

Comparison of Minimally Invasive and Modified Ravitch Pectus Excavatum Repair

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Background/Purpose: Minimally invasive repair of pectus excavatum (MIRPE) has gained wide acceptance during the last 4 years. This study compares, retrospectively, the experience at 2 large hospitals, 1 using MIRPE and the other a modified Ravitch repair (MRR).

Methods: From 1996 to 2000, 68 PE patients underwent MIRPE at one hospital, and 139 underwent MRR at another hospital. Ages ranged from 5 to 19 years (mean, 12) for MIRPE, and 3 to 51 years (mean, 17.3) for MRR. The mean pectus severity index was 4.2 for MIRPE and 4.9 for MRR (normal, 2.5).

Results: There were no deaths after MIRPE or MRR. Complications included 6 reoperations for MIRPE and none for MRR. There were 8 rehospitalizations for MIRPE and none for MRR. Ninety percent of MIRPE complications occurred in the first 25 cases. The mean blood loss was under 90 mL for both MIRPE and MRR. Mean operating time was 75 minutes for MIRPE and 212 minutes for MRR. Ninety-six percent of

MIRPE patients and no MRR patients had epidurals. Intravenous analgesics averaged 5 days for MIRPE and 1.7 days for MRR. Mean hospitalization was 6.5 days for MIRPE and 2.9 days for MRR. Mean time before return to work or school was 18 days for MIRPE and 12 days for MRR. The sternal bar was removed from 107 of 139 MRR patients (mean time, 19 minutes) and 18 of 68 MIRPE patients (mean time, 25 minutes).

Conclusions: Both MIRPE and MRR provide excellent clinical results. MRR has a longer operating time but decreased hospital stay, complication rate, and use of pain medications. Attention to technical operative details and surgeon's experience are essential for optimal results using both techniques.

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INDEX WORDS: Pectus excavatum, minimally invasive repair, modified Ravitch repair.

PECTUS EXCAVATUM (PE) is the most common chest wall malformation and one of the most frequent major congenital anomalies, occurring in approximately 1 in every 300 births.¹ The majority of patients with severe deformities will get progressive shortness of breath with exercise, decreased stamina and endurance, discomfort in the anterior chest, palpitations, and tachycardia, as well as concern regarding their appearance. The most common consideration by most family physicians has been related to the cosmetic appearance of the chest. Unfortunately, only a small portion of the PE patients have been referred for surgical repair, with most pediatric surgeons therefore performing few PE operations each year. The uncorrected deformity persists into adulthood with continued symptoms and psychological concerns as is evidenced by the large number of adult patients currently seeking surgical repair.²

Until recently, operations to correct PE deformities have been based largely on the technique described in 1949 by Ravitch,³ which includes subperichondrial resection of deformed costal cartilages, posterior sternal osteotomy, xiphoid excision, and anterior fixation of the sternum without a prosthesis. Numerous modifications of this technique have been recommended by various investigators during the ensuing 5 decades, including retention of the xiphoid, anterior sternal osteotomy, the use

of external harnesses or splints, and a variety of temporary internal support prostheses.⁴⁻¹⁰ The wide variety of techniques for the modified Ravitch repairs (MRR) currently in use has resulted in considerable variation in the long-term results reported after repair, the degree of postoperative pain, the limitation of activity, the complications, and the recurrence rate. It has been difficult to assess the results with the MRR overall, because most reported series during the last 2 decades have used different variations of the technique.^{5,8-11}

In 1997, the technique of minimally invasive repair of PE (MIRPE) was first reported by Nuss et al¹² to avoid several operative features of the MRR, including the anterior chest incision, elevation of pectoralis muscles, resection of costal cartilages, and the performance of a

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sternal osteotomy. The shorter operating time, smaller incisions, and considerably less dissection has made the MIRPE very appealing to surgeons and to patients, which has resulted in a large increase in the number of PE repairs performed in the United States during the last 4 years. To minimize complications with the MIRPE, a few modifications of the procedure initially described by Nuss have been reported.^{13,14}

It has been recommended by several surgeons that a comparison between the MIRPE and MRR should be made to advise surgeons and patients which operation might be most suitable for them. Although it would be desirable to develop a prospective study in which operating surgeons would alternately perform one or the other surgical technique, most surgeons become more skilled with one and do not perform the other as frequently or as well. A few recent reports from single institutions comparing the 2 techniques indicate that there is a higher complication and reoperation rate with the MIRPE and that older teenagers may be more difficult to correct.^{1,15,16}

In an attempt to provide an unbiased comparison of the 2 surgical techniques, this report reviews the clinical experience over a 4½-year period from 2 major university medical centers that perform a high volume of PE repairs, with 1 group performing only the MIRPE and the other using only the MRR. Approval from the Institutional Review Board of both the UCLA Medical Center and the Medical University of South Carolina was granted for conducting the current retrospective review of patients.

MATERIALS AND METHODS

From January 1996 through September 2000, 68 PE patients underwent MIRPE at 1 hospital, and 139 patients underwent MRR at the

other hospital (Table 1). A retrospective review of all patients undergoing PE repairs during this period was performed. Ages ranged from 5 to 19 years (mean, 12 years) for patients undergoing MIRPE, and from 3 to 51 years (mean, 17.3 years) for those undergoing MRR. Nineteen girls underwent MIRPE (28%), and 28 underwent MRR (19%). No patients from either group had major associated malformations, although 1 MRR patient had an atrial septal defect repaired through a median sternotomy 3 years earlier. The mean pectus severity index score (width of chest divided by distance between sternum and spine) was 4.2 for patients undergoing MIRPE and 4.9 for those undergoing MRR (normal chest, 2.5). None of the MIRPE patients had undergone a PE correction previously. Nine MRR patients had undergone a previous repair at other hospitals using a variation of the MRR without a substernal support bar, and each had a severe symptomatic recurrence requiring repair. The technique used for the MIRPE has been described previously¹⁴ as has the technique for the MRR.¹¹

RESULTS

There were no deaths after either the MIRPE or MRR. Complications included pneumothorax (10% for MIRPE and 2% for MRR), transient pericarditis (2% for MRR), and bar displacement (9% for MIRPE). Six MIRPE patients with bar displacement required reoperation to replace or reposition the pectus bar. Ninety percent of the complications with MIRPE occurred within the first 25 cases. None of the MRR patients has required a reoperation. The mean blood loss was under 90 mL for patients undergoing both the MIRPE and MRR. No patients from either group received a blood transfusion during or after the operation. The mean operating time for MIRPE patients was 75 minutes and was 212 minutes for MRR patients.

Epidural analgesia was used in 66 of 68 of MIRPE patients (96%) for an average of 3 days. None of the MRR patients had an epidural. Intravenous analgesic medications were administered for an average of 5 days for MIRPE patients and 1.7 days for MRR. The mean

Table 1. Patient Parameters Compared

Parameter	MIRPE	MRR
Number of patients	68	139
Average age (yr)	12 (5-19)	17.3 (3-53)
Mean pectus severity index	4.2 (3.2-9.5)	4.9 (3.1-9.8)
Previous pectus repair	0	9
Operating time (min)	75 (45-130)	212 (110-260)
Blood loss (mL)	90 (10-120)	90 (15-400)
Length of hospitalization (d)	6.5 (5-8)	2.9 (2-5)
Epidural used	66	0
Pneumothorax	7	3
Transient pericarditis	0	3
Intravenous analgesics (average d)	5 (3-7)	1.7 (1-3)
Patients placed in ICU	2	0
Bar displacement (flipped)	6	0
Reoperations	7	0
Rehospitalizations for pain	2	0
Return to school/work (average d)	18 (14-26)	12 (8-18)
Number sternal bars removed electively	18	107
Bar removal operating time (average min)	25 (17-40)	19 (15-31)
Time to bar removal (avg mo)	24 (23-26)	6 (5.5-6.5)

NOTE. Values in parentheses are ranges.

hospital stay was 6.5 days for MIRPE patients and 2.9 days for those undergoing MRR. Only 2 patients required a 1-day admission to the pediatric intensive care unit post-MIRPE; none of the MRR patients were placed in an intensive care unit (ICU). Two MIRPE patients were rehospitalized for pain management within 1 month after operation. No patients were rehospitalized after MRR. The mean time before return to school or work for MIRPE patients was 18 days and was 12 days for MRR patients.

The sternal bar was removed from 18 of the 68 MIRPE patients an average of 24 months' post repair with a mean operating time of 25 minutes. The sternal support bar was removed from 107 of the 139 MRR patients an average of 6 months postrepair, with a mean operating time of 19 minutes. No MRR or MIRPE patients were hospitalized for bar removal. No patients from either group undergoing bar removal has experienced a recurrent sternal depression.

DISCUSSION

As with many complex pediatric surgical operations, the results after PE repair are very operator dependent in that there is a significant learning curve regardless of whether the MIRPE or MRR techniques are used. Furthermore, there are many variations of the MRR used by different surgeons, including whether to routinely use a sternal support bar, which makes it difficult to compare the results from different hospitals. Similarly, a few variations of the MIRPE have been used by different surgeons, eg, routine use of thoracoscopy, use of lateral stabilizers, selective use of a third point fixation. The current study, therefore, was undertaken to compare the clinical experience with the 2 operative techniques performed by experienced surgeons who are beyond the initial learning curve from 2 hospitals at which a standard technique was used for all patients during the study period. The 4½-year study period was selected because the MIRPE was routinely used in one hospital during this period.

The demographics of the 2 study groups were similar with respect to number of boys and girls; however, the mean age of the MRR patients was 5.3 years older. Nine of the MRR patients underwent repair of a recurrent severe deformity after previous PE repair, whereas none of the MIRPE patients had undergone a previous repair.

The complications were low for patients from both groups compared with previous reports for both MRR

and MIRPE repair. Sternal bar displacement (flipping) is unique to the MIRPE patients but was uncommon after the first 25 patients had undergone repair and appears to be related to the surgeon's experience coupled with modifications in the operative technique used for MIRPE. No life-threatening complications were identified in either group. The reoperation rate was higher in the MIRPE group mainly because most of the patients that experienced bar displacement required surgery to replace or reposition the pectus bar. One patient from the MIRPE group had a pectus carinatum 1 year after placement of the pectus bar, and he required reoperation using the MRR to correct the deformity.

It is likely that the overall complication rate reported for the MIRPE technique in the United States will continue to decrease as surgeons gain knowledge and experience in performing this operation. However, our own experience indicates that both the MIRPE and MRR are associated with a steep initial learning curve and that careful attention to technical details is important to minimize complications.

The current review of the experience with the 2 operative techniques also showed that the postoperative course is somewhat different. Most patients that undergo MIRPE appear to experience more pain during the first weeks after surgery (higher use of analgesic medications and routine use of thoracic epidural), which also accounts for the longer hospital stay (6.5 days with MIRPE v. 2.9 days with MRR). It is difficult to compare costs of the MIRPE versus the MRR because the per diem charges vary greatly between the 2 hospitals.

It is apparent that both techniques are highly effective in correcting PE deformities. The early outcomes appear to be excellent with both techniques, as long as operation is performed by an experienced surgeon. A comparison of the long-term results after the 2 operative techniques (after removal of the sternal support bar) will not be available for several years and should evaluate, not only the recurrence rate and cosmetic results, but the patient satisfaction. The MRR is a more versatile technique because all types of pectus deformities, including asymmetric defects, carinatum deformities, and recurrent defects, in patients from early childhood to late adulthood may be repaired with good results. The decision as to which technique should be used must be individualized and made by the patient, his or her family, and the operating surgeon.

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Discussion

R. Shamberger (Boston, MA): The authors should be congratulated for their efforts to define the pros and cons between traditional repair of pectus excavatum and the Nuss procedure. It is incumbent on us as surgeons to perform outcomes analysis of new procedures we develop. Although the optimal method to perform this analysis would be a randomized trial, it is literally impossible to perform this type of trial in 2001, both because of surgeon preference and, more importantly, the inability to obtain patient and parent consent for randomization.

This retrospective review is a valiant effort by 2 high-volume institutions for pectus repair to address this question. It also highlights the problems with such a study where variations in institutional practice are apparent, such as lack of use of an epidural catheter at one institution and also variance in patient populations between the 2 institutions. The factors that would further enhance this form of study are first, to obtain prospective collection of the data; second, use of multiple institutions to obscure single institution bias in practices and patient selection; and, third, inclusion of monitors to assess pain rather than simply use a method and volume of pain medications to assess pain. This report clearly highlights the need for the prospective outcome study of pectus excavatum, which is planned. I have 3 questions for the authors.

First, you noted that 2 patients with the minimally invasive procedure required ICU stay, and I would be interested in what the reason was for that.

Second, did you identify any methods to decrease the extent of postoperative pain after the Nuss procedure, which has resulted in longer hospitalization and an extended interval between return to work or school?

And third, did you identify methods to decrease the increased risk of complications occurring when surgeons are early in their experience with the Nuss procedure?

S. Beanes (response): Thank you for your comments.

In regard to your first question, I believe in speaking with Dr Hebra that both of those patients were kept in the ICU strictly for monitoring in regard to their epidural. I believe they were a little bit groggy postoperatively so they just wanted to keep a closer eye on them.

The last 2 questions I think might be better answered by Dr Hebra in regard to mechanisms to decrease pain with the procedure.

In terms of your last question, I perhaps can entertain that in that they did note that their complications were early on as we had mentioned with the steep learning curve, so we did not factor that in, per se, in that we just noted that the majority of the complications with the minimally invasive repair were in the first third of the patients that were evaluated.

J.L. Grosfeld (Indianapolis, IN): First, I would like to thank Drs Beanes and Fonkalsrud for making a copy of the manuscript available before the meeting.

Dr Nuss' technique is a significant contribution to our surgical armamentarium in dealing with pectus excavatum. A major benefit of this minimally invasive procedure is that it does not require removal of the cartilaginous growth plates. If you look at the patients that underwent the Ravitch procedure and follow up with them for 15 or 20 years, you will notice there is a small percentage of patients that have overgrowth of the upper chest with hypertrophy of the second costal cartilages above the repair. This is related to the fact that the upper chest outgrows the lower chest because some of the growth plates are missing because of the resection of the costal cartilages. Despite the smaller incision and the shorter operating time, the Nuss procedure costs a little more, causes more postoperative pain, requires more pain medication, and results in a longer length of stay.

One thing we are missing in evaluating the efficacy of pectus repair is a long-term evaluation of those patients

who have restrictive pulmonary disease identified preoperatively. These are the individuals that tend to benefit most from the operation. Dr Alex Haller's chest index measurements using a CAT scan gives you a measurement, but it does not yield the kind of data that suggest the patient is improved objectively. Carefully carried out follow-up with pulmonary function studies (with stress testing exercise) that shows improvement of the pulmonary restrictive disease is necessary. Have you performed pre- and postoperative pulmonary function studies?

We have experienced overcorrection of the pectus defect using the Nuss procedure in patients with connective tissue disorders resulting in pectus carinatum. We, therefore, do not think that the Nuss procedure is a good operation for that group of patients. Other patients with severe chest wall asymmetry (particularly older teenagers) may not get a good result with simple bar insertion. We, therefore, would not select the Nuss procedure for this subset of patients as well. I wonder if the authors have had the same experience?

Thanks for allowing me to discuss your paper.

S. Beanes (response): Thank you Dr Grosfeld for your comments. In regard to one of your first comments, we are attempting to look into evaluating the patients both pre- and postoperatively, not only pulmonary function tests, but exercise function tests to better determine the physiologic limitations and then subsequent improvement postoperatively.

In regard to the patients, we did not notice any difference in those patients at our institution at UCLA with developing a carinatum defect or variation of it postoperatively.

D. Nuss (Norfolk, VA): Just very quickly, I want to congratulate the authors on 2 very fine papers. One comment I make, though, is that the Ravitch patients were operated on by a surgeon who had great experience and obviously did a wonderful job. The minimally invasive patients were the first 60 patients done by that institution, so it is not a true comparison.

The other point I want to make is that Dr Kelly from our institution is spearheading a multicenter trial to try and compare a prospective cohort of patients with both procedures.

Finally, I have a question. I notice there was a very high blood loss in the minimally invasive procedures in your series and I wondered why.

S. Beanes: Thank you Dr Nuss. To answer your final question, 90 mL we had noted for both. In regard to the exact technical aspect of the operation, why that was such, perhaps Dr Hebra might be able to answer better, but it was comparable with what was lost in the Ravitch repair.

In regard to your comment about the multicenter study, we wanted to compare, and you are absolutely right, the cases that were done with the Ravitch were done by a very experienced surgeon, and the 68 were the initial experience with the other group, but we did not wish to determine one was better than the other; we just wanted to present some initial data. Obviously, your procedure is new in the spectrum being that the Ravitch was described originally in 1949, but we just attempted to show some comparison data.