Original Article

Nuss procedure: Technical modifications to ease bending of the support bar and lateral stabilizer placement

Osman Zeki Karakuş, Oktay Ulusoy, Gülce Hakgüder, Oğuz Ateş, Çimen Olguner[1], Mustafa Olguner, Feza Mirac Akgür

Departments of Pediatric Surgery and [1]Anesthesiology, Dokuz Eylül University, Medical School, Izmir, Turkey

Address for correspondence:
Dr. Osman Zeki Karakuş, Department of Pediatric Surgery, Dokuz Eylül University, Medical School, 35340 Balcova, Izmir, Turkey.
E-mail: osman.karakus@deu.edu.tr

Submission: 21-01-2016
Accepted: 16-03-2016

Abstract:

BACKGROUND: Modifications defined to ease bending of the support bar and lateral stabilizer placement during minimal invasive repair of pectus excavatum (MIRPE) have not been reported. We herein report our experience with MIRPE including several technical modifications.

METHODS: A total of 87 patients who underwent MIRPE were evaluated retrospectively. Technical modifications are (1) a template drawn preoperatively according to the anthropometric measurements, (2) more laterally placed thoracal incisions, (3) single existing incision for multiple support bars, (4) to secure lateral stabilizers to support bar in inverted position.

RESULTS: The mean patient age was 11.2 ± 3.8 years. The mean operating time was 63.7 ± 18.7 min. The mean Haller index was 5.4 ± 2.1. Eight patients necessitated two support bars. The support bars were removed in 69 patients after the completion of treatment. Support bars were left in place 26.8 ± 4.3 months. Final chest contours of the 56 patients were evaluated as 12 months passed after support bar removal and excellent repair results were determined in 84.2%.

CONCLUSION: Preoperative bending of the support bar according to anthropometric measurements and fixation of the lateral stabilizers to the support bar in inverted position facilitates bar shaping and lateral stabilizer placement.

Key words:

Minimal invasive repair, minimal invasive repair of pectus excavatum, Nuss procedure, pectus excavatum, thorax deformity

Access this article online

Quick Response Code:

Website: www.thoracicmedicine.org

DOI: 10.4103/1817-1737.185758

Description of the minimal invasive repair of pectus excavatum (MIRPE)[1] leads to increased patient compliance for surgical correction of pectus excavatum (PE).[1-5] Sticking to the main principles of MIRPE, several technical modifications have been reported to avoid major and minor complications.[6-11] We have developed several technical modifications within our 12 years of experience to ease bending of the support bar and lateral stabilizer placement. Our main technical modification prepares a template according to the anthropometric measurements of each patient and bending the support bar preoperatively according to the template. We herein report our experience with MIRPE since 2002 including aforementioned and other technical modifications.

Methods

This study was approved by the Institutional Review Board (949-GOA, 2013/13-11). The records of patients who underwent MIRPE during May 2002–December 2014 were evaluated retrospectively. MIRPE was performed as described by Dr. Nuss with several technical modifications. These modifications are described below.

Technical modifications

1. A template was drawn preoperatively according to the anthropometric measurements of the patients, measured at the maximal depression level of the PE

How to cite this article: Karakus OZ, Ulusoy O, Hakguder G, Ates O, Olguner C, Olguner M, *et al*. Nuss procedure: Technical modifications to ease bending of the support bar and lateral stabilizer placement. Ann Thorac Med 2016;11:214-8.

deformity ensuring that bony sternum is present at this level. These measurements are as follows:

i. The transverse diameter of the thorax which marks the base of the template (a pelvimeter is used for this purpose)
ii. Anteroposterior diameter of the thorax: A rigid ruler is placed on the ridges of the PE defect, and anteroposterior diameter of the thorax (with one leg of the pelvimeter lying on the ruler) is measured, half of this measurement marks the height of the template
iii. The distances between the ridges of the PE defect to the midline, sum of these distances marks the mid portion of the support bar that is going to be relatively straight. These distances are equal in symmetrical cases and obviously different in asymmetrical cases
iv. The support bar was bent preoperatively according to this template [Figure 1] and the final curve adjustments of the support bar were done intraoperatively to ensure the snug fit of the support bar to the thoracic wall.

2. More laterally placed one-inch long thoracal skin incisions were used to improve the final cosmetic appearance of the residual scar, carrying the middle of the incisions to the midaxillary line. Thus, we made a 2.5 cm long incision with the midpoint of the incision on the midaxillary line
3. If more than one support bar was to be placed, the single existing incision was used with a generous subcutaneous dissection instead of making additional incisions. The spare guide nylon tape was grasped through a 3 mm port introduced into the thorax just by the PE ridge at the level of the second/third support bar and exteriorized. Exteriorized end of the nylon tape was passed through the subcutaneous tunnel connecting the port site and incision. Using the second/third nylon tape as a guide, the additional support bars were placed from the same incision leaving two intercostal spaces between the supports bar
4. Lateral stabilizers were secured to the support bar with steel wires while the support bar was still in inverted position, its convexity facing up. The support bar was flipped over together with the lateral stabilizers secured to the support bar while applying bilateral traction to the nylon tapes passed through the side holes of the support bar [Figures 2 and 3]. In case of single support bar usage, support bars were routinely secured bilaterally to the chest wall muscles with two lateral stabilizers. In case of multiple support bar usage, single lateral stabilizer for each support bar placed at contralateral sides was used.

Echocardiography, pulmonary function tests, and computed tomography/magnetic resonance imaging were obtained preoperatively.

Bilateral thoracoscopy was performed routinely through the same incision [Figure 4a and b]. Introducer with nylon tape was passed through between retrosternal and precordial space while thoracal space was observed with thoracoscopy. However, for the first 3 patients, in addition to thoracoscopy, a vertical subxiphoid incision was performed to aid passage of the support bar by retracting the sternum upward with a subxiphoid retractor. After gaining experience, the subxiphoid incision was abandoned. Between 2002 and 2008, pectus support bars were not commercially available in our country; therefore, custom made support bars and lateral stabilizers (Hipokrat AŞ, İzmir, Turkey) had been used till 2009. After 2009, commercially available support bars (Biomet Microfixation, Jacksonville, Florida, USA) have been used.

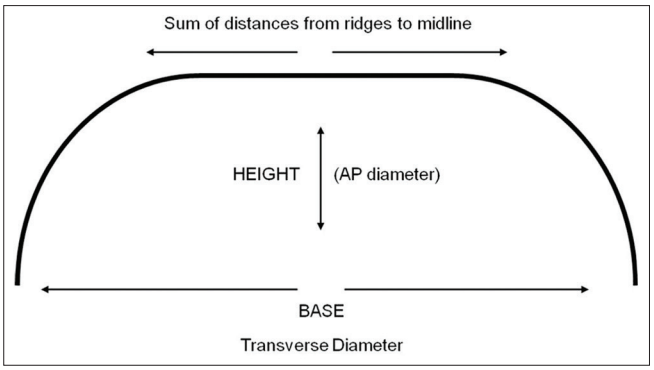

Figure 1: The template drawn according to the anthropometric measurements of individual patients

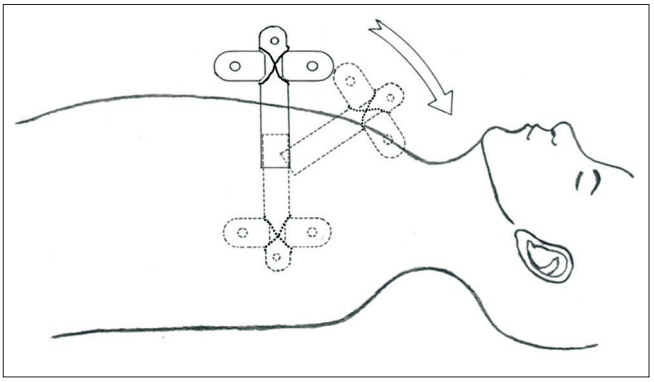

Figure 2: The bar was flipped over together with the stabilizers secured to the bar

Figure 3: Bilateral traction is applied to the bar with the aid of nylon tapes passed through the side holes of the bar and bar is flipped over with the lateral stabilizers secured to the bar with steel wires

During the postoperative period, pain relief was achieved with high lumbar (L1–L2 or T12–L1) epidural anesthesia to avoid thoracic epidural catheter complications. The catheter was left in place for 3 days. Nonsteroid anti-inflammatory agents were administered for 3–7 days (ibuprofen [10 mg/kg] in preadolescent, diclofenac sodium [1 mg/kg] in adolescent patients). At the beginning of 2011, lumbar epidural catheter placement was abandoned and pain relief was achieved by intravenous (IV) patient-controlled analgesia plus caudal analgesia.

Postoperative anatomic results were scored 12 months after support bar removal using the following three criteria: Excellent, good, and fair. If preoperative symptoms were resolved and chest appearance was normal, it was evaluated as excellent. If preoperative symptoms were resolved and chest appearance was improved, it was evaluated as good. If preoperative symptoms were improved and chest appearance was not completely normal, it was evaluated as fair.

Results

During this study frame time, 87 patients (24 girls and 63 boys) underwent MIRPE. The mean patient age was 11.2 ± 3.8 years (range, 5–21 years).

Preoperative echocardiogram showed mitral valve prolapse in 16 of our patients (18.3%). The preoperative forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1) values of the patients showed significantly lower results compared with the normal population. FVC and FEV1 were 83.2% and 81.6% of normal population, respectively.

The mean operating time was 63.7 ± 18.7 min (range, 48–145 min). The mean hospital stay was 5.2 ± 2.1 days (range, 3–9 days). The mean Haller index was 5.4 ± 2.1 (range, 3.0–8.4). PE deformity was asymmetric in 38 patients and symmetric in 49 patients.

Among the patients, one patient presented with failed Ravitch repair. Another patient had a right upper lobe bronchial atresia and lobectomy was performed together with the MIRPE. The upper lobectomy was performed and then the support bar was placed in the same session. This patient was not included in the calculation of operation time.

In this series, eight patients (9.2%) necessitated two support bars to elevate the sternum. Single support bar was not enough to lift the sternum, so we had to place a second support bar. Intraoperatively, the second support bar was bent as decision to place the second support bar was made.

The postoperative periods were uneventful in 85 patients; two patients needed a chest tube postoperatively for residual pneumothorax more than 5% [Table 1]. Two patients experienced muscle weakness at their left foot due to epidural anesthesia, but foot functions turned back to normal strength after 6–10 months.

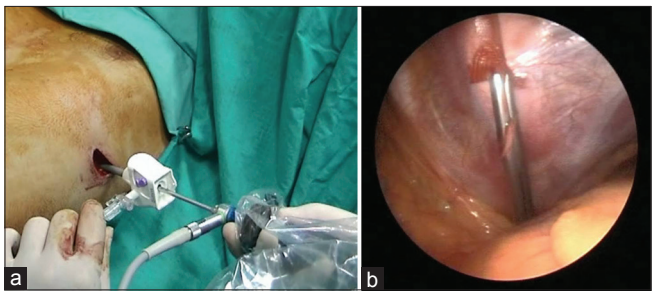

Figure 4: (a) Video-assisted thoracoscopic surgery through same incision. (b) Thoracoscopy; passage of introducer through precordial space

During postoperative follow-up, two patients had developed allergic skin reactions to the support bar or the lateral stabilizers which was managed with wound management. The support bar was slightly displaced upwards in a patient, but it was left in its place since it was still lifting the sternum. One of the lateral stabilizers was disconnected from the support bar while the other stabilizer was still keeping the support bar at correct position in another patient. The support bars of these two patients had been removed at the end of 2 years uneventfully.

Two patients (2.3%) required reoperation because of 45° and 80° rotation of the support bar. Pain intolerance was observed in one patient (1.1%) that could be only resolved by support bar removal after postoperative 4 weeks.

The support bars were removed in 69 patients after the completion of treatment. Support bars were left in place 26.8 ± 4.3 months (range, 22–44 months). The support bars had been removed without any problems. In our series, major or minor cardiac complications such as heart perforation and pericarditis have not been encountered.

A total of 56 patients' final chest contours and resolved symptoms were evaluated as 12 months passed after support bar removal; results are given in Tables 2 and 3. The patients who have had their support bars removed did not need a reoperation.

All patients continue chest, physiotherapy exercises at home.

Discussion

PE is the most common anterior chest wall deformity involving posterior depression of the sternum and dysmorphic costal cartilages.[12] Since 1998, MIRPE became the gold standard for the treatment of PE.

The use of bilateral thoracoscopy has been reported in both children and adults to facilitate safe passage of the support bar

Table 1: Early postoperative complications

	n (%)
Pneumothorax with spontaneous resolution	36 (41.4)
Pneumothorax necessitating chest tube	2 (2.3)
Muscle weakness at foot	2 (2.3)

Table 2: Results after 12 months postbar removal

	n=56 (%)
Excellent	48 (84.2)
Good	8 (14.1)
Fair	0 (0)

Table 3: Resolution of symptoms after bar removal (*n*=56)

	Preoperative *n* (%)	Postoperative *n* (%)
Mitral valve prolapse	12 (21.4)	7 (12.5)
Precordial pain	2 (3.5)	0 (0)
Palpitation	7 (12.5)	2 (3.5)
Dyspnea	3 (5.4)	0 (0)

between the sternum and pericardium.[11,13,14] According to some authors, blind manipulation causes fatal complications and thoracoscopic guidance is extremely important while guiding the introducer across the anterior mediastinum.[15,16] There are some centers which advocate routine usage of subxiphoid incision in place of thoracoscopy.[17,18] They advocate usage of finger guidance through subxiphoid incision to pass the support bar under the sternum. Subxiphoid incision is used to elevate sternum to ease dissection, especially in cases with the previous Ravitch repair with extensive adhesions.[6] The vertical subxiphoid incision forms a scar which widens as the child grows, forming an unpleasant appearance. We think that bilateral thoracoscopy without subxiphoid incision is the reliable method.

During MIRPE, bending of the support bar is done intraoperatively. This process may prolong operation time. Therefore, in our institution, the support bar is bent preoperatively using a template that is formed by the anthropometric measurements of individual patients. Preoperative bending of the support bar enables intraoperative molding of the support bar to its final shape accurately in a short period.

More laterally placed thoracal incisions were used, carrying the middle of the incisions to the midaxillary line at the maximal depression level of the PE deformity. Incision at this localization gives the opportunity to hide the incision scar under the arms of the patients in the neutral position.

For placement of additional support bars, additional incisions were not performed. With a generous subcutaneous dissection, the second support bar is placed from the same incision leaving two intercostal spaces between the support bars.

The most common complication of MIRPE is support bar displacement which requires reoperation. The displacement rate differs from 1.7% to 19%; the highest rates are mostly reported in former series where no lateral stabilizers were used.[2,3,5,8,19-23] As the same series were reviewed, it was clearly seen that the support bar displacement rates had reduced as the centers began to use lateral stabilizers. In many centers, only one lateral stabilizer is used to fix the support bar.[2,3,19-22] The support bar displacement rate is (2.3%) in the present series. This support bar displacement rate might be due to securing of the support bars bilaterally to the thoracal wall with two nonabsorbable lateral stabilizers. In addition, the lateral stabilizers prevent embedment of the support bar into the ribs; thus, the support bar removal is easier.

Another advantage of the lateral stabilizers is that they facilitate the turning over procedure of the support bar. After the support bar has been passed through the thoracic cavity, while its convexity facing up, the lateral stabilizers were fixed to the support bar with steel wires. Then, by applying bilateral traction to the support bar with the aid of nylon tapes, the support bar was flipped. This modification allows easy placement of lateral stabilizers. After the support bar has been flipped, the lateral stabilizers are fixed to the thoracic wall muscles with sutures.

Many techniques are described in the literature to reduce the support bar displacement.[8-11] Third point fixation is a simple modification in which, under thoracoscopic visualization, an additional nonabsorbable suture is passed around the support bar and one rib at the right of the sternum and the support bar was fixed at the middle also.[9] Some authors suggested the 5-point fixation with pericostal wire sutures.[8,22] Schaarschmidt *et al*. recommended placement of the support bar submuscularly to eliminate the support bar pressure on the muscles and to fix it to every rib it crosses by strong pericostal sutures under thoracoscopic vision in addition to lateral stabilizers.[10] Usage of two support bars as a standard procedure has been suggested during the initial operation to decrease support bar displacement rate.[24] However, it increases both the cost and the operation time.

During the postoperative period, the pain is controlled with high lumbar epidural anesthesia for 3 days. This provides excellent pain relief. Two of our patients experienced unilateral transient foot muscle weakness because of epidural anesthesia. More severe complications are reported in the literature, such as lower extremity paralysis.[5,25] Thus, thoracic epidural catheter placement was abandoned. Our anesthesia team conducted multimodal analgesia comprised caudal analgesia and/or IV patient-controlled analgesia with morphine and IV paracetamol instead of thoracic epidural catheter.

Conlsuion

Preoperative bending of the support bar according to anthropometric measurements facilitates bar shaping. Fixation of the lateral stabilizers to the support bar with steel wires, when the support bar was still in inverted position, facilitates lateral stabilizer placement. The placement of additional support bars from the same incision reduces the number of incisions.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. 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.
2. 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.
3. 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.
4. Cartoski MJ, Nuss D, Goretsky MJ, Proud VK, Croitoru DP, Gustin T, *et al.* Classification of the dysmorphology of pectus excavatum. J Pediatr Surg 2006;41:1573-81.
5. Kelly RE, Goretsky MJ, Obermeyer R, Kuhn MA, Redlinger R, Haney TS, *et al.* Twenty-one years of experience with minimally invasive repair of pectus excavatum by the Nuss procedure in 1215 patients. Ann Surg 2010;252:1072-81.
6. Redlinger RE Jr., Kelly RE Jr., Nuss D, Kuhn MA, Obermeyer RJ,

Goretsky MJ. One hundred patients with recurrent pectus excavatum repaired via the minimally invasive Nuss technique – Effective in most regardless of initial operative approach. J Pediatr Surg 2011;46:1177-81.
7. Sidden CR, Katz ME, Swoveland BC, Nuss D. Radiologic considerations in patients undergoing the Nuss procedure for correction of pectus excavatum. Pediatr Radiol 2001;31:429-34.
8. 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.
9. 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.
10. Schaarschmidt K, Kolberg-Schwerdt A, Dimitrov G, Straubeta J. Submuscular bar, multiple pericostal bar fixation, bilateral thoracoscopy: A modified Nuss repair in adolescents. J Pediatr Surg 2002;37:1276-80.
11. Schaarschmidt K, Kolberg-Schwerdt A, Lempe M, Schlesinger F, Bunke K, Strauss J. Extrapleural, submuscular bars placed by bilateral thoracoscopy – a new improvement in modified Nuss funnel chest repair. J Pediatr Surg 2005;40:1407-10.
12. Shamberger RC. Congenital chest wall deformities. In: Grosfeld JL, O'Neill JA, Fonkalsrud EW, editors. Pediatric Surgery. 6th ed. St. Louis, Missouri: Mosby; 2006. p. 894-919.
13. Cheng YL, Lee SC, Huang TW, Wu CT. Efficacy and safety of modified bilateral thoracoscopy-assisted Nuss procedure in adult patients with pectus excavatum. Eur J Cardiothorac Surg 2008;34:1057-61.
14. Palmer B, Yedlin S, Kim S. Decreased risk of complications with bilateral thoracoscopy and left-to-right mediastinal dissection during minimally invasive repair of pectus excavatum. Eur J Pediatr Surg 2007;17:81-3.
15. Castellani C, Schalamon J, Saxena AK, Höellwarth ME. Early complications of the Nuss procedure for pectus excavatum: A prospective study. Pediatr Surg Int 2008;24:659-66.
16. Ohno K, Nakamura T, Azuma T, Yamada H, Hayashi H, Masahata K. Modification of the Nuss procedure for pectus excavatum to prevent cardiac perforation. J Pediatr Surg 2009;44:2426-30.
17. Miller KA, Woods RK, Sharp RJ, Gittes GK, Wade K, Ashcraft KW, *et al*. Minimally invasive repair of pectus excavatum: A single institution's experience. Surgery 2001;130:652-7.
18. St Peter SD, Sharp SW, Ostlie DJ, Snyder CL, Holcomb GW 3rd, Sharp RJ. Use of a subxiphoid incision for pectus bar placement in the repair of pectus excavatum. J Pediatr Surg 2010;45:1361-4.
19. Engum S, Rescorla F, West K, Rouse T, Scherer LR, Grosfeld J. Is the grass greener? Early results of the Nuss procedure. J Pediatr Surg 2000;35:246-51.
20. 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.
21. Hosie S, Sitkiewicz T, Petersen C, Göbel 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.
22. Clark JJ, Johnson SM. Single incision Nuss procedure for pectus excavatum. Pediatr Surg Int 2011;27:733-6.
23. Park HJ, Kim KS, Lee S, Jeon HW. A next-generation pectus excavatum repair technique: New devices make a difference. Ann Thorac Surg 2015;99:455-61.
24. Stanfill AB, DiSomma N, Henriques SM, Wallace LJ, Vegunta RK, Pearl RH. Nuss procedure: Decrease in bar movement requiring reoperation with primary placement of two bars. J Laparoendosc Adv Surg Tech A 2012;22:412-5.
25. Allison CE, Aronson DC, Geukers VG, van den Berg R, Schlack WS, Hollmann MW. Paraplegia after thoracotomy under combined general and epidural anesthesia in a child. Paediatr Anaesth 2008;18:539-42.