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Minimally Invasive Surgery Using Abramson Method Is Safe and Successful in Pectus Carinatum Deformity

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Abstract

Objective: Pectus carinatum is the second most common congenital deformity after pectus excavatum. While pectus carinatum deformity has been corrected with open surgery (Ravitch) for nearly 50 years, a minimally invasive correction procedure was defined by Abramson in 2005.

Methods: The Abramson procedure, which has been adopted by many centers, was applied to 68 patients with pectus carinatum deformity between 2010 and 2021 in our clinic. All patients who underwent surgery during this period were evaluated for clinical features, postoperative complications, patient satisfaction, and long-term results.

Results: All patients in this study were male. There was no female patient who applied to the polyclinic and did not undergo surgery. The mean age of the patients was 16.7 years and 28.5% of the patients had a family history of pectus deformity. The mean follow-up period of the patients whose bar was removed was calculated at 27 months. No complications were observed. No patient had recurrence after bar removal. Considering the mid-long term complications, intense pain required the use of painkillers for 3 months in 7 (10.2%) patients and a break in the wire suture was detected after the second year in 4 (5.8%) patients.

Conclusion: Abramson technique should be preferred to open surgery in suitable patients. It can be used safely in cases where brace application is not sufficient or in deformities that do not have a brace indication.

Keywords: Pectus carinatum, Abramson, minimally invasive

Introduction

Pectus carinatum (PC) is a chest wall deformity that occurs as a result of pushing the sternum anteriorly together with abnormally growing costal cartilages. There are several types based on the peak of the deformity: the most common is the chondrogladiolar (involving the lower sternum) form and the much less common is chondromanubrial form (involving the upper sternum) with symmetrical or asymmetrical protrusion. It is the second most common chest wall deformity after pectus excavatum. It is seen in an average of 10 000 births, although its frequency varies among societies. Male/female incidence rate is 4/1. The incidence in the patient's family history is 25%. The most common deformity accompanying pectus carinatum is scoliosis in the range of 12%-20%. Most of the patients are asymptomatic.[1,2] Since the 1950s, pectus carinatum deformity has been corrected by open surgery (Ravitch technique). In 2005 (Horacia Abramson, Argentina), a new correction technique was described by Abramson as a minimally invasive method.[3] Inspired by the Nuss procedure used for the correction of pectus excavatum deformity, this procedure is used in many centers, including our clinic.[3]

The Abramson procedure was used for the first time in our clinic on June 17, 2010. The total number of surgeries is less than pectus excavatum as in all clinics. We examined the clinical features, surgical suitability, surgical details, postoperative complications, patient satisfaction, and long-term surgical results of all our patients who underwent surgery. It was aimed to transfer experience and contribute to the knowledge in the literature.

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Methods

This study was approved by the chairmanship of the Clinical Research Ethics Committee of the Cerrahpasa Faculty of Medicine of the University of Istanbul Cerrahpasa (Date: May 20, 2022, approval number: E-83045809-604.01.01-384744).

Written informed consent was obtained from all participants who participated in this study.

Surgical Technique

The procedure was performed under general anesthesia with single-lumen orotracheal intubation. The patient is placed in a supine position with both arms open to the sides at shoulder level. The level where the deformity is the highest is marked with a sterile marker pen. In addition, the intercostal spaces are marked in both hemithorax. The template (Biomet, Jacksonville, USA) is bent according to the shape desired to be given to the patient's chest. The steel bar (Biomet) used is shaped according to this template. Levels of the steel stabilizers to be placed on the ribs are marked on both hemithorax after the shaped bar is placed on the skin (Figure 1). Approximately 3 cm incisions are made at the marked levels. Soft tissue on the 2 ribs at the planned level is dissected from the incisions after passing the skin, subcutaneous tissue, and muscle tissue. Each rib is rotated through the periosteum with a

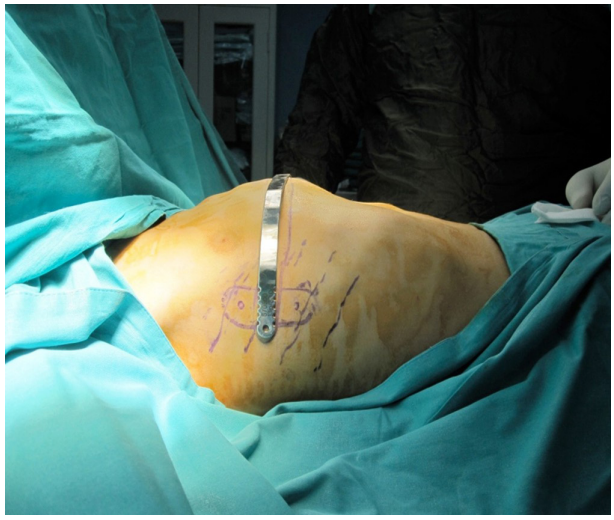

Figure 1. The shaped bar is placed on the skin and the levels of the stabilizers to be placed on the ribs are marked on both hemithorax.

spirally twisted double steel suture wire (Figure 2). Dissection is made to the midline passing under the muscle layer. In this way, a tunnel is created. It is entered through the right side incision with a trocar thoracic drain, proceeded through the opened tunnel, and passed through the upper level of the sternum, and the drain is removed from the left incision (Figure 3). Trocar is withdrawn and the drain is left in the tunnel. Stabilizers are placed on the ribs by lightly binding them with the help of wires. A shaped bar is placed in the tunnel with the help of the drain (Figure 4). The ends of the bar are inserted into the grooves in the fasteners. The bar and stabilizer are tightly knotted and fixed submuscularly with wire sutures while compressing the sternum from above (Figure 2). In this way, maximum pressure and close position to the sternum are provided. Cut muscle tissue, subcutaneous tissue, and skin are sutured, and the process is terminated.

Postoperative 3-day analgesia treatment is given as follows: first-day epidural/ intravenous (iv) control analgesia and oral analgesia in the following days. Also, respiratory physiotherapy and mobilization are performed. The patient is discharged after confirmation with the control chest x-ray. Control examinations are planned on the 10th day, 1st month, 6th month, 12th month, and 2nd year

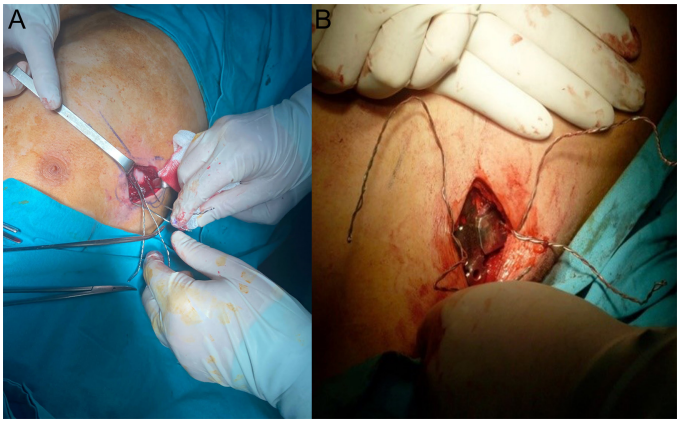

Figure 2. (A). Each rib is rotated through the periosteum with a spirally twisted double steel suture wire. (b=B). Bar and stabilizer are tightly knotted and fixed submuscularly with wire sutures while compressing the sternum from above.

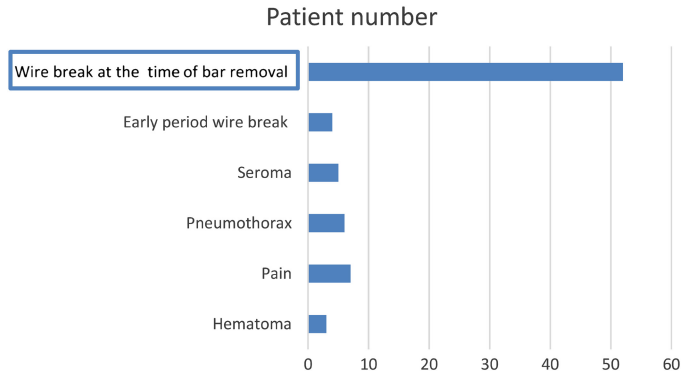

Figure 3. Complications

postoperatively. In the first months, the points to be considered (posture, heavy lifting, avoiding contact, etc.) are explained to the patient.

Bar Removal Technique

The bar removal procedure is performed in a supine position with both arms opened wide. The patient was placed close to the left side of the surgical table. First of all, the left old incision is opened and stabilizer, bar, and—if used—steel wire are accessed with the help of cautery. Steel wire is cut with wire scissors and pulled out of the body by holding it with a wire porter. The stabilizer and the left end of the bar are separated from the surrounding tissue adhesions and ossifications. The left end of the bar is straightened with a bar bender. The stabilizer and bar are removed from the skin. The bar bender is passed to the bar part that is removed from the skin, and the bar is rotated to the right and left with a controlled 30˚ angle. Bar is removed by pulling with the hook and tissue layers are closed appropriately.

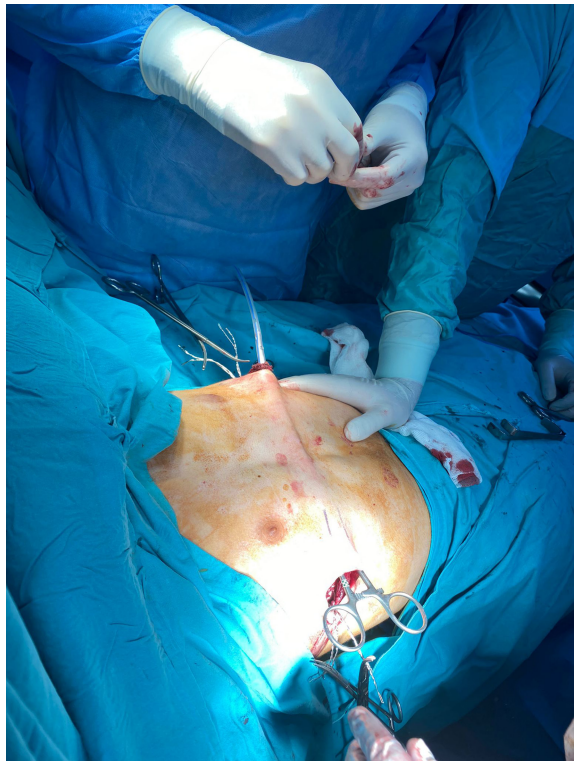

Figure 4. The trocar is withdrawn and the drain is left in the tunnel.

Patients

Preoperative clinical data, demographic characteristics, operative data, follow-up findings, postoperative complications, and post-discharge medical conditions of all patients were recorded. Posteroanterior and lateral chest x-rays were performed for all patients before surgery and thorax computed tomography was surgical desicion to surgery. Nickel allergy test (nickel-plated stabilizer to be used on the patient is attached to the inner surface of the wrist before the procedure and 24 hours later, it is tested to see if there is a reaction on the skin), pulmonary function test, cardiological examination including Echocardiography (ECHO) (5% mild mitral regurgitation was present), and cardiac evaluation were performed and there was no additional pathological finding. We have used sternum flexibility to select patients suitable for minimally invasive surgery. We have applied the Abramson method after obtaining consent from patients over the age of 18, from patients under the age of 18, and from their first-degree relatives.

Around 68 patients with pectus carinatum deformity underwent correction by a minimally invasive method (Abramson Method) between June 2010 and June 2021. The indication for surgery was the request for shape correction due to aesthetic (cosmetic) anxiety in all of the patients. There was no shortness of breath or chest pain in the outpatient clinic admissions. Nuss and Abramson procedure (Sandwich procedure) was performed on 2 patients in the same session because of the excavatum–carinatum coexistence. All of the patients were of the chondro gladiolar type and had a flexible chest structure selected by the chest compression test (the test is done by pressing the most protruding part of the rib cage with the palm of the hand). No additional pathology was detected in the examination and evaluation of any patient.

All patients were male. The mean age of the patients was 16.7 years and 28.5% of the patients had a family history of pectus deformity. Coexistence of scoliosis was present in 8% (5 patients). The Cobb angle was used to measure the extent of scoliosis. Bones forming the upper and lower ends of the curvature are detected in the spine. Parallel lines are drawn from the upper edge of the upper vertebra and the lower edge of the lower vertebra. The angle between these 2 lines is determined as the Cobb angle, angles < 10° are considered to represent minor spinal asymmetry, those between 10° and 20° are followed carefully, those between 25° and 40° required orthoses, >40° required surgery, angles greater than 70° indicate severe scoliosis,[4] and patients above 10° are referred to orthopedics and the necessity of surgery is questioned. Cobb angle was calculated to be less than 10° in 5 patients. Therefore, scoliosis surgery was not considered necessary for any of the patients.

Results

There was no female patient who applied to the polyclinic and did not undergo surgery. This is our first finding that clearly contradicts the 1 : 4 ratio in the literature. Mean Haller index was 2.05(1.32-2.13), mean forced expiratory volume ($FEV)_1$ was 93%, and FEV_1/forced vital capacity (FVC) was 104.6 %. The mean surgery time was 75 minutes (60-110 minutes). Only 2 cases were patients with a combined deformity of 100 and 110 minutes who underwent additional procedures. The mean surgery time was 53.75 (30-90) minutes in patients who were excluded and treated for isolated PC. No significant blood loss was observed in any of the patients. After the surgical procedure, all patients were taken to the clinic for postoperative recovery. The complaints of pain were observed to be above the standard in all patients. The mean validation of digital visual analog scale (VAS) pain score was calculated to be 4.6.[2,4-6] For pain control, 43 (63.2%) patients received controlled analgesia with epidural catheter (5 mg/h marcain, 5 µg/s fentanyl), and 25 (36.8%) patients were administered iv (5 µg/h fentanyl, 3 mg/h morphine) analgesia In addition, if needed, iv paracetamol 500 mg 4×1 and non steroid anti inflamatory drugs (NSAID) (ibuprofen, paracetamol) were given to patients. Although the mean VAS decreased at the end of the first 24 hours, it was 5.78 later. Therefore, 58 patients continued with controlled analgesia on the first postoperative day. The VAS score was measured to be 3.81 (1.2-6.5) on the second day, and oral non-steroidal anti-inflammatory drugs were routinely given to the patient (Table 1).

Table 1. Results

CT scan Haller index	**2.05 (1.32-2.13)**
FEV_1 lt	3.38
FEV_1 %	93
FEV_1/FVC %	104.6
Mean surgery time (minute)	75
Mean VAS score	4.6
Hospital stay (day)	2.9 (1-6)

The mean hospital stay of the patients was 2.9 (1-6) days. The mean postoperative follow-up period was 29.39 months (18-41). Considering the early postoperative complications in addition to pain, pneumothorax not requiring tube thoracostomy was observed in 6 (8.8%) patients (less than 20%), and hematoma in the tunnel opened under the muscle and ecchymosis in the skin were observed in 3 (4.4%) patients. Considering the mid- and long-term complications, intense pain that required the use of painkillers for 3 months in 7 (10.2%) patients and a break in the wire suture were detected after the second year in 4 (5.8%) patients (the broken piece of the broken wire suture on the skin in 1 patient was removed, and other patients were followed up until the time of bar removal since no skin damage or seroma developed). When we analyzed the patients who used painkillers for a long time, we found that all of them were over 21 years old. We think that patients feel more pain because of less age-related chest wall flexibility. No recurrence was observed in patients with broken wires. Seroma was seen at the incision sites in 5 (7.35%) patients (Figure 3).

The inserted bar was removed after 2-3 years (mean: 29.45 months, 24-41 months) (Figure 5). The appropriate time was determined by interviewing the patients and their relatives. Early

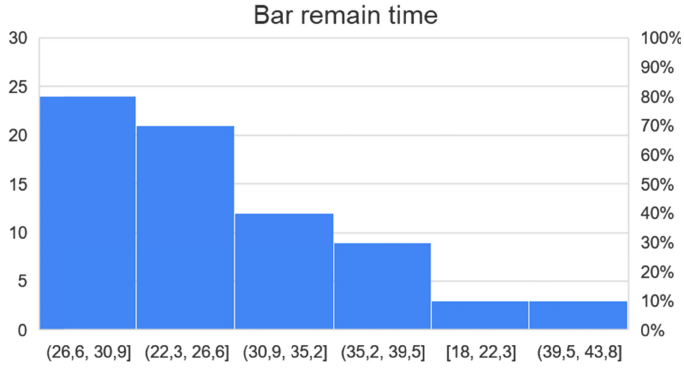

Figure 5. Bar Remain Time

removal of the bar may trigger relapse, especially in adolescence, but excessive holding of the bar may cause iatrogenic pectus excavatum as a result of wire breakage. We determined the time of removal according to the findings with regular controls made in patients. The bar was removed under general anesthesia in 98.5% of the operated patients. The mean follow-up period of the patients whose bar was removed was calculated to be 27 months. No complications were observed. After removing the bar, all patients were followed up completely. No recurrence was observed (deformity was not observed again). Minimal overcorrection after bar removal was detected in 3 patients, but it was not considered as a recurrence by the patient and their relatives.

Outpatient control was carried out by trained personnel with the same questions to all patients by face-to-face interview or by telephone interview, especially during the pandemic period. Two (2.9%) patients were moderately satisfied with chronic pain, 27 (39%) patients were well satisfied, and 39 (58.1%) patients were excellently satisfied.

Discussion

For many years, the open surgical procedure described by Ravitch has been the standard surgical approach to carinatum deformity.[6,7] This surgical technique is a very invasive method that may require cartilage resection, sternal osteotomy, and sternum resection. The Abramson technique was described after Nuss technique. Since it is minimally invasive, it does not have the disadvantages associated with open surgery. The incisions are smaller and sternal osteotomy or resection is not required.

Recognition of the procedure dates back to 2005 when it was suggested that intrathoracic compression on the deformed sternum could be achieved using a minimally invasive technique as an alternative to open surgery in selected cases of pectus carinatum.[3] The technique has subsequently been adopted by many, some using specially modeled bars, changing the length of the bar, using screws or wires for fixation, or in some cases without any fixations, using video-assisted techniques, or just a thoracoscopic approach.

In the pre-procedural clinical evaluation, it is decided whether the thorax is flexible or not, depending on the compression of the protruding area manually while leaning against a wall and the complete reduction of the deformity.[8-10] We evaluated the chest flexibility using a similar method in our series. However, some use the determination of the Haller index both preoperatively and after surgical correction.[9,11]

Pectus carinatum deformity is seen as chondromanubrial, chondrogladiolar, and mixed types. Since the chondromanubrial type is usually rigid, it is difficult to place the bar in front of the sternum and therefore open surgery is preferred.[8,12,13] Chondrogladiolar-type carinatum deformity is more suitable for the Abramson procedure.[8] In our series, all patients had chondrogladiolar type carinatum deformity. In 2008, the results of the first 40 patients who were operated on with this procedure were published, reporting a successful correction rate of 89%.[12] However, there was a high complication rate (62.5%). These complications included skin irritation due to adherence to the bar, allergic cutaneous reactions and seroma in 14 patients, bar dislocation in 5 patients, wire breakage in 3 patients, pneumothorax and infection at the incision site in 1 patient, and persistent pain in the other.

In our series, 7 (10.29%) patients had pain that required the use of painkillers for 3 months, 4 (5.8%) patients had broken wire sutures after the second year, and 5 (7.35%) patients had seroma at the incision sites. In a recent review, the cumulative complication rate for minimally invasive repair of the pectus carinatum was reported to be 39.2%, and skin irritation was found to be the most common morbidity.[1] The most common complication in our series was pneumothorax (8.8%) in the early postoperative period and seroma (7.35%) in long-term follow-up.

The difficulties we experienced with wire fracture in our series may be due to the more inflexible structure of the chest wall compared to those reported by Abramson. Therefore, patient age is important, but the appropriate age range may vary by region. Yüksel et al[8] found that the ideal age range is 12-18 years when working with patients aged 11-20. The ages of the cases in the study of Katrancıoğlu et al[9] ranged between 12 and 20 years. In our series, the age range was recorded as 16-21.[14]

In the process of defining the technique, the position of the bar it was changed with each technique starting from the subcutaneous bar, and finally it was changed to submuscular, retropectoral. It was aimed to prevent skin adhesion, which is a common complication.[3,12] In our series, we placed the ends of the bars submuscularly We decided on the pectoral muscle placement according to the chest wall structure and developmental status of the patients.

The presternal position of the middle of the bar and the use of a manual guide to position the bar help minimize the risk of both entering the pericardium and damaging the heart, lungs, and major blood vessels.[11,15,16] Using a long bar seems to require good fixation, such as fixation plates, subperiosteal wires, and screws to hold the bar in place.[6,8] We preferred a long bar (number 13 most often) in our series and tunneled carefully with the manual guide.

A second operation is required in all cases using bar implants. Most authors have stated that they should remove the bars or supports after at least 2 years. The authors agree that holding the bars longer may lead to iatrogenic pectus excavatum, especially in pubertal individuals, while early removal may cause the deformity to recur.[3,8,9,11-13,15,16] To date, the bar has been removed in 98.5% (67) of our patients who underwent Abramson. Bar removal was performed under general anesthesia and the patients were discharged on the same day. No complications were observed. No patient had recurrence after bar removal.

Large clinical series using compressive orthotic support for chondrogladiolar pectus carinatum have been reported by surgeons from all over the world.[17-19] Due to the success of bracing treatment, patients referred for surgery are usually selected cases with significant deformities, asymmetric deformities, and difficult cases of rigid structure. In some patients, bracing treatment may be preferred to minimize pressure for convenience before surgery.[20] Alternative non-surgical treatments for pectus carinatum have been reported by some authors.[17-19] This type of treatment involves the use of a compression brace. Two lightweight aluminum bars are placed on the front and back of the chest wall. For compression in pectus carinatum, the front bar is used opposite the rear bar. The bars remain in place until the results are satisfactory. However, due to the length of the process, this method may not be well tolerated. Jung et al[17] used the compression brace technique as the initial treatment in suitable patients but preferred surgical treatment in patients who were not suitable for this type of treatment. It was emphasized that sternal compliance is the most important factor in this method. The other non-surgical method was the dynamic compression method and it has promising results. The disadvantage is the long treatment time and the lack of clarity about how much pressure should be applied.[1,17]

It is not easy to wear orthoses in adolescent patients due to the long treatment period. There are significant and real concerns about comfort, clothing, impracticality, and suffering from bullying. The patient's decision to continue wearing the brace and its success are intricately related to how long active brace therapy

should be applied and the amount of pressure to be applied in the treatment.

The Abramson technique is an effective, minimally invasive technique with a short operation and hospitalization time, low morbidity rate, and minimal postoperative pain. This technique should be preferred to open surgery for suitable patients.

Surgical innovation has resulted in a significant expansion of treatment options for PC over the past 2 decades. In addition to the classic Ravitch open repair, noninvasive and minimally invasive options are increasingly available. Appropriate patient selection and joint decision-making with the patient and family are very important.

Most results of orthotic studies have been reported based on patient compliance, a subjective variable that is difficult to measure. We recommend that the open surgical modified Ravitch technique be applied only to patients with severe asymmetric chest wall deformities that cannot be formed.

In line with all this information, we can say that minimally invasive surgery is safe and successful because the results of orthosis use are subjective and depend on patient compliance, and open surgery is preferred only in severe asymmetric deformities.

Centers dedicated to the treatment of chest wall anomalies continue to emerge. These will undoubtedly improve the care of patients with chest wall anomalies and provide further innovation in the evaluation and treatment of these anomalies.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of İstanbul University-Cerrahpaşa (Date: May 20, 2022, approval number: E-83045809-604.01.01-384744).

Informed Consent: Written informed consent was obtained from all patients.

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Declaration of Interests: The authors declare that they have no competing interest.

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References

1. Muntean A, Stoica I, Saxena AK. Pigeon chest: comparative analysis of surgical techniques in minimal access repair of pectus carinatum (MARPC). *World J Pediatr*. 2018;14(1):18-25. [CrossRef]
2. Huddleston CB, Chest Wall YJG. Deformities. In: Feins R. H.,Colson Y. L.,Rocco G.,eds. *Shields General Thoracic Surgery Joseph LoCicero III*. 8th ed; Philadelphia; Wolters Kluwer; 2019:1237-1331.
3. Abramson H. A minimally invasive technique to repair pectus carinatum [preliminary report]. *Arch Bronconeumol*. 2005;41(6):349-351. [CrossRef]
4. Park HJ, Kim KS. The sandwich technique for repair of pectus carinatum and excavatum/carinatum complex. *Ann Cardiothorac Surg*. 2016;5(5):434-439. [CrossRef]
5. Negrini, et al. SOSORT Guidelines: Orthopaedic and Rehabilitation Treatment of Idiopathic Scoliosis during growth. *Scoliosis Spinal Disord*. 2018;13(3);2016.
6. Pérez D, Cano JR, Quevedo S, López L. New minimally invasive technique for correction of pectus carinatum. *Eur J Cardio Thorac Surg*. 2011;39:271-273.
7. Luu TD, Kogon BE, Force SD, Mansour KA, Miller DL. Surgery for recurrent pectus deformities. *Ann Thorac Surg*. 2009;88(5):1627-1631. [CrossRef]
8. Yüksel M, Bostanci K, Evman S. Minimally invasive repair of pectus carinatum using anewly designed bar and stabilizer: a singleinstitution experience. *Eur J Cardiothorac Surg*. 2011;40(2):339-342. [CrossRef]
9. Katrancioglu O, Akkas Y, Karadayi S, Sahin E, Kaptanoğlu M. A is the Abramson technique effective in pectus carinatum repair? *Asian J Surg*. 2018;41(1):73-76. [CrossRef]
10. Lee SY, Song IH, Lee SJ. Minimal invasive extrathoracic presternal compression using a metal bar for correction of pectus carinatum. *Pediatr Surg Int*. 2014;30(1):25-30. [CrossRef]
11. Poullis M. Modified Nuss repair for pectus carinatum. *Interact Cardiovasc Thorac Surg*. 2010;11(3):221-222. [CrossRef]
12. Hock A. Minimal access treatment of pectus carinatum: a preliminary report. *Pediatr Surg Int*. 2009;25(4):337-342. [CrossRef]
13. Abramson H, D'Agostino J, Wuscovi SA. A 5-year experience with a minimally invasive technique for pectus carinatum repair. *J Pediatr Surg*. 2009;44(1):118-123. [CrossRef]
14. Kálmán A. Initial results with minimally invasive repair of pectus carinatum. *J Thorac Cardiovasc Surg*. 2009;138(2):434-438. [CrossRef]
15. Kálmán A. Initial results with minimally invasive repair of pectus carinatum. *J Thorac Cardiovasc Surg*. 2009;138(2):434-438. [CrossRef]
16. Pérez D, Cano JR, Quevedo S, López L. New minimally invasive technique for correction of pectus carinatum. *Eur J Cardiothorac Surg*. 2011;39(2):271-273. [CrossRef]
17. Jung J, Chung SH, Cho JK, Park SJ, Choi H, Lee S. Brace compression for treatment of pectus carinatum. *Korean J Thorac Cardiovasc Surg*. 2012;45(6):396-400. [CrossRef]
18. Stephenson JT, Du Bois J. Compressive orthotic bracing in the treatment of pectus carinatum: the use of radiographic markers to predict success. *J Pediatr Surg*. 2008;43(10):1776-1780. [CrossRef]
19. Martinez-Ferro M, Fraire C, Bernard S. Dynamic compression system for the correction of pectus carinatum. *Semin Pediatr Surg*. 2008;17(3):194-200. [CrossRef]
20. Emil S. Current options for the treatment of pectus carinatum: when to brace and when to operate? *Eur J Pediatr Surg*. 2018;28(4):347-354. [CrossRef]