

Evaluation of Pectus Bar Position and Osseous Bone Formation

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Purpose: Minimally invasive repair has become a popular approach for pectus excavatum (PE). The bar is secured to the thoracic wall and left for approximately 2 years. The authors have noticed an intense bone formation (BF) around some of these bars at removal. A review of children undergoing bar removal was performed to better understand this BF in relation to bar placement.

Methods: A retrospective review of children undergoing bar removal after PE repair since January 1998 was performed. Chart review included age at bar insertion and removal, bar insertion position (subcutaneous [SC] v submuscular [SM]), BF on Chest x-ray and at bar removal, operating time, and estimated blood loss (EBL).

Results: Thirty-six patients underwent bar removal during the study period (16 SC and 20 SM). Chest x-ray evaluation was possible in 27 patients (16 SM, 11 SC). No difference

existed for length of time the bar was in place or age at insertion/removal between groups. EBL was higher in the SM (18.3 v 8.8 mL, not significant). BF was seen radiographically in 15 SM and 3 SC patients ($P < .001$). BF was encountered at removal in 19 SM patients and a single SC patient ($P < .001$). Operating time was statistically longer ($P < .01$) for the SM group (30.2 v 15.6 min).

Conclusions: Bar position during repair of PE is important. SM positioning virtually always results in BF with increased EBL and statistically longer operating time at removal. Careful placement of the bar in the SC position without violating the fascia should be used to avoid these undesirable effects. *J Pediatr Surg* 38:953-956. © 2003 Elsevier Inc. All rights reserved.

INDEX WORDS: Pectus excavatum, osteogenesis.

SINCE THE INITIAL report of the minimally invasive pectus bar repair by Nuss et al¹ in 1998, the technique has rapidly gained acceptance and is our preferred approach for the repair of pectus excavatum in children and adolescents. The technique has been shown to be safe with good cosmetic outcome as well as shorter operating times and less blood loss than the traditional Ravitch repair.²⁻⁴ The minimally invasive technique utilizes 2 symmetric incisions in the lateral thoracic wall through which a convex bar is placed into the substernal position to leverage the deformity into a more anatomically correct position. Stabilizers are placed on the end of the bar to hold it in position while the thoracic deformity remodels. The bar is left in place for 24 to 36 months, at which time it is removed by reopening the lateral incisions. This study reports significant bone formation (BF) differences we have identified around the bar in relation to bar location with regard to the layers of the lateral thoracic wall.

MATERIALS AND METHODS

After obtaining IRB approval (IRB Exempt #02 01-04X), the charts of all patients that underwent removal of a minimally invasive pectus bar (Walter Lorenz Co, Jacksonville, FL) at Children's Mercy Hospital in Kansas City, MO between January 1998 and September 2002 were reviewed retrospectively. Our patient selection for minimally invasive repair of pectus excavatum has previously been delineated.⁴ Inclusion criteria required the patient to have undergone bar insertion at our institution.

The placement of the bar in all cases utilized 2 symmetric incisions

(about 2 cm) in the midaxillary line. A pocket was created in either the submuscular (SM) or a subcutaneous (SC) tissue for placement of the bar ends. The early experience with minimally invasive pectus repair at our institution was carried out primarily by 2 surgeons. They followed the Nuss description in similar fashion with the one exception, that is, where the bar was positioned in the lateral thoracic wall. One preferred to create a SM pocket, whereas the other held to Dr Nuss' initial technique using an SC pocket. Since September 1999, we have routinely secured the bar to the chest wall in either the subcutaneous or subfascial location with stabilizers to prevent bar migration.

The charts were reviewed for patient demographics, radiographic evidence for BF, and operative findings. Patient demographics included age at insertion, age at removal, and length of time the bar was in place. Chest radiography (CXR) before removal, if available, of patients were reviewed for evidence of bone formation around the bar or bar ends. The insertion operative notes were reviewed, and the bar location (SM or SC) was noted in the data collection. In addition, the bar removal operative notes were reviewed for evidence of BF around the bar and operative complications. Operating times and estimated blood loss were recorded from the anesthetic record. Statistical analysis was performed using the Student's *t* test, with a *P* value less than .05 being considered significant.

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RESULTS

Thirty-six patients underwent removal of a minimally invasive pectus bar during the study period. There was no statistical difference with regard to bar positioning at the time of insertion. Sixteen patients were identified as having the bar in the SC position, whereas 20 had it placed in the SM location. Mean age at insertion was 10.1 years for all patients and did not differ between groups (9.8 ± 4.2 years in SM ν 10.2 ± 5.1 years in SC). Mean age at removal also did not differ between groups and was 12.2 years for the entire study group. The length of time the bar was in place was similar between the SM and SC groups, 24.2 ± 3.6 and 24.4 ± 2.7 months, respectively.

CXR interpretation for BF was available in 16 patients with the bar in the SM position and 11 patients in the SC position. Bone formation was identified statistically more often ($P < .001$) in the SM than the SC placed bars, with 15 of the 16 SM-placed bars (93.8%) and, in stark comparison, only 3 of 11 SC-placed bars (27.3%) having radiographic evidence of BF.

Operative findings of BF supported the CXR interpretation. Again, SM-placed bars were statistically more prone to BF than SC bars. In fact, 95% (19 of 20 bars) of SM-placed bars had BF compared with only 6.3% (1 of 16 bars) of the SC bars ($P < .001$). The addition of bar stabilizers did not appear to affect bone formation. Twenty patients had their bar placed with no stabilizers, 5 had a single stabilizer placed, and 11 had bilateral stabilizers placed. Ten of 10 bars placed SM without stabilizers had BF, whereas only a single SC bar out of 10 had BF ($P < .01$). When stabilizers were used, 9 of 10 SM bars placed had BF, whereas no bars of the 7 placed SC had BF ($P < 0.01$).

Operating time was 15.6 ± 5.6 minutes in the SC group, which was statistically shorter ($P < .01$) than the SM group (30.2 ± 16.4 minutes). Although blood loss was less in the SC group (8.8 mL ν 18.3 mL) it did not

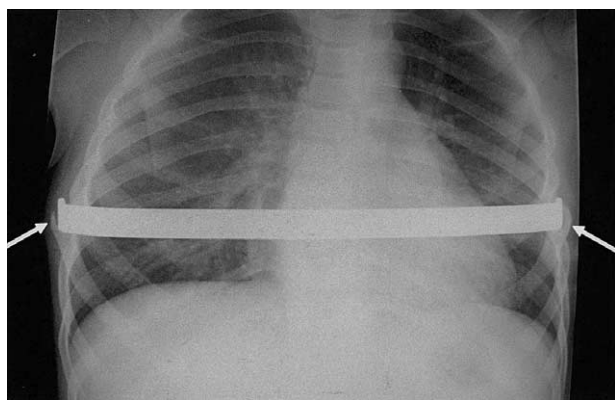


Fig 1. Chest radiograph shows a minimally invasive pectus bar that has been in place for 2 years. Note the bone formation around the ends of the bar bilaterally.



Fig 2. Right lateral aspect of a CXR shows bone growth around the removed minimally invasive pectus bar.

reach statistical significance ($P = .10$). There were no operative complications associated with bar removal, and all patients underwent bar removal on an outpatient basis.

DISCUSSION

Minimally invasive pectus bar repair is generally the preferred approach by pediatric surgeons for children

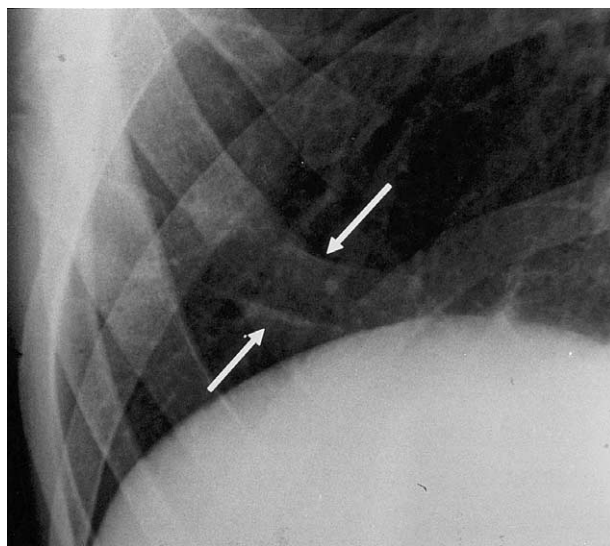


Fig 3. Close proximity view of the right hemithorax of a patient after removal of a pectus bar shows osteogenesis around the bar tract.



Fig 4. Right lateral CXR shows a "tight" bar placed in the subcutaneous position with no evidence of new bone formation around it.

and young adults with pectus excavatum. The initial report by Nuss¹ clearly describes the creation of a skin tunnel in which the ends of the bar reside during the remodeling process. This skin tunnel is equivalent to the SC position we describe here. Sufficient time was allowed for correction of the excavatum deformity (mean, 24.1 months), and the bars were removed. During these removals, we noticed aggressive osseous formation in some instances and virtually no reaction in others. The BF described in the results was seen more commonly around the ends of bars (Figs 1 and 2) but occasionally could be seen around the bar tract itself (Fig 3). The BF was intense enough in several cases to require bone chisels to remove the new bone growth so the bar could be removed, and in one instance fluoroscopy was required to identify the bar in the SM pocket. These extraoperative measures resulted in significantly longer mean operating times in the SM group.

The single case of the SC placed bar with BF found at removal is unique in that the bar was found in the muscle of the lateral thoracic wall on the left side and in the

subcutaneous tissue on the right. The operative notes clearly state its position in the SC location at the time of its insertion. Two scenarios could explain this finding. First, the bar may have been too tight, resulting in migration through the fascia. This seems unlikely, especially given instances in which a bar appears tight on CXR before removal, yet has no evidence for BF (Fig 4). A more likely explanation is that a defect was made in the fascia on the left side during the bar insertion, and the end of the bar migrated under the fascia into the muscle layer through this fascial defect.

Regardless, we have clearly shown that there are clinical implications to bar position and osseous bone formation around them, with the almost universal development of BF around bars placed SM. There have been numerous reports citing bone growth around foreign bodies and medical appliances.^{5,6} In most instances, the appliance or instrumentation is placed on the surface or near the periosteum, and the new bone growth is advantageous with regard to fixation of the appliance. The presence of bone elements in combination with a foreign body seems to be critical. In fact, Morreton et al⁷ compared mineral trioxide and ethoxybenzoic acid cement with regard to osteogenesis in association with intraosseous and subcutaneous implantation. They found that neither substance induced osteogenesis in the subcutaneous location; however, both resulted in osteogenesis when placed in association with osseous elements.

Our experience with bar removal and new bone growth around them has not been reported previously in the literature. Although we do not have cellular evidence, based on the literature, we postulate that the development of new bone formation is a combination of events including the proximity of the osseous structures of the lateral thoracic wall (ie, ribs), the presence of a foreign body (ie, the bar), and the presence of the correct cellular elements. The development of bone around these bars does have clinical implications, and careful placement of the bar in the SC position without violating the fascia should be used to avoid these undesirable effects.

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Discussion

Dr Meier (Hershey, PA): This was very interesting and very relevant. I have a couple of questions. First, did you see any differences in flipping of the bar between the 2 groups? Second, did you compare postoperative pain between the 2 groups? I think this is a real problem a lot of us are faced with. Have you noticed any difference in pain between the 2 groups?

D. Ostlie (response): I will answer your second question first because it is easier. This is a retrospective review, so there is no way I could go back and evaluate pain effectively. Your other question regarding the bar flipping: in our presentation at the AAP last year, we found 5 bars out of 100 that flipped. No bars have flipped since we started using 2 stabilizers (one on each side),

regardless of the position of the bar. So, I don't think the position of the bar necessarily predicts bar movement. You may be alluding to the article in the *Journal of Pediatric Surgery* in September, in which the authors recommend placing the bar in the submuscular position with something like 14 stitches. I don't think that that approach is superior in preventing bar flipping provided you use 2 stabilizers; at least that has been our experience. Dr Coran has a very novel technique of securing the bar around the ribs. I think that as long as it is secured properly, it does not make a difference where you put it in the lateral chest wall to prevent bar movement, but obviously there may be a difference with regard to bone formation.