Modified Robicsek procedure for pectus excavatum in adult patients

Masatsugu Hamaji, Kei Hiraoka, Dawn E. Jaroszewski and Claude Deschamps*

INTRODUCTION

Most pectus excavatum patients seek care during their childhood or adolescence; however, adults with pectus excavatum often do not receive care for this because of the bias of the paediatrician or family physician, who may have the notion that it poses no serious health problem. Repair of pectus excavatum offers both cosmetic and physiological improvements [1]. The most common procedures for pectus excavatum are the Ravitch procedure and the Nuss procedure. Although some studies have reported comparing the Nuss and the Ravitch procedures in children, such reports do not exist for adults [2–4]. The Nuss procedure was recently reported to achieve comparable short-term outcome in adult patients [5, 6], while others reported higher short-term complication rates [7–9]. The different complication rates may suggest that a portion of adult patients can be treated by the Nuss procedure but also that the others may be better treated by an open approach. In this report, we reviewed our open repair (modified Robicsek procedure) for a relatively heterogeneous adult patient cohort to clarify the role of an open repair in adult patients in this era.

METHODS

This study was approved by the institutional review board at Mayo Clinic. The requirement for patient consent was waived. A retrospective chart review was performed in our prospectively maintained surgical database. Between 2001 and 2012, 46 consecutive adult patients underwent modified Robicsek procedure with polypropylene mesh for pectus excavatum or combined excavatum and carinatum, which were performed by a single surgeon (C.D.) at Mayo Clinic Rochester. There were 30 males and 16 females, with a median age of 25.5, ranging from 17 to 60 years, including 15 patients older than 30. The inclusion criteria for our procedure were adult aged 15 or older with any type of pectus excavatum (including recurrent, asymmetric or carinatum combined). The exclusion criteria were pectus carinatum only, because carinatum only does not require mesh support for the sternum. Preoperative patient characteristics are summarized in Table 1. Thirty-six (78.3%) of all patients had a history of previous repair, carinatum combined, scoliosis or asymmetry.

Preoperative investigation included physical examination, chest X-ray, pulmonary function test and chest computed tomography

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(CT) as routine, while three-dimensional chest CT and cardiopulmonary function test were performed only in most recent patients.

With the patient under general anaesthesia and epidural anaesthesia in supine position, a vertical midline incision typically for males or a bilateral submammary typically for females is made. The pectoralis muscles are detached and retracted laterally; thereupon, all involved cartilages are exposed. The abnormal or depressed segments are resected subperichondrially. Rectus abdominal muscles are detached from xiphoid process, which is removed. The sternum is slightly rotated as appropriate. One or more transverse osteotomies of the sternum at the level of its abnormal rotation is performed posteriorly with the Gigli saw (Fig. 1) and, if necessary, in case of combined excavatum and carinatum, an osteotome anteriorly as well. Bone graft fragments are typically placed at the osteotomy sites to maintain the osteotomy angle, and the sternum is secured with interrupted 2-0 Vicryl sutures only at occasional anterior osteotomies. A folded polypropylene mesh (Marlex Mesh; Davol, Inc., Bard Cardiosurgery, Cranston, RI, USA) is secured on one side of the chest wall with interrupted polypropylene sutures number 1, is slipped under the sternum, and is secured on the other side and the costal arch (Fig. 2). Rectus abdominal muscles are reattached to the sternum and pectoralis major muscles are reaproximated with reabsorbable stitches in the midline. The wound is irrigated with antibiotic solution. One chest tube is placed in each pleural space and one flat Jackson-Pratt drain between a pectus major muscle and the mesh on each side.

Postoperatively, the patient was asked to wear a plastic chest protector, which continues to be worn while riding a motor vehicle or when anticipating possible contact to his anterior chest for 6 months. Also the patients were instructed not to engage in contact sports for 6 months and lifting weights >10 pounds for 6 weeks.

The postoperative follow-up interval was 7.0 ± 15.1 months (mean ± standard deviation). Postoperative short-term outcome was evaluated by perioperative complications seen within 30 days of surgery and by the chest appearance at first postoperative visits at 4–8 weeks from surgery. Recurrence of pectus excavatum was diagnosed in chest morphology by surgeon’s physical examination, which typically was confirmed by chest CT. Mid-term outcome was evaluated by postoperative mid-term recurrence of pectus excavatum after the first postoperative visits. No routine chest CT or pulmonary function test was performed postoperatively unless indicated, but all the patients were asked to contact us with any concern at any time.

Table 1: Summary of preoperative characteristics of all 46 patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number/Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Male</td>
</tr>
<tr>
<td>Median age (range)</td>
<td>25.5 (17–60)</td>
</tr>
<tr>
<td>Preoperative FEV1% predicted (mean + SD)</td>
<td>88.9 ± 18.1</td>
</tr>
<tr>
<td>Preoperative Haller index (mean + SD)</td>
<td>4.51 ± 1.43</td>
</tr>
<tr>
<td>Deformity type</td>
<td></td>
</tr>
<tr>
<td>Excavatum</td>
<td>43 (93.5%)</td>
</tr>
<tr>
<td>Excavatum + carinatum</td>
<td>3 (6.5%)</td>
</tr>
<tr>
<td>Asymmetry</td>
<td>31 (67.4%)</td>
</tr>
<tr>
<td>Severity of deformity</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>25 (54.3%)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3 (6.5%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>16 (34.7%)</td>
</tr>
<tr>
<td>Associated disorders</td>
<td></td>
</tr>
<tr>
<td>Marfan syndrome</td>
<td>2 (4.3%)</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>4 (8.6%)</td>
</tr>
<tr>
<td>Symptoms</td>
<td></td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>10 (21.7%)</td>
</tr>
<tr>
<td>One or more symptoms</td>
<td>36 (78.3%)</td>
</tr>
<tr>
<td>Chest pain/discomfort/ pressure</td>
<td>28 (60%)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>27 (58.7%)</td>
</tr>
<tr>
<td>Palpitation</td>
<td>4 (8.7%)</td>
</tr>
<tr>
<td>Prior operation for pectus excavatum</td>
<td></td>
</tr>
<tr>
<td>Nuss procedures</td>
<td>5 (10.9%)</td>
</tr>
<tr>
<td>Classic Ravitch procedure</td>
<td>3 (6.5%)</td>
</tr>
<tr>
<td>Others</td>
<td>4 (8.6%)</td>
</tr>
<tr>
<td>One or more procedures</td>
<td>11 (23.9%)</td>
</tr>
</tbody>
</table>

FEV1: forced expiratory volume in 1 s.

Figure 1: Posterior osteotomy is typically performed on the sternal body with the Gigli saw and the xiphoid process is removed. Pieces of bone grafts, harvested from the parasternal cartilages, were placed under the osteotomy.

Figure 2: A folded polypropylene mesh is secured to the anterior chest wall as described by Robicsek.
Potential risk factors for perioperative complications and early failure in pectus repair were analysed with χ² test or Fisher’s exact test and Mann–Whitney test. Potential risk factors for postoperative mid-term recurrence were analysed using Cox proportional hazard regression model. When a P-value was <0.15 in univariate analysis, the variable was included in multivariate analysis. P-values < 0.05 were considered statistically significant. We used JMP Version 8.0.1 (copyright 2008 SAS Omstitute, Inc.) as statistical software.

RESULTS

Perioperative outcomes

The operation time ranged from 109 to 286 min, with a median of 184 min. Twenty-two patients (48%) were operated with vertical incision and 24 patients (52%) with bilateral submammary incision. No postoperative mortality was seen. Perioperative morbidity (within 30 days of surgery) was seen in 11 patients (24%). No patient had more than one complication. The morbidity included 4 patients (8.7%) of superficial wound infection, 4 patients (8.7%) of postoperative anaemia requiring blood transfusion, 2 patients (4.3%) of polypropylene mesh infection and 1 patient (2.2%) of left pleural and pericardial effusions requiring thoracoscopic drainage. Of the 2 patients (5%) of mesh infection, 1 patient required a reoperation to remove the mesh on the postoperative Day 12 and another operation to place a brand new mesh 1 year later. The other patient required partial removal of the mesh on the postoperative Day 20 and the infection subsided afterwards. Both of the 2 patients have not had any subsequent mesh infection or any other complication. The median hospital stay was 6 days, ranging from 4 to 34 days. The median wound tube drainage was 5 days, ranging from 3 to 34 days. For perioperative complications, in univariate analysis, type of pectus (pectus excavatum vs combined excavatum and carinaatum, P = 0.0726) showed a tendency and a lower preoperative %FEV1.0 predicted (P = 0.0268) was a significant risk factor, while none of age (P = 0.4357), gender (P = 0.829), operation time (P = 0.143), number of resected cartilages (P = 0.981), asymmetry (P = 0.665), bone graft (P = 0.761), number of osteotomies (P = 0.60), incision (vertical vs submammary, P = 0.609), previous pectus repair (P = 0.765), scoliosis, (P = 0.192), Marfan syndrome (P = 0.412), Haller index (P = 0.1935) or symptomatic (P = 0.134) proved to be a significant risk factor or a tendency. In multivariate analysis, only a lower preoperative %FEV1.0 predicted turned out to be a significant risk factor (P = 0.0088, odds ratio: 0.923).

Mid-term outcome (recurrence of pectus excavatum)

One patient (2.2%) experienced a recurrence of pectus excavatum 1 year from surgery in the follow-up. Preoperative higher Haller index showed a tendency for mid-term recurrence, but was not a significant factor (P = 0.058). None of gender (P = 0.298), age (P = 0.394), operation time (P = 0.394), number of resected cartilages (P = 0.579), severe asymmetry (P = 0.579), bone graft (P = 0.412), number of osteotomies (P = 0.579), incision (vertical vs submammary, P = 0.290), previous pectus repair (P = 0.579), type of deformity (excavatum vs combined excavatum and carinaatum, P = 0.579), severity of pectus excavatum (P = 0.429), symptomatic (P = 0.579) and postoperative short-term complication (P = 0.412) proved to show a tendency or be a significant prognostic factor.

Surgery for recurrent pectus excavatum

As given in Table 1, 12 of all patients underwent previous repairs for pectus excavatum prior to our repairs. Of the 12 patients, 2 patients (16.7%) had perioperative complications, both of which were postoperative anaemia requiring blood transfusion. Another patient was noted for residual pectus excavatum at the first postoperative visit (early failure), but no patient had mid-term recurrence.

DISCUSSION

Pectus excavatum repair contributes to both physiological and psychological improvement in adult patients [1]. Although there are a lot of procedures described for pectus excavatum repair, we have two main approaches: an open approach (Ravitch or modified Ravitch procedure) and a minimally invasive approach (Nuss or modified Nuss procedure). While most of the studies comparing the Nuss and the Ravitch procedures in children reported no significant difference in cosmetic or physiological outcomes as well as perioperative complications, comparative reports do not exist for adults [2–4].

Excellent long-term outcome of modified Ravitch repair via an open approach has been reported in adult patients [1, 10, 11], whereas only short-term outcome of Nuss procedure in adult patients was reported to date [7, 8, 12]. Some articles reported that the Nuss procedure for adult patients achieved short-term outcomes comparable to open repair [6, 11], while other previous reports suggest that adult patients undergoing the Nuss procedure...
are at high risk [7–9] of short-term complications. Given the insuffi-
cient evidence that a minimally invasive approach can achieve
comparable outcomes to an open approach, we have opted for an
open approach to treat adult pectus excavatum patients.

Recurrent pectus excavatum following prior repair may be
more often seen in adult patients than in paediatric patients and
has been paid a special attention to. An open approach [13, 14]
and modified Ravitch repair with polypropylene mesh (Robicsek
procedure) for recurrent pectus excavatum is associated with satis-
factory outcome in a case series [15], whose findings are consistent
with our result. Although recent publications have reported that
a minimally invasive approach could be used for recurrent pectus
excavatum, their postoperative complication rates appear much
higher than ours [16, 17], and long-term outcome in adult recur-
cent pectus excavatum has not been reported yet. We were able
to treat recurrent pectus excavatum in the same way as we did
non-recurrent pectus excavatum, which appears to be one of the
advantages of our procedure.

The classic open (Ravitch) repair has no sternal support under-
neath [18], which may be reasonable in paediatric and adolescent
pectus excavatum patients [19] considering their physical growth,
but no sternal support was reported to be associated with a poten-
tially unstable sternum [20]. Given the minimal physical growth in
adult patients, a priority should be given to sternal stability by sternal
support. Open repair with sternal support, either biological or non-
biological, has been associated with excellent long-term results [15,
21, 22]. Due to the rarity of adult pectus excavatum patients, it is dif-
cult to compare different materials (biological vs non-biological)
or different sizes (one large piece vs several bands) for sternal support.

Our report included a patient cohort of open repair for adult
pectus excavatum using polypropylene mesh for sternal support,
as originally described by Robicsek [15]. Our modified Robicsek
procedure has sought for simplicity, universality and safety. In
contrast to a minimally invasive approach, our procedure is of a
single-stage characteristic. Our modified osteotomy, with its angle
supported by bone graft and the mesh, appears technically easier
and requires shorter time than wedge osteotomy. Also we remove
xiphoid processes, leaving no concern for its ischaemic necrosis or
postoperative excessive upward angulation. We prefer to apply
one large piece of mesh, instead of several mesh bands [21, 23]
because of its ease of making a homogenous place for the angle-
corrected sternum to lie on and its shorter procedure time. We
have applied the same procedure to deal also with complex de-
formities, such as recurrent pectus excavatum, combined excav-
atum and carinatum or asymmetry. We used no metal bar, to avoid
persistent pain and devastating complications [24, 25].

Our study’s limitations included a relatively small patient cohort,
the heterogeneous patient group, no routine postoperative radio-
 logical evaluation, no routine long-term visit and its retrospective
study design. Our follow-up period is not enough for long-term
outcome. We did not compare with adult patients undergoing a
repair by a minimally invasive approach (Nuss procedure) as a
control.

In conclusion, modified Robicsek procedure with polypropyl-
ene mesh was associated with satisfactory perioperative outcome
and low incidences of mesh infection, early failure and mid-term
recurrence. The advantages over a minimally invasive approach
included a proved mid-term outcome, one-stage characteristic
and no devastating complications. The procedure is recom-
  mended for adult pectus excavatum patients, including those with
recurrent, severe or asymmetric pectus excavatum, as an initial or
reoperative procedure.

Conflict of interest: none declared.

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