline longitudinal skin incision was made over the lower sternum, which was lifted by a hook or traction suture through the incision. The medioclavicular and parasternal wedge resections of small costal segments (preserving the perichondrium) and V-shaped osteotomies of the anterior cortical plate of the sternum were performed by Luer bone rongeurs (through the incision) and bone punches (through trocar incisions) as in a standard Hegemann-Willital or Ravitch repair under endoscopic sight (Fig 1B). The resected rib segments were longest near the maximal carinatum deformity and minimal on the opposite side. Two perforated stainless steel struts with sharpened tip (Lettenbauer Inc, Erlangen, Germany) were entered into the submuscular pouch through the skin incision or the port holes and were pierced through the sternum to lie exactly between the ventral and dorsal sternal corticalis, preferably above and below the partial sternal osteotomy. The struts were shortened and bent under endoscopic assistance to match the desired form of the thorax. The ribs and perichondrium were resutured to each other and the sternum by axial reanastomosis (Fig 2A), and the bars were secured to multiple ribs using heavy pericostal sutures (Vicryl 2, Ethicon Inc, Somerville NJ) as described elsewhere [5, 6] by semi-open endoscopic assistance (Fig 2B). Finally the rectus abdominis was refixed to the sternum and costal arches, and the pectoral muscles were united in the midline.

Fig 1. (A) View from the anterior axillary line toward the left sternal edge (a) in the space created by subpectoral CO2 insufflation. Note the excellent view of a dissected rib (r), the intercostal muscle (i), the pectoralis muscle (p) above, and the parasternal perforating vessels (v). (B) The same space, while a rib (r) osteotomy (o) is performed by a Luer bone rongeur (b) in a semi-open way or under videoendoscopic control.
The subpectoral space received liberal bilateral drainage, whereas pleural drainages or decompression of the pleural space, which had been standard in the conventional technique, were no longer necessary with minimal access repair, except in the earlier and older patients.

**Results**

All 37 operations could be performed by minimal access repair. There was no substantial hemorrhage except mild oozing from costal resections and sternotomies, and no conversions to an open procedure. Operating times came down from an initial 240 minutes to 150 minutes in the later cases, and averaged about 180 minutes. This compares favorably with the 210 minutes with our open technique [5] and the 193 minutes reported by Fonkalsrud [1]. For safety all patients had preoperatively donated a unit of their own blood, which some received back. The postoperative course was uncomplicated, except a moderate submuscular hematoma and a seroma with minor wound dehiscence both managed conservatively and uneventfully. All patients left the hospital between postoperative day 7 and 10, which is much shorter than the nearly 3 weeks for our conventional repairs. There was no bar dislocation or need for a redo operation. Thirty-three patients rated their postoperative result as excellent (Fig 3), 4 as good, and all had permanent relief from their preoperative limitations and complaints. In 21 patients, the struts were removed uneventfully through the same incisions with maintenance of the repair and no recurrence so far. From our and the patients’ assessment, results are as good or better than with open repair, and all patients asserted that they would have had the minimal access repair again and preferably earlier in life.

**Comment**

Little is standardized in pectus carinatum therapy and Lester [7] stated 40 years ago, that “protrusion anomalies of the anterior chest wall are widely recognized, poorly understood and generally neglected,” which is still true in many respects. Data on incidence and frequency in relation to funnel chests differ within a wide range. In 1975, Ravitch [8] reported the incidence of pectus carinatum to be 7.1% (25 of 350) of their excavatum numbers [8], whereas we had 12.5% (37 of 296) in our minimal access patients [2–4], and 14% in our open series (111 of 791) [5, 6], whereas Shamberger and Welch [9] reported 20.8% (152 of 758).

Pectus carinatum has often been regarded as a purely aesthetic problem, but Ravitch [8] described “very severe breathing restriction,” and Fonkalsrud [1] reported shortness of breath (2 oxygen-dependent patients) and decreased stamina in most of their patients (85 of 90 [94%]), just as we did. Treatment options vary considerably from frank nihilism, compressive orthotics [10], cartilage and sternal resections with [1, 5] and without [8, 9] struts, with most reports comprised of less than 10 patients [10, 11].

Surprisingly, endoscopic techniques have not been used for pectus carinatum, except a rudimentary Japanese attempt by Koyobashi [11] in 1997, who advanced an endoscope through the main incision with the intent of reducing scar size, at the cost of multiple stab incisions for costal dissection in addition. Unfortunately they had to compromise on results (ie, none excellent and two
fair), blood loss, and operative time. In 6 pectus excavatum and 2 carinatum patients (age range, 4 to 20 years), they required between 5.4 and 10 hours for the repair, which is unacceptable considering that mainly young patients of 4 to 14 years of age were treated. We operated on the more time-consuming adolescents and young adults in one third of that time. Koyobashi and his colleagues admitted that their access was best suited to very young patients with extreme skin elasticity. However, doing everything through one small skin incision provoked prolonged skin retraction and skin edge bruising. Accordingly, Koyobashi had 2 of 8 (25%) healing disturbances of the skin due to “over retraction of the incision site.”

As we perform most of the dissections by endoscopy under insufflation, the midline incision is used for less than half of the operative time, which reduces the time for skin edge trauma. Moreover, the extensive detachment of skin and muscles from the bony thorax renders the small skin incision so mobile that it can be shifted on the thorax to virtually every point required. So far, minimal access repair of pectus carinatum was limited by the need for extensive dissection of the ventral thoracic cage between both axillary lines. We achieved this by introducing bilateral submuscular CO₂-insufflation and performing the entire dissection of the pectoral muscles from the ribs and sternum under endoscopic vision. Although the same radical repair as conventionally was performed, most of the dissection was completed by endoscopy with excellent sight and hemostasis. Segmental rib resections and sternotomies were done by endoscopic assistance in a semi-open way from the 2.9 cm to 4.7 cm (mean, 3.6 cm) midline (in the girls’ bilateral submammary) or trocar accesses. Conversely incision sizes had been 15 cm to 25 cm in conventional open repairs. Two transsternal struts were introduced and fixed pericostally, similarly with Fonkalsrud who recommends Atkins struts for pectus carinatum.

In this experience the endoscopic dissection was standardized to assist the minimal access semi-open technique effectively. Eighty-nine percent of the results were excellent and the rest were good, which is better than our well-standardized open Hegemann-Willital repair. No additional accesses were used; we just converted previous drain sites to port sites. Judging from our limited
experience, this simple technique reduces operative time moderately and access size substantially, without compromising on results. Moreover, endoscopy-assisted minimal access repair of the pectus carinatum improved patient comfort and accelerated early mobilization considerably.

Admittedly this is an early experience with short follow-up, and improvements will follow. Nevertheless other centers should start now to evaluate this new technique in order to enlarge the experience of minimal access pectus carinatum repair and to contribute further improvements.

Disclosures and Freedom of Investigation
Used technology was purchased, and the same as for Nuss repairs. Authors had full control of the study design, methods used, outcome measurements, analysis of data, and production of the written report.

Supported by Sonnenfeld Stiftung, Berlin, Germany and the Mickey Foundation, Berlin, Germany, and McDonald’s, Kinderhilfe-Munich, Germany.

References

Disclaimer
The Society of Thoracic Surgeons, the Southern Thoracic Surgical Association, and The Annals of Thoracic Surgery neither endorse nor discourage use of the new technology described in this article.

INVITED COMMENTARY

Pectus excavatum and carinatum are well recognized cosmetic deformities of the chest wall that are often left untreated. Unfortunately many primary care physicians do not appreciate the physiologic and psychologic benefit that surgery can provide and often advise against an operation that in their minds trades an abnormality in chest wall contour for a prominent scar in the front of the chest. In the case of pectus excavatum, referrals for surgical repair began to increase when the less invasive technique introduced by Donald Nuss became an option. By introducing a curved reinforced stainless steel bar through small lateral incisions, Nuss’s minimally invasive technique elevates the depressed sternum without rib resection, sternal osteotomy, or anterior chest incision [1]. Unfortunately the Nuss technique has not been applicable to the less common carinatum deformity, which still requires access to the affected sternum and anterior rib cage to permit cartilage resection and sternal osteotomy, an approach that until now has required a prominent anterior incision.

The authors of this article [2] describe how they have minimized the surgical incision for pectus carinatum without compromising the principles of anterior chest wall reconstruction well described by Ravitch [3], Welch [4], and others [5]. Key to this approach is the use of CO₂ insufflation to elevate the chest wall muscles off of the ribs and sternum. Endoscopes then guide transcutaneous detachment of the pectoralis muscles, separation of the sternum from the anterior mediastinum, resection of costal segments on both sides of the sternum, osteotomy of the outer sternal plate, and placement of one or two stainless steel struts to support the sternum. This is a large series of an uncommon chest wall deformity with what seems to be excellent results. The results demonstrated in the patient who is pictured are impressive.

However, the authors have not eliminated the anterior incision as did Nuss with his innovation. Nevertheless they have markedly decreased its size, because according to them, the detachment of the skin and muscles from the chest wall permits mobilization of the small incision to all points required for rib resection and osteotomy. Because this technique requires much more than the insertion of a bar, it is unlikely to save as much time for the surgeon as the Nuss approach has for pectus excavatum. However, these surgeons did experience a decrease in operative time from 3½ to 3 hours.

In summary, these authors have developed a less invasive technique for the treatment of an under diagnosed and under treated chest wall deformity that will...