Evidence Review:

Surgical correction for pectus deformity (all ages)
NHS England

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Surgical correction for pectus deformity (all ages)

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Prepared by Turnkey Clinical Evidence Review Team on behalf of NHS England Specialised Commissioning
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1. Introduction

Pectus abnormalities cover a range of deformities affecting the anterior thorax, specifically the sternum and adjacent rib cartilages. The incidence is less than 10 per 1,000 population, with the vast majority of patients being affected to only a very minor degree.

Pectus abnormalities arise due to an unevenness of the growth of the chest wall and are therefore commonest in teenagers and young adults, but can also affect children. It is more common in males. There are two main types of deformity – pectus excavatum and pectus carinatum, the former being the commoner of the two. Typically they are isolated deformities but they are sometimes associated with other musculoskeletal or connective tissue abnormalities such as scoliosis, Poland’s syndrome and Marfan’s syndrome. They can be familial.

Most pectus deformities become apparent in the first decade of life but are often not noticed until the adolescent growth spurt. If not corrected, the deformity is permanent.

There are currently a number of surgical and non surgical techniques available and individuals with a pectus deformity may be referred to a thoracic surgical clinic for advice. Based on NHS Secondary Users Services data, it is estimated that approximately 380 pectus surgery operations are performed by the NHS in England each year.

This policy considers the evidence for two surgical procedures used to correct pectus deformity - Nuss (minimally invasive repair of pectus excavatum – MIRPE) and Ravitch. The Nuss procedure is generally only applicable in pectus excavatum whilst the Ravitch procedure can be used for both pectus excavatum and pectus carinatum.

2. Summary of results

The evidence review of surgical correction of pectus excavatum using the Nuss procedure (minimally invasive repair of pectus excavatum) or the Ravitch/modified Ravitch procedure (open thoracic surgery) was undertaken with a view to answer the following research questions:

- Is there evidence that surgical correction improves cardiorespiratory reserve and functionality for the patient?
- Is there evidence that surgeon volume impacts on the outcomes of surgery (infection and revision rates)?
- What is the evidence in terms of quality, safety and adverse events associated with surgical correction?
- Is there evidence relating to eligibility and thresholds for surgery?

In summary, the current body of clinical evidence is largely limited to case series and reports. As such, the systematic reviews and meta-analysis of these observational studies are at risk of significant bias and confounding. Most studies do not attempt to address statistical heterogeneity between studies or take into account surgical skill variations amongst individual surgeons, between centres and over time. The absence of a standardised measure/scale to weigh clinical benefits (physical, psychological and quality of life) against the significant morbidity caused by the procedures presents a challenge to any conclusion regarding benefits of the intervention.

Cardiorespiratory reserve, functional and physical outcomes:

Johnson et al, 2014 found no linkage between ages of operative treatment with outcomes. There was no clear difference in outcomes between the Nuss and Ravitch populations across all age groups, but slightly better outcomes in the Nuss paediatric group as compared to all other groups. Nasr et al, 2010 found no difference in patient satisfaction between both techniques among studies looking at this outcome. A meta-analysis of 2476 cases (1555 Nuss, 921 open surgery) from 23 international studies (Chen et al, 2012) reported more improvement in physiological measures of lung function with the Nuss procedure compared to open surgery, with best results 3 years after surgery. Authors also reported that cardiovascular function after surgery improved by greater than one-half standard deviation. However, no supporting analysis was included in the publication. This meta-analysis was powered to compare physiological pulmonary function change by type of pectus...
procedure performed and time after surgery. None of the studies had a healthy (non-pectus) or no-intervention comparator arm or linked the physiological lung function with clinical presentation (dyspnoea, chest pain, exercise intolerance) pre- and post-surgery. Hence, it cannot be used to draw an inference on the clinical effectiveness of pectus procedure on lung function. Authors also reported that cardiovascular function after surgery improved by greater than one-half standard deviation. However, no supporting analysis was included in the publication. Other large case series (Kelly et al, 2013. Žganjer et al, 2011) report positive improvement of chest wall in varying degrees as well as improvement in pulmonary function. Most studies report 80-90% good to excellent anatomic surgical outcomes. Given the limitations in the study design, the overall evidence in this category needs to be viewed with caution.

Outcomes of surgery (infection and revision rates):

There were no studies that directly compared the impact of surgeon volume and outcomes of surgery. In a retrospective review of all primary Nuss procedure repairs of pectus excavatum performed in a one large US centre over 21 years, complications decreased markedly over 21 years since surgery was first offered in the centre. Bar displacement rate requiring surgical repositioning decreased from 12% in the first decade to 1% in the second decade (Kelly et al, 2010). This provides a limited view of the impact of surgical experience and patient volume on outcomes.

Quality, safety and adverse events associated with surgical correction:

NICE guidance in 2009 (IPG310; 2009) concluded that current evidence on the safety and efficacy of placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure) is adequate to support its use provided that normal arrangements are in place for clinical governance, consent and audit. It confirmed that placement of pectus bars for pectus excavatum should be carried out only by surgeons with cardiac and thoracic training and experience, who are capable of managing cardiac or liver injury, and where there are facilities for this. The procedure should be carried out only by surgeons with specific training in inserting the device, and they should perform their initial procedures with an experienced mentor. The efficacy and safety of the procedure was based on data from a UK register for 260 patients and multiple case series, small surveys and expert opinion.

The systematic literature review did not find any randomised control trials or high quality meta analysis that could further update the comparative efficacy of different types of surgeries or provide a comparison with a no-intervention group. The best available evidence comes from a systematic review of 39 studies involving 807 adult and 2716 paediatric cases (Johnson et al, 2014) which focused on comparison of the Ravitch, Nuss, and other surgical treatments for pectus excavatum across age groups. The analysis showed that complication rates varied across studies however Nuss and Ravitch procedures were generally safe for paediatric and adult patients with no perioperative mortality reported. Re-operation rates in adults were highest for implant procedures at 18.8% followed by Nuss 5.3% and Ravitch 3.3% but there was no significant difference in re-operation rates in children. Nasr et al, 2010 found that there was no significant difference in overall complication rates between both techniques in the nine studies included in the meta-analysis. Looking at specific complications, postoperative pneumothorax and hemorthorax, the rate of reoperation because of bar migration or persistent deformity was significantly higher in the Nuss group. Most case series identified major and minor complications related with the surgery ranging from allergy to nickel (Nuss bars), pneumothorax, hemorthorax and pericardial tears in perioperative period to bar displacement and asymmetrical corrections that required re-operations.

Eligibility and thresholds for surgery:

Leading US centres report inclusion criteria for surgery as severe pectus excavatum that fulfils two or more of the following: CT index greater than 3.25, evidence of cardiac or pulmonary compression on CT or echocardiogram, mitral valve prolapse, arrhythmia, or restrictive lung disease (Kelly et al, 2007. Kelly et al, 2010).

Self-perception has been identified as an important element in decision making in pectus surgery. There is significant body image dysmophia and poor co-relation between objective physiological and perceived impact (mental quality of life and self-esteem) in patients with pectus deformities (Steinman et al, 2011). This highlights the role of psychological evaluation in patient selection and possible need for counselling and management of expectations for patients with exaggerated dysmorphic tendencies.
Evidence indicates that median age for pectus surgery is increasing, with many surgeries in patients above the age of 18 years without any significant difference in outcomes amongst the younger and older patients. (Johnson et al, 2014. Kelly et al, 2010)

3. Research questions

- Impact of surgical correction on cardiorespiratory reserve and functionality for the patient
- Impact of surgeon volume and outcomes of surgery (infection and revision rates)
- Quality, safety and adverse events associated with surgical correction
- Eligibility and thresholds for surgery

4. Methodology

A review of published, peer reviewed literature has been undertaken based on the research questions set out in Section 3 and a search strategy agreed with the lead clinician and public health lead for this policy area. This has involved a PubMed search and search of the Cochrane database for systematic reviews, in addition to review of any existing NICE or SIGN guidance. The evidence review has been independently quality assured.

An audit trail has been maintained of papers excluded from the review on the basis of the inclusion and exclusion criteria agreed within the search strategy. The full list has been made available to the clinicians developing the policy where requested.

5. Results

A detailed breakdown of the evidence is included in the Appendix.
## Appendix One

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Study design and intervention</th>
<th>Outcomes</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>-</td>
<td>Ravitch procedure</td>
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<tr>
<td>Other Procedures</td>
<td></td>
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<td>-</td>
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<tr>
<td>Children</td>
<td>Nuss - 1500</td>
<td></td>
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<tr>
<td></td>
<td>Ravitch - 1186</td>
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<td>Robicsek - 30</td>
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</tbody>
</table>

### Outcomes

- **Primary Outcome**
  - 1. Surgery time
  - 2. Use of epidurals
  - 3. Length of Stay (LOS)
  - 4. Complication rates
  - 5. Resorption rates
  - 6. Outcomes
  - 7. Improvement in cardiac and pulmonary symptoms

- **Secondary Outcome**
  - 1. Surgery time
  - 2. Use of epidurals
  - 3. Length of Stay (LOS)
  - 4. Complication rates
  - 5. Resorption rates
  - 6. Outcomes
  - 7. Improvement in cardiac and pulmonary symptoms

### Reference


### Other

- This meta analysis allows comparison of the Ravitch, Nuss, and other surgical treatments for pectus excavatum across age groups which is not available in any single good quality study. The key finding of the analysis was that it did not show any linkage between age of operative treatment with outcome. The authors conclude that the Nuss and Ravitch procedures are safe and effective for paediatric and adult patients. They found no clear difference in outcome ratings between the Nuss and Ravitch populations across all age groups, but slightly better outcomes in the Nuss paediatric group as compared to all other groups.

- Some of the significant limitations to this analysis which limit its generalisability are as follows:
  1. The studies included are mostly case series and reports which is reflective of the current level of evidence available for these interventions
  2. The analysis does not take into account surgical skill variations amongst individual surgeons, between centres and over time
### FOR PUBLIC CONSULTATION ONLY

<table>
<thead>
<tr>
<th>Case series</th>
<th>Nuss (bar minimally invasive) surgery</th>
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<tbody>
<tr>
<td>1. Late complications (&gt;30 days post-op)</td>
<td>2. Respiratory rates 3. Improvement (normalisation) of chest wall 4. Functional improvement (change in pulmonary function)</td>
</tr>
<tr>
<td>1. Of 182 patients with complete follow-up (56%), 19% had late complications, similarly distributed, including subternal bar displacement in 7% and wound infection in 2%. 2. All 13 cases (7%) of bar or strut displacement required reoperation. Data shows another 2 cases of displacement due to trauma. It is not clear if these were included in the 13 cases and whether a reoperation was needed. There were no deaths. 3. 92.8% of patients showed positive improvement of chest wall in varying degrees. Mean initial CT scan index of 4.4 improved to 3.0 post operation (severe &gt;3.2, normal = 2.5). Computed tomography index improved at the deepest point (apex left) and also upper and middle sternum. In a small subset of patients (6.2%, n = 10), the pectus index at the deepest point was actually worse after operation, with a mean increase of 0.30 (SD= 0.21). A. Pulmonary function tests improved (forced vital capacity from 88% to 93%, forced expiratory volume in 1 second from 87% to 90%, and total lung capacity from 94% to 100% of predicted (p &lt; 0.001 for each). VO2 max during peak exercise increased by 10.1% (p = 0.015) and O2 pulse by 19% (p = 0.007) in 20 subjects who completed both pre- and postoperative exercise tests.</td>
<td></td>
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<tr>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Refer to outcome results</td>
<td>Refer to outcome results</td>
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<tr>
<td>The study concludes that there is significant improvement in chest shape, lung function at rest and exercise after surgical correction of pectus excavatum. It also concludes that the surgery can be performed safely in a variety of centres. The key limitation of the study is the absence of a no-intervention control group as well as randomised assignment of treatment options. This is understandably challenging in a practical setting, therefore this case series of fairly large number of patients was shortlisted for clinical evidence review. Patients were scheduled for operative repair by the method of choice for the particular surgeon and family (of 327 patients, 294 underwent Nuss procedure and 43 underwent open procedure). It should be noted that a failure to enrol similar numbers of open and Nuss operation patients also compromised the ability to compare the two operations. There was no stratification of data by surgical team’s experience, post-operative care regime etc. Authors have highlighted the difficulty in standardising the exercise data due to reporting protocol and equipment difference. In view of the above and the fact that the study has significant risk of response bias as only 56% of patient (182 out of 327) completed the follow up and that the lung function conclusion was based on a subset of 20 subjects who completed both pre and postoperative exercise tests, the study results should only be reviewed as low grade clinical evidence for late complications and chest wall normalisation outcomes for Nuss procedure, without weight, age or standardisation for surgical experience and infrastructure.</td>
<td></td>
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</table>
This meta-analysis was powered to compare the efficacies of different surgical techniques for the correction of pectus excavatum, focusing on the Nuss and Ravitch procedures. The study aimed to evaluate the clinical outcomes and functional recovery after these procedures, with a particular emphasis on postoperative lung function.

### Outcomes

1. **Improvement in Pulmonary Function**
   - FEV1 increased significantly 3 years after surgical correction of PE using a minimally invasive technique, with the Nuss procedure associated with better results than the Ravitch procedure. FEV1 changes after surgical correction favored the Ravitch procedure at 1 year (WMD = 2.19, 95%CI −4.18 to 8.56). However, by year 3, the Nuss procedure was favored (WMD = 3.00, 95%CI −0.46 to 6.45).
   - Although FEV1 decreased within 1 year after surgical correction of PE using both minimally invasive and open techniques, greater FEV1 improvement occurred 3 years after the Nuss procedure (WMD = 4.31, 95%CI −1.80 to 10.42) than after the Ravitch (WMD = 0.28, 95%CI −0.15 to 0.41) procedure.
   - In the open surgical repair group, FEV1 changes favored the open repair at 1 year and year 3 postoperatively (WMD = 4.34, 95%CI −4.31 to 12.98), but three years after the open procedure, FEV1 was increased significantly (WMD = 0.05, 95%CI −0.07 to 0.16) compared to the Ravitch procedure (WMD = −4.31, 95%CI −11.75 to 3.82).

2. **Long-term Outcomes**
   - Three years after surgery, TLC improved after the Nuss procedure, showed better postoperative results (WMD = 3.52, 95%CI −2.44 to 9.49) than the Ravitch procedure (WMD = 0.18, 95%CI 0.06 to 0.31).
   - FEV1 increased significantly 3 years after surgical correction of PE using a minimally invasive technique, with the Nuss procedure associated with better results than the Ravitch procedure.
   - Although FEV1 decreased within 1 year after surgical correction of PE using both minimally invasive and open techniques, greater FEV1 improvement occurred 3 years after the Nuss procedure than after the Ravitch procedure.
   - In the open surgical repair group, FEV1 changes favored the open repair at 1 year and year 3 postoperatively, but three years after the open procedure, FEV1 was increased significantly compared to the Ravitch procedure.

### Complications

- **Operative Mortality:** Zero. All patients had pneumothorax in the course of operation.
- **Postoperative Complications:**
  - PE patients: 36 pneumothoraces, two clinically significant periasternal pleura tears without other complications, one patient had a fracture of the sternum, and two had cellulitis.
  - Cardiac: Two patients had pericarditis, one patient had nephrotomy, two had pericarditis, and two had cellulitis.
  - Other: Early results: Excellent results (75%), good result in 25 (19%), and poor result in 2 (16%).

### Long-term Outcomes

- **Postoperative Results:**
  - Excellent results were observed in 74 patients (72.9%), good results in 21.6%, and poor results in 3.5%.

### References

2. For public consultation only.
The study is a systematic review and limited meta-analysis of the data from 9 retrospective/prospective (case series) studies. The search methodology used by authors conforms more with finding comparable studies for inclusion in a meta-analysis instead of a complete systematic review on the topic. The authors found no randomized control trials fit for inclusion on systematic literature search. We therefore agree with the authors that while the results of this meta-analysis fail to provide overwhelming support to either approach, and both approaches are acceptable. Meta-analysis for observational studies, such as this one, has the risk of significant contamination from bias, confounding and statistical heterogeneity between studies.

| 2 | Other | NA | Nuss | Procedure | Clinical effectiveness of the intervention | Perioperative outcomes | NA | NA | NA | NA | Near, Ahmad; Fecteau, Annie; Wales, Paul W.. Comparison of the Nuss and the Ravitch procedure for pectus excavatum repair: a meta-analysis. J. Pediatr. Surg. 2010;88(6):1773-1779. | Refer to outcome results | Refer to outcome results | The study is a systematic review and limited meta-analysis of the data from 9 retrospective/prospective (case series) studies. The search methodology used by authors conforms more with finding comparable studies for inclusion in a meta-analysis instead of a complete systematic review on the topic. The authors found no randomized control trials fit for inclusion on systematic literature search. We therefore agree with the authors that while the results of this meta-analysis fail to provide overwhelming support to either approach, and both approaches are acceptable. Meta-analysis for observational studies, such as this one, has the risk of significant contamination from bias, confounding and statistical heterogeneity between studies. | 3 | Case-control | 40 | Nuss | Clinical effectiveness of the intervention | Perioperative outcomes | The time of surgery was greater with SCP than with Nuss and epidural was longer for Nuss. There was no difference in relation to duration of hospital stay and follow-up. No significant differences were found when comparing the number of patients who had complications between the two groups. However, when comparing the number of complications in each group, more complications were found in the Nuss group. More positive results were observed in the SCP group than the Nuss group but the difference was not statistical significant. Most patients in both groups had favourable results and were very satisfied with the aesthetic results achieved. | NA | NA | NA | NA | Coelho, Marlos de Souza; Silva, Ruy Fernando Kuenzer Caetano; Bergonse Neto, Nelson; Stori, Wilson de Souza, dos Santos, Anna Flávia Ribeiro; Mendes, Rafael Garbittoti; Fernandes, Lucas de Matos. Pectus excavatum surgery: sternochondroplasty versus Nuss procedure. Ann. Thorac. Surg. 2009;44(5):886-892. | Refer to outcome results | Refer to outcome results | This is not a case control study but an observation of outcomes of a retrospectively selected cohort of patients. The criteria for selection of patients in the study and for the type of surgery is unclear. In view of the study design and analysis undertaken, the authors’ conclusion that sternochondroplasty surgery yielded better results than the Nuss procedure for asymmetric pectus excavatum is evidenced only for the 40 patients included in the study. |
Clinical effectiveness of the intervention

A. Is anatomically severe pectus excavatum associated with abnormal pulmonary function?

B. Early results (up to 3 months postoperative)
   1. Length of stay
   2. Perioperative complications and mortality
   3. Pain, different between two procedures

Because of disproportionate enrolment and similar early complication rates, statistical comparison between operation types was limited.

A. Median preoperative CT index was 4.4. Pulmonary function testing before operation showed mean forced vital capacity of 90% of predicted values; forced expiratory volume in 1 second (FEV1), 89% of predicted; and forced expiratory flow during the middle half of the forced vital capacity (FEF25-75%), 86% of predicted.

B. Early post correction results showed that operations were performed without mortality and with minimal morbidity at 30 days postoperatively. Median hospital stay was 4 days.

C. Post-operative pain was a median of 3 on a scale of 10 at time of discharge; the worst pain experienced was the same as was expected by the patients (median 8), and by 30 days after correction or operation, the median pain score was 1.

2 Case series 80 cases, 82 controls Quality of life and body image prior to surgical correction in pectus deformity patients

<table>
<thead>
<tr>
<th>Case-control</th>
<th>90 cases; 82 controls</th>
<th>Quality of life and body image prior to surgical correction in pectus deformity patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective severity of the deformity: funnel chest index by Hümmer and the Haller index.</td>
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<tr>
<td>Quality of life 2a. Disease-specific quality of life Questionnaire modified for Adults (NO-mA).</td>
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<tr>
<td>2b. Health-related quality of life was determined by the Short-Form-36 Health Survey (SF-36).</td>
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<tr>
<td>3b. Dysmorphic Concern Questionnaire (DCQ).</td>
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<tr>
<td>3c. Self-evaluation of the subjective impairment of the appearance.</td>
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<tr>
<td>4b. General Depression Scale (ADS).</td>
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<tr>
<td>4c. Self-rating of self-esteem</td>
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<tr>
<td>Compared with control group results, physical quality of life was reduced in patients with pectus excavatum, while mental quality of life was decreased in patients with pectus carinatum (p&lt;0.05). Body image was highly disturbed in all the patients and differed significantly from the control group (p&lt;0.01). Patients with pectus carinatum appeared to be less satisfied with their appearance than those with pectus excavatum (p&lt;0.07). Body image distress was multi-variately associated with both reduced mental quality of life and low self-esteem (p&lt;0.001). Body image did not influence physical quality of life. Patients displayed no elevated rates of mental disorders according to Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV) criteria.</td>
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</table>

3 Case series 69 Conservative treatment with custom fitted brace, worn 12-15 hours a day for up to 1 year.

<table>
<thead>
<tr>
<th>Case series</th>
<th>69 Conservative treatment with custom fitted brace, worn 12-15 hours a day for up to 1 year.</th>
<th>Impact of compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Correction angle of PC measured by standardised lateral views</td>
<td>1. Mean correction angle of 10 degrees in the children’s group and 5 degrees in the adolescent group</td>
<td></td>
</tr>
<tr>
<td>2. Patient rated outcomes</td>
<td>2. 82% of adolescent patients judged the result as “excellent” or “good”</td>
<td></td>
</tr>
<tr>
<td>1. Mean correction angle of 10 degrees in the children’s group and 5 degrees in the adolescent group</td>
<td>2. 82% of adolescent patients judged the result as “excellent” or “good”</td>
<td></td>
</tr>
<tr>
<td>2. Patient rated outcomes</td>
<td>2. 82% of adolescent patients judged the result as “excellent” or “good”</td>
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</tbody>
</table>


Self-perception is an important element in decision making in pectus surgery. This study provides a framework of body image evaluation that could be included in the assessment of patients with chest deformities. Additional post-surgical assessment would be useful in evaluating the impact of surgical correction on quality of life and body image especially in patients with exaggerated dysmorphic concerns. There is significant evidence in literature on limited satisfaction with the surgical outcome in patients with extreme dysmorphia. The key limitation of the study is the possibility of selection bias given that only patients with pectus deformity who presented themselves for surgical intervention were included in the study.

Additionally, it is a retrospective case control study with significant heterogeneity in subgroups including difference in study population numbers, has not been adequately addressed.

- This is a single institution case series involving a selective group of patients. While the results look promising, absence of randomised selection of patients, comparator group and long term follow-up on patients (reversion of bone deformities after removal of external support is known), limit the wider application of the findings.
## Lung function and Cardiac Index at rest and bicycle exercise, before, 1 year and 3 years after Nuss procedure for pectus excavatum (PE)

<table>
<thead>
<tr>
<th>Case</th>
<th>Control</th>
<th>26 controls</th>
<th>Lung function and cardiac index at rest and bicycle exercise, before, 1 year and 3 years after Nuss procedure for pectus excavatum (PE)</th>
<th>Clinical effectiveness of the intervention</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
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<tr>
<td>1</td>
<td>49 patients</td>
<td>26 controls</td>
<td>Preoperatively, patients had lower forced expiratory volume in the first second of expiration (FEV1): 86% ± 13% as compared with controls (94% ± 10%), p = 0.003. Postoperatively, no difference was found in FEV1 between the 2 groups.&lt;br&gt;2. Preoperatively, patients had lower maximum cardiac index, mean ± SD: 6.6 ± 1.2 l·min⁻¹·m⁻² compared with controls 8.1 ± 1.0 l·min⁻¹·m⁻² during exercise (p = 0.0001). One year and 3 years postoperatively, patients' maximum cardiac index had increased significantly and after 3 years there was no difference between patients and controls (8.1 ± 1.2 l·min⁻¹·m⁻² and 8.3 ± 1.6 l·min⁻¹·m⁻², respectively [p = 0.572]).</td>
<td>&lt;br&gt;1. Preoperatively, patients had lower forced expiratory volume in the first second of expiration (FEV1): 86% ± 13% as compared with controls (94% ± 10%), p = 0.003. Postoperatively, no difference was found in FEV1 between the 2 groups.&lt;br&gt;2. Preoperatively, patients had lower maximum cardiac index, mean ± SD: 6.6 ± 1.2 l·min⁻¹·m⁻² compared with controls 8.1 ± 1.0 l·min⁻¹·m⁻² during exercise (p = 0.0001). One year and 3 years postoperatively, patients' maximum cardiac index had increased significantly and after 3 years there was no difference between patients and controls (8.1 ± 1.2 l·min⁻¹·m⁻² and 8.3 ± 1.6 l·min⁻¹·m⁻², respectively [p = 0.572]).</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>2</td>
<td>Case</td>
<td>series</td>
<td>Clinical effectiveness of the intervention</td>
<td>Clinical effectiveness of the intervention</td>
<td>In primary operation: 1 bar was placed in 69%, 2 bars in 35% and 3 bars in 0.4%.&lt;br&gt;Postoperative Complications: Allergy to nickel: 28% (35 patients)&lt;br&gt;Wound infection: 4% (17 patients)&lt;br&gt;Pneumothorax: 0.6% (6 patients)&lt;br&gt;Volume and learning curve: Complications decreased markedly over 21 years since surgery was first offered in the centre. Bar displacement rate requiring surgical repositioning decreased from 12% in the first decade of the surgeries to 1% in the second decade. The median age of patients has gradually shifted over the years from 6 years to 14 years with up to 10% of patients above 18 years of age.</td>
<td>Post-operative outcomes</td>
<td>A good or excellent anatomic surgical outcome was achieved in 95.8% of patients at the time of bar removal. A fair result occurred in 4%, poor in 0.8%, and recurrence of sufficient severity to require reoperation occurred in 11 primary surgical patients (1.4%).</td>
</tr>
</tbody>
</table>


While the study shows the difference in FEV1 and cardiac index for pectus patients compared to normal adults, actual clinical significance of the comparative reduction in FEV1 and cardiac index preoperatively and the improvement post-operatively was not established. In addition, the potential for selection bias and hence the representativeness of case and control groups has not been adequately addressed.

### Post-operative outcomes

A good or excellent anatomic surgical outcome was achieved in 95.8% of patients at the time of bar removal. A fair result occurred in 4%, poor in 0.8%, and recurrence of sufficient severity to require reoperation occurred in 11 primary surgical patients (1.4%).


This is a single institution case series. All patients have been included in the study. Comparison of outcomes amongst surgeons is not included. The study provides a view of the impact of surgical experience and patient volume on outcomes.
## Appendix Two

### Literature search terms

<table>
<thead>
<tr>
<th>Assumptions / limits applied to search:</th>
<th>Original search terms: The search will look at the NUSS and Ravitch operations rather than minor procedures. The search will also consider the paediatric and adult populations separately.</th>
</tr>
</thead>
</table>
| Updated search terms - Population      | Pectus Deformities  
Pectus Carinatum  
Curraino-Silverman Syndrome  
Pectus Carinatum, Arcuate  
Pectus Carinatum, Chondrogladiolar  
Pectus Carinatum, Chondromanubrial  
Pouter Pigeon Breast  
Pectus Excavatum  
Funnel Chest  
Pectus Abnormalities  
Sternum Abnormalities  
pectus anomaliesas, scoliosis, marfans syndrome |
| Updated search terms - Intervention    | Mirpe Procedure  
Nuss Procedure  
Ravitch Procedure |
| Updated search terms - Comparator      | Subcutaneous Implant  
Breast Augmentation  
Suction Devices  
Minor Surgery  
Minor Surgeries |
| Updated search terms - Outcome         | None |

### Inclusion criteria

In order of decreasing priority, the following are included:

1. All relevant systematic reviews and meta-analysis in the last 5 years and those in 5-10 years period which are still relevant (e.g. no further updated systematic review available)
2. All relevant RCTs and those in the 5-10 years period which are still relevant (e.g. not superseded by a next phase of the trial / the RCT is one of the few or only high quality clinical trials available)  
   >>>> If studies included reach 30, inclusion stops here
3. All relevant case control and cohort studies, that qualify after exclusion criteria  
   >>>> If studies included reach 30, inclusion stops here
4. All relevant non analytical studies (case series/ reports etc.) that qualify after exclusion criteria  
   >>>> If studies included reach 30, inclusion stops here
5. Expert opinion
### Specific inclusion criteria

**English language**
- Published after 2009 (following the NICE guidelines published in the same year)

**Title/Abstract**
- The PICO specifies a distinction between adult and paediatric evidence, although age filters are not applied in the first instance due to inconsistent results.

4 additional articles as per the suggestion of the Policy Working Group:


### General exclusion criteria

- Studies with the following characteristics will be excluded:
  1. Do not answer a PICO research question
  2. Comparator differs from the PICO
  3. < 50 subjects (except where there are fewer than 10 studies overall)
  4. No relevant outcomes
  5. Incorrect study type
  6. Inclusion of outcomes for only one surgeon/doctor or only one clinical site

### Exclusion criteria

- **Specific exclusion criteria**
  - Mild pectus deformities
  - Age.
  - The majority of patients undergoing treatment are between 14-18 years of age. There is some variation in practice between paediatric and adult thoracic surgeons regarding age but most thoracic surgeons tend not to offer surgery (for PE) after 30 years of age. Technically, though, there is no age restriction.