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Johannes Schalamon, Stefan Pokall, Jana Windhaber and Michael E. Hoellwarth

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Minimally invasive correction of pectus excavatum in adult patients

Johannes Schalamon, MD, Stefan Pokall, MD, Jana Windhaber, MD, and Michael E. Hoellwarth, MD, Prof

Objective: The repair of pectus excavatum by minimally invasive surgery (Nuss procedure) is well established among pediatric surgeons. Studies on adult patients are rare. We analyzed the efficacy of minimally invasive pectus repair in a series of adult patients.

Methods: We prospectively included all adult patients with minimally invasive repair of funnel chest treated from 2000 to 2005. The pectus bar was inserted under thoracoscopic control. On the right side a stabilizer was used to prevent bar displacement. Postoperative pain control was provided by epidural catheters. Clinical checks were performed 2 weeks, 3 months, and then annually after discharge.

Results: Forty-three adult patients (39 men, 4 women) with a mean age of 22 years (range 18-39 years) were included. Mean duration of the operative procedures was 70 minutes (range 29-125 minutes); mean length of hospital stay was 9.3 days. Bars were removed from 15 patients 3 years after implantation. Minor complications occurred in 8 patients (19%), with intrapleural effusions being most frequent (n = 5). Three patients (7%) had major complications: drainage of a pneumothorax (n = 2) and bar displacement (n = 1). The cosmetic results were excellent and patient satisfaction was high.

Conclusions: We conclude that the Nuss procedure was beneficial in adult patients. Dislocation of the pectus bar can be prevented by submuscular placement. The use of corticosteroids may be helpful in case of repeated, uncontaminated pleural effusions. Patient satisfaction and the acceptable number and kind of complications are encouraging.

Pectus excavatum is the most frequent chest wall deformity with an incidence of approximately 1:1000.[1] The deformity was first described by Bauhinus[2] in 1594. The first reported operative repair was published by Meyer[3] in 1911. Ravitch,[4] Rehbein, and Wernicke,[5] Sauerbruch,[6] and others presented modifications, but the technique with extensive rib resections and sternal resection/elevation remained more or less unchanged for almost 80 years. In 1998 Nuss and associates[7] presented a novel minimally invasive method for correction of funnel chest. The procedure includes the insertion of a stainless steel bar retrosternally through the patient's chest, elevation of the sternum, and correction of the funnel chest by using the ribs as pressure countering. The bar is left in place for 2 to 3 years and then is removed preferably as a 1-day surgical procedure.[8] The method was primarily designed for prepubertal children and the optimal age for repair was recommended between 12 and 16 years.[9,10] Although the method is widely accepted among the pediatric surgical community,[11-14] reports focusing on adult patients with pectus excavatum and minimally invasive correction are rare.[15] The aim of this study was to analyze the efficacy of the Nuss procedure in a series of adult patients with pectus excavatum.

From the Department of Pediatric Surgery, Medical University of Graz, Austria

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Address for reprints: Michael E. Hoellwarth, Department of Pediatric Surgery, Medical University of Graz, Auenbruggerplatz 34, 8036 Graz, Austria (E-mail: michael.hoellwarth@meduni-graz.at).

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Abbreviations and Acronyms
NSAID = nonsteroidal anti-inflammatory drug
PDS = polydioxane

Methods

We prospectively followed up all patients with funnel chest repair since January 2000. For the present study, we selected those patients who were 18 years or older at the time of surgical correction of the funnel chest. The protocol included a preoperative clinical examination including computed tomography of the thorax and documentation of the clinical history. In a group of patients with high-grade funnel chest, a preoperative and postoperative documentation of the performance capacity by bicycle ergometry and lung function was added. Indication for surgery was a chest wall deformity that was unacceptable for the patient. During operative repair, access to the thorax was gained by small bilateral skin incisions in the midaxillary line. A submuscular tunnel was preformed by blunt dissection to the highest point of the funnel (thoracic entry and exit points). Under right-sided thoracoscopic control (5-mm trocar, wide-angle optic, carbon dioxide insufflation pressure of 10 mm Hg), a long steel rod (introducer) was inserted into the thorax and pushed through behind the sternum ventral to the pericardium. After fixation of a cotton tape to the eyelet at the end of the introducer, the introducer was pulled back, thereby guiding the cotton tape through the thorax. The Lorenz pectus bar (Lorenz Surgical, Inc, Jacksonville, Fla) was pre-bent to the desired thorax shape. After being fixed to the cotton tape, the bar was pulled through the tunnel with the convex side down. Finally the bar was turned. On the right side the bar was fixed with a stabilizer plate and either a 1.0-mm wire or a 1.0-mm polydioxane (PDS) cord in a diagonal (Figure 1) around the ribs to prevent the bar from flipping. In case of very long and severe forms of pectus excavatum, an additional bar was introduced. Finally, the insufflated gas was evacuated through the 5-mm trocar.

Postoperative pain management was provided by preoperatively placed epidural catheters and administration of ropivacaine. Nonsteroidal anti-inflammatory drugs (NSAIDs) and intravenous rescue medication with opiates (piritramid) were used in case of severe pain episodes. Patients were monitored at the intensive care unit for 24 hours. Mobilization was started on the first postoperative day by physical therapists. The patients were discharged from the hospital when pain control was possible without intravenous administration of pain medication. Our protocol included a clinical follow-up at 2 weeks, 3 months, and then annually after discharge. The bars were left in position for 3 years and removed through a right-sided or bilateral thoracic incision. At the time of this report, patients had been followed up for 6 months to 5 years (mean 1.9 years) after the initial operation.

Results

In the period from January 2000 to December 2004, 43 adult patients (39 men, 4 women) with a mean age of 22 years (range 18-39 years) were operated on for correction of funnel chest deformities. The preoperative fronto-sagittal index according to Backer, Brunner, and Larsen[16] was 27.8 mean (range 13-48) and the mean vertebral index was 29.7 (range 20-44). In 23 patients (53%) the chest wall deformity was asymmetric; in 10 of these patients a scoliosis was documented preoperatively. Other comorbidity was hyperlipidemia, ventricular septal defect, dermatitis seborrhea, and a history of stomach ulcer in 1 patient each. Two patients had unsuccessful previous funnel chest repair (silicone implantation and Ravitch technique, respectively). In 35 patients (81%) a single bar was used for correction, and in 8 patients (19%) the insertion of a second bar became necessary. Intraoperative problems at bar placement were not documented. In the first 27 patients the stabilizer was fixed with wire, and in the last 8 patients a PDS suture was used for fixation. PDS sutures for bar fixation have been used exclusively in the 8 patients with two bars. Mean duration of the operative procedures was 70 minutes (range 29-125 minutes). The length of hospital stay at initial surgery ranged from 7 to 17 days (mean 9.3 days).

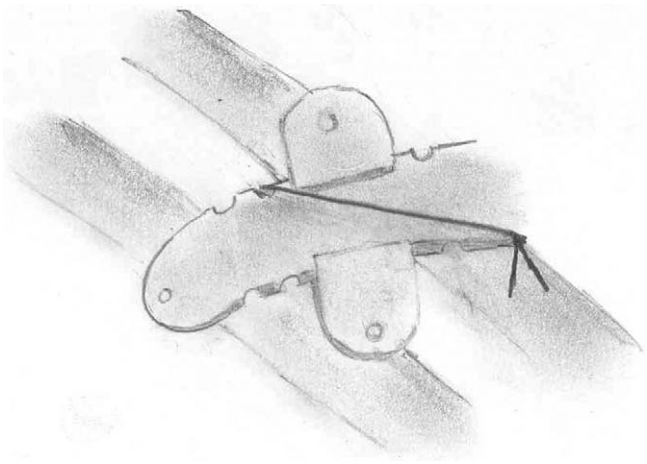

Figure 1. Method of bar fixation.

Bar Removal

So far, bars have been removed from 15 of these patients 3 years after implantation with a mean operation time of 39 minutes (range 23-59 minutes). The mean duration of hospital stay for bar removal was 3.1 days (range 3-5 days). Twelve bars were successfully removed by right-sided thoracic incision only. In the remaining 3 patients an additional left-sided thoracic incision became necessary because of extensive ossification around the left-sided bar end. No complications were documented related to the bar removal.

Mobilization

During the intensive care unit stay, breathing exercises were started by the physical therapists. Mobilization was possible

in 35 of 43 patients (81%) on day 1 after the operation. In 2 patients with postoperative pneumothorax, mobilization was possible on days 3 and 4 after the operation. In another 4 patients, the administration of intravenous rescue medication for pain control complicated early mobilization; 2 further patients refused to stand up despite being free of pain. These adults were mobilized 3 to 5 days after the operation.

Antibiotics

In all but 2 patients, perioperative antibiotic prophylaxis for prevention of postoperative infections was performed. Fourteen of these had single-shot antibiotics (cefuroxime). Of the remaining 27 patients, 25 had antibiotic treatment ranging from 2 to 10 days (mean 4.6 days). Another 2 patients had continuous antibiotic treatment (15 and 18 days, respectively) as a consequence of elevated blood levels of C-reactive protein (up to 240 mg/L; normal 8 mg/L) and leukocytes (up to 17 g/L, normal 11.5 g/L), but without clinical signs of infection.

Minor Complications (n = 8; 19%)

Most of our patients had transitory minor postoperative fluid collections detected in the pleural space without clinical relevance. In 5 patients (12%), the puncture of a pleural effusion (350-1200 mL) became necessary. Whereas 3 punctures were performed during the hospital stays (on postoperative days 4, 5 and 7), 1 patient had puncture of a pleural effusion 3 weeks after the operation. One additional 28-year-old female patient had repeated bilateral pleural effusions and required repeated punctures up to 10 weeks after the bar implantation. All bacterial cultures from the effusion remained sterile. The effusions resolved completely after administration of oral cortisone for a period of 2 weeks.

In 1 patient, the stabilizer plate became dislocated, without clinical consequences. One patient returned 2 weeks after discharge with severe back pain and was readmitted for 4 days. The pain resolved with physical therapy and intermittent treatment with piritramid. Another patient had a pleural hernia as a consequence of disrupted intercostal muscles. The hernia was covered with a muscle and fascia flap at bar removal.

Major Complications (n = 3; 7%)

On the first postoperative day, the drainage of a clinically relevant pneumothorax became necessary in 2 patients. The drains were removed on days 3 and 4, respectively. In 1 patient,upward displacement of the bar became obvious 10 days after the operative procedure; however, the correction of the funnel was still acceptable and did not necessitate a reoperation.

Outcome

The mortality in our patients was zero. No reoperations were required. All patients were satisfied with the cosmetic results. Yet, the surgeons graded the postoperative results as excellent in 39 (91%) patients, whereas in 4 patients (9%) the correction was described as incomplete with a minor residual funnel and/or asymmetric thickening in the parasternal region, mainly as a consequence of a primary asymmetric deformity (Figure 2). After bar removal, the patients (n = 15) had been followed up a mean of 5.4 months (range 1-10 months) at the time of this report. None of these patients has had a recurrence of the funnel chest deformity so far.

Discussion

The pediatric chest is more flexible and compliant than the adult chest, because chest wall stiffness increases owing to the maturity of ossification.[17] The different bone quality compared with that of children may influence surgeons in decision-making concerning minimally invasive funnel chest repair in adults. In a retrospective survey, Hebra and associates[18] conducted a comprehensive survey of American Pediatric Surgical Association members to review technical problems, complications, and outcomes of the Nuss procedure. A majority of surgeons indicated a higher risk for complications with the Nuss procedure in patients older than 15 years of age. Molik and coworkers[19] described a lack of efficacy in older teenagers, in contrast to Ong and associates,[20] who found good results in a teenaged group of patients with minimally invasive funnel chest repair. Thus, studies focusing on adults with minimally invasive surgery such as the Nuss repair for funnel chest deformities are rare. Most operative interventions for funnel chest repair in adults are still performed by the technique published by Ravitch.[4] A single report by Coln and colleagues[15] indicates a successful use of the Nuss procedure in 8 adult patients with promising results. A number of other authors included adult patients in their series of minimally invasive funnel chest corrections.[21-24] Bar displacement and pleural effusions were the main complications in the group of older teenagers and adult patients and occurred in 3% to 17% of the patients. Fonkalsrud and coworkers,[25] as well as Boehm, Muensterer, and Till,[26] compared the Nuss and Ravitch techniques in children and adolescents. The report of Boehm, Muensterer, and Till[26] was limited to 28 patients (21 Nuss method vs 7 Ravitch method); Fonkalsrud and associates[25] retrospectively compared the experience of two different hospitals with each of the hospitals performing one of the techniques only. Nevertheless, both authors found fewer complications and a shorter hospital stay related to the Ravitch technique, with bar displacement again being the most frequent complication in the Nuss group. Kim and associates[22] explained the increased rate of bar dislocations with the higher force required to elevate the sternum in

Figure 2. Preoperative and postoperative images.

adults compared with children.[27] We did not experience such a considerable rate of bar displacements in our series of adult patients. Only 1 patient presented with an incompletely upward flipped bar early after operation but did not require reoperation. The difference may result from the fact that we placed the bar directly on the ribs on its way into the thorax by building a submuscular tunnel. Without underlying muscular tissue, we are able to fix the stabilizer plate as well as the bar around the rib in a diagonal fashion. In contrast, fixation tends to be unstable when the bar is placed on the muscle tissue as recommended by Nuss,[7] and on the slippery layer the bar can turn easily. Unfortunately, direct placement of the bar on the patient's ribs induces ossification around the bar. Despite avoiding late dislocation of the bar, the ossification may complicate bar removal. We found that an extensive 5-point bar fixation with steel wires, as published by Hebra,[28] Park,[29] and their associates, is not necessary. In none of the patients did the the deformity recur after bar removal. Despite our preliminary short-term follow-up results, we assume that the pectus bar acts as a brace for the elevation of the sternum in a way similar to that of braces in the jaw of an adult. Teeth in adults stay in place after braces are removed.

Pleural effusions were the most frequent complications in our series. Although most of the patients had minimal effusions detected by thoracic x-ray films or ultrasound within the first 2 days after surgery, a puncture was required in 5 patients. The temporary presence of pleural effusions may be explained by the empty space being created by elevation of the sternum. In 1 female patient, repeated punctures for drainage of uncontaminated fluid raised the suspicion of an underlying immunologic mechanism. Our patient did not respond to treatment with NSAIDs, but temporary treatment with cortisone was successful in this case. The production of pleural effusions after bar implantation recalls the widely known postpericardiotomy syndrome (Dressler syndrome), although our patients had no pericardial effusion. Postpericardiotomy syndrome may oc-

cur after surgical interventions in which the pericardial space is involved.[30] It is believed that the manipulation initiates an autoimmune process with subsequent inflammation of the pericardium. Muensterer and associates[31] described the case of a 14-year-old boy with postpericardiotomy syndrome after a Nuss procedure who was successfully treated with corticosteroids after unsuccessful use of NSAIDs. The commonly used treatment options for postpericardiotomy syndrome are corticosteroids, NSAIDs, and puncture.[32] Since the underlying mechanism may be similar in persistent pleural effusions after minimally invasive repair of pectus excavatum, we recommend a similar strategy in this case.

We believe that the indications for surgery should include both physical and psychologic aspects and that they should be thoroughly discussed with the patients before operation.

Although we did not observe life-threatening complications or failure of correction, the surgeon should indicate the possibility of cardiac perforation,[33] major infections with or without the necessity of bar removal,[34,35] and the occurrence of complications necessitating repeated surgical interventions.

For more than 60 years there has been an ongoing discussion in the literature about possible cardiac disability associated with a funnel chest.[36] Although early publications could not identify funnel chest–related cardiac anomalies,[37] more recent publications have identified several patients with preoperative mitral valve prolapse and echocardiographic improvement after bar implantation.[38] Other authors[39] have described an improved right ventricular function after pectus excavatum repair. In addition, a minor postoperative improvement of pulmonary function has been diagnosed,[40] although a Canadian group[41,42] found only subjective improvement in the exercise tolerance and a postoperative decline in pulmonary function. Twenty of our patients with high-grade funnel chest had spirometry and exercise testing by cycle-ergometry preoperatively and 6 months after surgery. The results (not included in this study) did not show significant improvements, either in lung capacity or in exercise tolerance. Moreover, a not significant trend toward deterioration of vital capacity and exercise tolerance was noticed. The interpretation of these results may be problematic from a methodologic point of view because of the short interval of 6 months between surgery and exercise testing. An analysis of long-term results will be necessary to identify possible benefits of the minimally invasive funnel chest correction on cardiorespiratory function.

In our series, the indication for surgery was a chest wall deformity that was unacceptable to the patient. Einsiedel[43] stated that patients with funnel chest require long-term psychotherapy because of its influence on all areas of life. Therefore, we believe that surgery is justified in patients having psychosocial problems.

Even though our results are very preliminary, we conclude that the Nuss procedure was beneficial in adult patients. Patient satisfaction and the acceptable number and kind of complications are encouraging.

References

1. Kelly RE Jr, Lawson ML, Paidas CN, Hruban RH. Pectus excavatum in a 112-year autopsy series: anatomic findings and the effect on survival. *J Pediatr Surg.* 2005;40:1275-8.
2. Bauhinus I. Observatio 264. In: Schenck von Grafenberg J, editor. Observationum medicarum, rararum, novarum, admirabilium, et montrosarum, liber secundus: De partibus vitalibus, thorace contentis. 1594. p. 516.
3. Meyer L. Zur chirurgischen Behandlung der angeborenen Trichterbrust. *Verh Berliner Med.* 1911;42:364-73.
4. Ravitch MM. The operative treatment of pectus excavatum. *Ann Surg.* 1949;129:429-44.
5. Rehbein F, Wernicke HH. Operation der Trichterbrust. *Z Orthop Ihre Grenzgeb.* 1958;89:475-81.
6. Sauerbruch F. Die Chirurgie der Brustorgane. Berlin: Springer Verlag; 1920.
7. Nuss D, Kelly RE Jr, Croitoru DP, Katz ME. A 10-year review of a minimally invasive technique for the correction of pectus excavatum. *J Pediatr Surg.* 1998;33:545-52.
8. Hosie S, Sitkiewicz T, Petersen C, Gobel P, Schaarschmidt K, Till H, et al. Minimally invasive repair of pectus excavatum—the Nuss procedure. A European multicentre experience. *Eur J Pediatr Surg.* 2002; 12:235-8.
9. Fonkalsrud EW. Current management of pectus excavatum. *World J Surg.* 2003;27:502-8.
10. Boehm RA, Muensterer OJ, Till H. Comparing minimally invasive funnel chest repair versus the conventional technique: an outcome analysis in children. *Plast Reconstr Surg.* 2004;114:668-73.
11. Bohosiewicz J, Kudela G, Koszutski T. Results of Nuss procedures for the correction of pectus excavatum. *Eur J Pediatr Surg.* 2005;15:6-10.
12. Croitoru DP, Kelly RE Jr, Goretsky MJ, Gustin T, Keever R, Nuss D. The minimally invasive Nuss technique for recurrent or failed pectus excavatum repair in 50 patients. *J Pediatr Surg.* 2005;40:181-6.
13. Jacobs JP, Quintessenza JA, Morell VO, Botero LM, van Gelder HM, Tchervenkov CI. Minimally invasive endoscopic repair of pectus excavatum. *Eur J Cardiothorac Surg.* 2002;21:869-73.
14. Hendrickson RJ, Bensard DD, Janik JS, Partrick DA. Efficacy of left thoracoscopy and blunt mediastinal dissection during the Nuss procedure for pectus excavatum. *J Pediatr Surg.* 2005;40:1312-4.
15. Coln D, Gunning T, Ramsay M, Swygert T, Vera R. Early experience with the Nuss minimally invasive correction of pectus excavatum in adults. *World J Surg.* 2002;26:1217-21.
16. Backer OG, Brunner S, Larsen V. Radiologic evaluation of funnel chest. *Acta Radiol.* 1961;55:249-56.
17. Papastamelos C, Panitch HB, England SE, Allen JL. Developmental changes in chest wall compliance in infancy and early childhood. *J Appl Physiol.* 1995;78:179-84.
18. Hebra A, Swoveland B, Egbert M, Tagge EP, Georgeson K, Othersen HB Jr, et al. Outcome analysis of minimally invasive repair of pectus excavatum: review of 251 cases. *J Pediatr Surg.* 2000;35:252-7.
19. Molik KA, Engum SA, Rescorla FJ, West KW, Scherer LR, Grosfeld JL. Pectus excavatum repair: experience with standard and minimal invasive techniques. *J Pediatr Surg.* 2001;36:324-8.
20. Ong CC, Choo K, Morreau P, Auldist A. The learning curve in learning the curve: a review of Nuss procedure in teenagers. *Aust N Z J Surg.* 2005;75:421-4.
21. Uemura S, Nakagawa Y, Yoshida A, Choda Y. Experience in 100 cases with the Nuss procedure using a technique for stabilization of the pectus bar. *Pediatr Surg Int.* 2003;19:186-9.
22. Kim do H, Hwang JJ, Lee MK, Lee DY, Paik HC. Analysis of the Nuss procedure for pectus excavatum in different age groups. *Ann Thorac Surg.* 2005;80:1073-7.
23. Zallen GS, Glick PL. Miniature access pectus excavatum repair: lessons we have learned. *J Pediatr Surg.* 2004;39:685-9.

24. Park HJ, Lee SY, Lee CS. Complications associated with the Nuss procedure: analysis of risk factors and suggested measures for prevention of complications. *J Pediatr Surg.* 2004;39:391-5.
25. Fonkalsrud EW, Beanes S, Hebra A, Adamson W, Tagge E. Comparison of minimally invasive and modified Ravitch pectus excavatum repair. *J Pediatr Surg.* 2002;37:413-7.
26. Boehm RA, Muensterer OJ, Till H. Comparing minimally invasive funnel chest repair versus the conventional technique: an outcome analysis in children. *Plast Reconstr Surg.* 2004;114:668-73.
27. Fonkalsrud EW, Reemtsen B. Force required to elevate the sternum of pectus excavatum patients. *J Am Coll Surg.* 2002;195:575-7.
28. Hebra A, Gauderer MW, Tagge EP, Adamson WT, Othersen HB Jr. A simple technique for preventing bar displacement with the Nuss repair of pectus excavatum. *J Pediatr Surg.* 2001;36:1266-8.
29. Park HJ, Lee SY, Lee CS, Youm W, Lee KR. The Nuss procedure for pectus excavatum: evolution of techniques and early results on 322 patients. *Ann Thorac Surg.* 2004;77:289-95.
30. Khan AH. The postcardiac injury syndromes. *Clin Cardiol.* 1992;15: 67-72.
31. Muensterer OJ, Schenk DS, Praun M, Boehm R, Till H. Postpericardiotomy syndrome after minimally invasive pectus excavatum repair unresponsive to nonsteroidal anti-inflammatory treatment. *Eur J Pediatr Surg.* 2003;13:206-8.
32. Zeltser I, Rhodes LA, Tanel RE, Vetter VL, Gaynor JW, Spray TL, et al. Postpericardiotomy syndrome after permanent pacemaker implantation in children and young adults. *Ann Thorac Surg.* 2004;78: 1684-7.
33. Willekes CL, Backer CL, Mavroudis C. A 26-year review of pectus deformity repairs, including simultaneous intracardiac repair. *Ann Thorac Surg.* 1999;67:511-8.
34. Calkins CM, Shew SB, Sharp RJ, Ostlie DJ, Yoder SM, Gittes GK, et al. Management of postoperative infections after the minimally invasive pectus excavatum repair. *J Pediatr Surg.* 2005;40:1004-7.
35. Van Renterghem KM, von Bismarck S, Bax NM, Fleer A, Hollwarth ME. Should an infected Nuss bar be removed? *J Pediatr Surg.* 2005; 40:670-3.
36. AH Bill Jr. Funnel chest: indications for surgery and the time of choice for operation. *Pediatrics.* 1953;11:581-7.
37. Evans, W. Heart in sternal depression. *Br Heart J.* 1946;8:162-70.
38. Croitoru DP, Kelly RE Jr, Goretsky MJ, Lawson ML, Swoveland B, Nuss D. Experience and modification update for the minimally invasive Nuss technique for pectus excavatum repair in 303 patients. *J Pediatr Surg.* 2002;37:437-45.
39. Kowalewski J, Brocki M, Dryjanski T, Zolynski K, Koktysz R. Pectus excavatum: increase of right ventricular systolic, diastolic, and stroke volumes after surgical repair. *J Thorac Cardiovasc Surg.* 1999;118: 87-92.
40. Lawson ML, Mellins RB, Tabangin M, Kelly RE Jr, Croitoru DP, Goretsky MJ, et al. Impact of pectus excavatum on pulmonary function before and after repair with the Nuss procedure. *J Pediatr Surg.* 2005;40:174-80.
41. Sigalet DL, Montgomery M, Harder J. Cardiopulmonary effects of closed repair of pectus excavatum. *J Pediatr Surg.* 2003;38:380-5.
42. Bawazir OA, Montgomery M, Harder J, Sigalet DL. Midterm evaluation of cardiopulmonary effects of closed repair for pectus excavatum. *J Pediatr Surg.* 2005;40:863-7.
43. Einsiedel E, Clausner A. Funnel chest. Psychological and psychosomatic aspects in children, youngsters, and young adults. *J Cardiovasc Surg (Torino).* 1999;40:733-6.

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