

# NATIONAL INSTITUTE FOR HEALTH AND CLINICAL EXCELLENCE

## INTERVENTIONAL PROCEDURES PROGRAMME

### Interventional procedure overview of placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

Pectus excavatum is an abnormality of the chest in which the breastbone sinks inward (sometimes called funnel chest). The condition is mainly a cosmetic problem, although it can impair cardiac and respiratory function. Placement of a pectus bar (also known as MIRPE [minimally invasive repair of pectus excavatum] or the Nuss procedure) involves placing one or two steel bars under the breastbone to raise it and correct the abnormal shape. The pectus bar, which is bent into a curve to fit the patient's chest, is put in place through one or more small openings in the chest. The bar or bars are usually removed within a few years of them being inserted.

## Introduction

The National Institute for Health and Clinical Excellence (NICE) has prepared this overview to help members of the Interventional Procedures Advisory Committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and specialist opinion. It should not be regarded as a definitive assessment of the procedure.

## Date prepared

This overview was prepared in January 2009.

## Procedure name

- Placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

## Specialty societies

- Association of Paediatric Anaesthetists of Great Britain and Ireland
- British Association of Paediatric Surgeons
- Society for Cardiothoracic Surgery in Great Britain and Ireland.

## Description

### ***Indications and current treatment***

Pectus excavatum is the most common congenital deformity of the sternum and anterior chest wall. It is a progressive condition and the degree of chest deformity worsens as the child grows and develops. Most patients with pectus excavatum have only cosmetic disfigurement but this is sometimes accompanied by impaired cardiac or respiratory function.

Current treatment options include open surgical repair, subperichondrial resection of abnormal costal cartilages, transverse osteotomy and internal fixation of the sternum (known as the Ravitch procedure). The corrected anterior sternal position may or may not be temporarily supported with a substernal bar. Surgery typically takes place in mid to late childhood.

### ***What the procedure involves***

Placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure) is performed with the patient under general anaesthesia. The procedure is performed through several small incisions on either side of the chest using thoracoscopy.

After subcutaneous tunnelling, one or two curved steel bars are inserted under the sternum with the convexity facing posteriorly. The pectus bar is rotated 180° using a 'flipper' device with the aim of pushing out the sternum and correcting the deformity. Various fixation techniques have been used to limit the movement of the pectus bar, including lateral stabilisers attached to the bar and ribs using wires and/or sutures. The bars are usually removed within 3 years as an elective procedure.

### ***List of studies included in the overview***

This overview is based on approximately 3000 patients from 10 case series, 1 case report and 260 patients from a UK register.

Other studies that were considered to be relevant to the procedure but were not included in the main extraction table (table 2) have been listed in appendix A.

## ***Efficacy***

### ***Cosmetic appearance***

The register holds data for 260 patients from 13 centres across the UK who had the Nuss procedure between 2000 and 2008<sup>1</sup>. Thirty per cent of patients came from one centre; four centres submitted data for more than 20 patients and three centres submitted data for fewer than seven patients. The mean age of patients at the time of the procedure was 16 years (range: 5–85 years) and 88% were male.

Patients were asked to score their cosmetic appearance before the operation (on a scale from 1 [dislike] to 10 [like]). Of 109 patients with a preoperative score recorded, 72% had a score of 1–3, 25% had a score of 4–7, and 3% had a score of 8–10. The mean score at baseline was 3.1. Cosmetic appearance at follow-up was rated from 1 (the same as before the operation) to 10 (perfect). Of 119 patients with a postoperative score recorded, 1 patient scored their cosmetic appearance as 1–3 (the same as before the operation), 20% scored it as 4–7, and 79% had a score of 8–10 (26 patients scored their cosmetic appearance as ‘perfect’). The mean score at last follow-up was 8.4 (median follow-up: 170 days; range: 4–2477 days).

A case series of 947 patients reported that of 521 patients who had the bar removed and had a follow-up of 2 years, 83.3% had an ‘excellent’ cosmetic result, 12.3% had a ‘good’ result, 1.7% had a ‘fair’ result (method of assessing results not stated), 1.2% had a ‘poor’ result and 1.5% had a failed repair (recurrence of pectus excavatum)<sup>2</sup>.

A case series of 322 patients reported that the repair results were ‘excellent’ in 91% (294/322) of patients, ‘good’ in 9% (28/322), and ‘fair’ in 1% (4/322) (method of assessing results and duration of follow-up not stated). These results added together sum to more than 322 – no explanation is given for this anomaly<sup>3</sup>.

In a multicentre case series of 172 patients, cosmetic appearance was evaluated by surgeons (on a scale from 1 [excellent] to 10 [poor]) after the procedure (follow-up not stated) in 124 patients. Of these patients, 59% (73/124) had an ‘excellent’ result, 23% (28/124) had a ‘good’ result and 19% (23/124) had a ‘fair’ result<sup>4</sup>.

### ***Quality of life***

In a survey of 43 patients (response rate: 53%) who had either the Nuss procedure or open surgical repair for pectus excavatum (Ravitch procedure), there were no differences in health-related quality of life (assessed using the Child Health Questionnaire) or in physical and psychosocial quality of life (assessed using the Pectus Excavatum Evaluation Questionnaire) between the groups (mean follow-up: 16 months after the Nuss procedure). However, Nuss patients felt ‘less bothered’ by the appearance of their chest (corresponding to median Likert scores of 4.0 and 3.0;  $p = 0.02$ ) and experienced less frequent ‘chest pain or discomfort’ (corresponding to median Likert scores of 3.0 and 2.0;  $p = 0.04$ ) than Ravitch patients<sup>5</sup>.

### ***Patient satisfaction***

Forty-five patients were surveyed at a mean of 54 months after the Nuss procedure (response rate: 89%). The mean score for satisfaction with postoperative appearance (rated from 1 [very dissatisfied] to 5 [extremely satisfied]) was 4.1 ( $\pm 0.8$ ). The patients rated their self-esteem before the procedure (rated retrospectively on a scale from 1 to 10) as 6.3 ( $\pm 1.2$ ) which improved to 7.9 ( $\pm 0.8$ ) after the procedure. In response to an item asking if

they would have the operation again, the mean score (on a scale from 0 [no] to 10 [yes]) was 9.1 ( $\pm$  2.7)<sup>6</sup>.

## **Safety**

In the register, there were 24 perioperative adverse events (9%; 24/260) and 49 postoperative adverse events (19%; 49/260). Adverse events were categorised as 'major' if they required bar removal, further interventional procedures, intravenous antibiotics or if they delayed discharge. All other adverse events were categorised as 'minor'<sup>1</sup>.

Thirteen of the perioperative adverse events were 'major' and occurred during bar insertion. These were: pleural effusion (n = 3), pneumothorax (n = 3) and one case each of bar migration, infection, pain, lower lobe collapse, persistent air leak, and pericardial effusion. One patient had a fall in blood pressure when the second bar was inserted, which was later found to be because of inferior vena cava tenting from previous adhesions (this resolved when the second bar was removed).

Periprocedural adverse events during bar removal included one patient with intraoperative bleeding and one patient with pneumothorax (both of which delayed discharge).

Of the 49 postoperative adverse events, 23 were categorised as 'major'. These were: infection (n = 13), bar migration (n = 4) and one case each of pleural effusion, haematoma, pain, granulomas over stabiliser plates, a broken retaining wire causing discomfort (removed as a day case), and a protruding wire (removed surgically).

Pneumothorax occurred in 55% (369/668), 9% (15/167), 7% (24/322), 3% (5/172) of patients in four case series (most of these resolved spontaneously)<sup>7,8,4,3</sup>. Bar or stabiliser displacement occurred in 10% (70/668), 5% (9/172), 3% (11/322), and 2% (3/167) of patients in three case series<sup>7,4,3</sup>. In the first case series, 50 bar displacements required surgical revision, in the second case series, four bar displacements were flipped bars that were classified as major complications and in the last case series all three bar displacements required reoperation<sup>7,3,8</sup>. Wound infection, pneumonia, pleural effusion, pericardial effusion, and pericarditis were reported in 1–3% of patients in three case series<sup>7,4,3</sup>.

The case series of 668 patients reported transient Horner's syndrome secondary to the epidural analgesia in 24% (162/668) of patients<sup>7</sup>.

In both the case series of 167 and 172 patients, there was one case of liver perforation. In both the case series of 167 and 322 patients, there was one case of intraoperative cardiac perforation<sup>8,4,3</sup>. One case report reported four cases of cardiac injury during surgery including one death from the injury<sup>9</sup>.

The case series of 167 patients also reported 15 cases of intraoperative rupture of the intercostal muscles (in older patients), 10 cases of haemothorax or haematopneumothorax, and seven cases of minor pericardial tears<sup>8</sup>.

IP overview: placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

A retrospective review of 863 patients who received the Nuss procedure reported 13 cases of infection (2%) and 19 cases of metal allergies (2%). Three patients with recurrent infections and three patients with allergic skin breakdown required early pectus bar removal<sup>10,11</sup>.

## Literature review

### *Rapid review of literature*

The medical literature was searched to identify studies and reviews relevant to minimally invasive placement of pectus bar for pectus excavatum. Searches were conducted of the following databases, covering the period from their commencement to 23/10/08 and updated on 05/05/09: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the Internet were also searched (see appendix C for details of search strategy).

The following selection criteria (table 1) were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

**Table 1 Inclusion criteria for identification of relevant studies**

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients with pectus excavatum.
Intervention/test	Placement of pectus bar (MIRPE or the Nuss procedure).
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

### *Existing assessments of this procedure*

There were no published assessments from other organisations identified at the time of the literature search.

***Related NICE guidance***

Below is a list of NICE guidance related to this procedure. Appendix B gives details of the recommendations made in each piece of guidance listed.

**Interventional procedures**

- Minimally invasive placement of pectus bar. NICE interventional procedures guidance 3 (2003). Available from [www.nice.org.uk/IPG3](http://www.nice.org.uk/IPG3)

**Table 2 Summary of key efficacy and safety findings on placement of pectus bar for pectus excavatum (MIRPE or the Nuss procedure)**

Abbreviations used: PE, pectus excavatum; CT, computed tomography; HES, Hospital Episode Statistics; SD, standard deviation																								
Study details	Key efficacy findings	Key safety findings	Comments																					
<p>Study type: <b>prospective registry (13 centres)</b><sup>1</sup></p> <p>Country: UK</p> <p>Study period: April 2000–Dec 2008</p> <p>Study population: patients who had minimally invasive repair of PE.</p> <p><b>n = 260</b></p> <p>Age: 16 years (mean), 5–85 years (range)</p> <p>Sex: 88% male</p> <p>Inclusion criteria: n/a</p> <p>Technique: minimally invasive repair of PE.</p> <p>Follow-up: <b>369 days (mean), 4–2477 (range)</b></p> <p><b>Centres:</b></p> <table border="1"> <tr> <td>1</td> <td>Great Ormond Street (London)</td> <td>29% (74/260)</td> </tr> <tr> <td>2</td> <td>Alder Hey (Liverpool)</td> <td>17% (44/260)</td> </tr> <tr> <td>3</td> <td>Royal Brompton (London)</td> <td>12% (30/260)</td> </tr> <tr> <td>4</td> <td>Paediatric Surgery (Leeds)</td> <td>9% (24/260)</td> </tr> <tr> <td>5</td> <td>Norfolk and Norwich University</td> <td>8% (20/260)</td> </tr> <tr> <td>9</td> <td>Nottingham City</td> <td>5% (14/260)</td> </tr> <tr> <td>8</td> <td>Diana Princess of</td> <td>5%</td> </tr> </table>	1	Great Ormond Street (London)	29% (74/260)	2	Alder Hey (Liverpool)	17% (44/260)	3	Royal Brompton (London)	12% (30/260)	4	Paediatric Surgery (Leeds)	9% (24/260)	5	Norfolk and Norwich University	8% (20/260)	9	Nottingham City	5% (14/260)	8	Diana Princess of	5%	<p><b>Presenting signs/symptoms</b></p> <ul style="list-style-type: none"> <li>Asthma currently or in the past: 15%</li> <li>Chest wall tenderness: 86%</li> <li>Teased/embarrassment: 83%</li> </ul> <p><b>Pectus type</b></p> <ul style="list-style-type: none"> <li>Symmetrical: 38%</li> <li>Rib-flaring: 15%</li> <li>Both symmetrical and rib-flaring: 9%</li> </ul> <p><i>Note: 135 patients had no data recorded for this variable</i></p> <p><b>Operative details</b></p> <ul style="list-style-type: none"> <li>Thoracoscope used: 63% (163/260)</li> </ul> <p><i>Note: 43 patients had no data recorded for this variable</i></p> <ul style="list-style-type: none"> <li>Mean length of hospital stay: 7 days (range: 3–37 days)</li> <li>Stabilisers used: 1 (14%), 2 (56%), 3 or 4 (2%), none (22%)</li> </ul> <p><i>Note: 13 patients had no data recorded for this variable</i></p> <p><b>Bar removal</b></p> <ul style="list-style-type: none"> <li>37% (97/260) of patients have had the bar removed at a mean 2.4 years after bar insertion (range: 5 days–5.9 years)</li> <li>Reasons for removal: <ul style="list-style-type: none"> <li>Routine: 84% (81/97) – removed at a mean of 2.7 years after bar insertion</li> <li>Complications: 12% (12/97) – removed at a mean of 260 days after bar insertion</li> <li>Not cosmetically acceptable: 2% (2/97) – removed around 290 days after insertion</li> </ul> </li> </ul> <p><b>Cosmetic appearance</b></p> <p>- Patient-assessed score rated from 1 to 10.</p>	<p><b>Perioperative adverse events: 9% (24/260)</b></p> <p><u>Major (n = 13)</u></p> <ul style="list-style-type: none"> <li>Pleural effusion: 3</li> <li>Pneumothorax: 3</li> <li>Bar migration: 1</li> <li>Infection: 1 (follow up not clear)</li> <li>Pain: 1</li> <li>Other: 4 <ul style="list-style-type: none"> <li>lower lobe collapse;</li> <li>fall in blood pressure with insertion of second bar, later found to be because of inferior vena cava tenting from previous adhesions (second bar removed with immediate benefit)</li> <li>persistent air leak</li> <li>pericardial effusion</li> </ul> </li> </ul> <p><u>Minor (n = 9)</u></p> <ul style="list-style-type: none"> <li>Pneumothorax: 3</li> <li>Infection: 2</li> <li>Bar migration: 1</li> <li>Haematoma: 1</li> <li>Other: 2 (1 patient had urinary retention; 1 patient had left-sided Horner's syndrome for 48 hours which resolved spontaneously)</li> </ul> <p><b>Postoperative adverse events: 19% (49/260)</b></p> <p><u>Major (n = 23)</u></p> <ul style="list-style-type: none"> <li>Infection: 13</li> </ul>	<p>Validation of register (with HES): 144 patients were submitted to the register between 2004–07 from 11 units. The only available comparator code from HES data included both Nuss and Ravitch procedures, of which 254 were recorded in 27 hospitals in the same period. A letter to lead clinicians yielded responses from 12 of the 16 non-submitting hospitals (75%) and showed that five were doing open procedures only; five were not doing either (coding errors) and two centres were doing Nuss but had not submitted data to the register.</p> <p>Adverse events were coded as 'major' if they required bar removal, reoperation or further interventional procedures, intravenous antibiotics or if they delayed discharge.</p>
1	Great Ormond Street (London)	29% (74/260)																						
2	Alder Hey (Liverpool)	17% (44/260)																						
3	Royal Brompton (London)	12% (30/260)																						
4	Paediatric Surgery (Leeds)	9% (24/260)																						
5	Norfolk and Norwich University	8% (20/260)																						
9	Nottingham City	5% (14/260)																						
8	Diana Princess of	5%																						

	Wales (Birmingham)	(13/260)	<p><i>Note: baseline scores and discharge/follow-up scores are rated using a different scale so may not be directly comparable. Baseline scores are rated from 1 (dislike) to 10 (like); discharge and follow-up scores are rated from 1 (as before the operation) to 10 (perfect).</i></p> <p><i>39 of the 119 patients with a cosmetic appearance score at a follow-up appointment had had the bar removed (80 had not).</i></p> <table border="1"> <thead> <tr> <th>Score</th> <th>Baseline</th> <th>Discharge</th> <th>Last follow-up*</th> </tr> </thead> <tbody> <tr> <td>1 (dislike/as before operation)</td> <td>12% (13/109)</td> <td>0</td> <td>1% (1/119)</td> </tr> <tr> <td>2</td> <td>21% (23/109)</td> <td>0</td> <td>0</td> </tr> <tr> <td>3</td> <td>39% (43/109)</td> <td>0</td> <td>0</td> </tr> <tr> <td>4</td> <td>11% (12/109)</td> <td>3% (3/98)</td> <td>2% (2/119)</td> </tr> <tr> <td>5</td> <td>10% (11/109)</td> <td>2% (2/98)</td> <td>3% (3/119)</td> </tr> <tr> <td>6</td> <td>3% (3/109)</td> <td>3% (3/98)</td> <td>3% (3/119)</td> </tr> <tr> <td>7</td> <td>1% (1/109)</td> <td>8% (8/98)</td> <td>13% (16/119)</td> </tr> <tr> <td>8</td> <td>3% (3/109)</td> <td>26% (25/98)</td> <td>18% (21/119)</td> </tr> <tr> <td>9</td> <td>0</td> <td>45% (44/98)</td> <td>39% (47/119)</td> </tr> <tr> <td>10 (like/perfect)</td> <td>0</td> <td>13% (13/98)</td> <td>22% (26/119)</td> </tr> <tr> <td><b>Mean score (± SD)</b></td> <td><b>3.1 (± 1.5)</b></td> <td><b>8.4 (± 1.3)</b></td> <td><b>8.4 (± 1.5)</b></td> </tr> </tbody> </table> <p><i>* Taken as the cosmetic appearance score recorded at last follow-up evaluation for each patient; mean duration of follow-up: 369 days, median: 170 days, range: 4–2477.</i></p>	Score	Baseline	Discharge	Last follow-up*	1 (dislike/as before operation)	12% (13/109)	0	1% (1/119)	2	21% (23/109)	0	0	3	39% (43/109)	0	0	4	11% (12/109)	3% (3/98)	2% (2/119)	5	10% (11/109)	2% (2/98)	3% (3/119)	6	3% (3/109)	3% (3/98)	3% (3/119)	7	1% (1/109)	8% (8/98)	13% (16/119)	8	3% (3/109)	26% (25/98)	18% (21/119)	9	0	45% (44/98)	39% (47/119)	10 (like/perfect)	0	13% (13/98)	22% (26/119)	<b>Mean score (± SD)</b>	<b>3.1 (± 1.5)</b>	<b>8.4 (± 1.3)</b>	<b>8.4 (± 1.5)</b>	<ul style="list-style-type: none"> <li>• Bar migration: 4</li> <li>• Pleural effusion: 1</li> <li>• Haematoma: 1</li> <li>• Pain: 1</li> <li>• Other: 3 <ul style="list-style-type: none"> <li>- granulomas over plates</li> <li>- broken retaining wire causing discomfort which was removed as a day case</li> <li>- protruding wire which was removed surgically.</li> </ul> </li> </ul> <p><b>Minor (n = 26)</b></p> <ul style="list-style-type: none"> <li>• Infection: 10</li> <li>• Pleural effusion: 3</li> <li>• Bar migration: 3</li> <li>• Pain: 4</li> <li>• Other: 6 <ul style="list-style-type: none"> <li>- continuing lung base collapse self-resolving</li> <li>- pneumothorax following fall which required conservative treatment</li> <li>- removal of wire from lateral wound</li> <li>- nipple noted to be inverted</li> <li>- wound dehiscence</li> <li>- granulomas over plates noted several months after bar insertion.</li> </ul> </li> </ul> <p><b>Adverse events during bar removal (n = 6)</b></p> <ul style="list-style-type: none"> <li>• Small haematoma drained at bar removal.</li> <li>• Haematoma (minor).</li> <li>• Infection.</li> <li>• Intraoperative bleeding that delayed discharge.</li> <li>• Urinary retention.</li> <li>• Pneumothorax that delayed discharge.</li> </ul>	<p>'Minor' adverse events were all others (including those where there was no information to suggest it was 'major').</p>
Score	Baseline	Discharge		Last follow-up*																																																	
1 (dislike/as before operation)	12% (13/109)	0		1% (1/119)																																																	
2	21% (23/109)	0		0																																																	
3	39% (43/109)	0		0																																																	
4	11% (12/109)	3% (3/98)		2% (2/119)																																																	
5	10% (11/109)	2% (2/98)		3% (3/119)																																																	
6	3% (3/109)	3% (3/98)		3% (3/119)																																																	
7	1% (1/109)	8% (8/98)	13% (16/119)																																																		
8	3% (3/109)	26% (25/98)	18% (21/119)																																																		
9	0	45% (44/98)	39% (47/119)																																																		
10 (like/perfect)	0	13% (13/98)	22% (26/119)																																																		
<b>Mean score (± SD)</b>	<b>3.1 (± 1.5)</b>	<b>8.4 (± 1.3)</b>	<b>8.4 (± 1.5)</b>																																																		
10	Freeman (Newcastle)	5% (12/260)																																																			
6	Western Bank (Sheffield)	4% (9/260)																																																			
7	Glenfield (Leicester)	4% (9/260)																																																			
11	Southampton General	2% (6/260)																																																			
12	Royal Devon & Exeter	2% (4/260)																																																			
13	Northern General (Sheffield)	<1% (1/260)																																																			



Abbreviations used: PE, pectus excavatum; CT, computed tomography			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Nuss et al. (2005)<sup>7</sup></p> <p>Study type: <b>retrospective case series</b></p> <p>Country: USA</p> <p>Study period: 1987–July 04</p> <p>Study population: patients who had minimally invasive repair of PE (56 patients had previous failed operations for PE).</p> <p><b>n = 668</b></p> <p>Age: not stated</p> <p>Sex: not stated</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE.</p> <p>Follow-up: <b>not stated</b> ('at least 1 year')</p> <p>Conflict of interest: none stated</p>	<p><b>Cosmetic results</b></p> <p>- <i>Method of assessment not described.</i></p> <p>- <i>Patients who have had the bar removed and had follow-up of at least 1 year after bar removal (follow-up ranging from 1 to 15 years; n = 190) rated the results as:</i></p> <ul style="list-style-type: none"> <li>• excellent: 78% (149/190)</li> <li>• good: 13% (25/190)</li> <li>• fair: 5% (9/190)</li> <li>• failed (recurrence of PE): 4% (7/190).</li> </ul> <p>- <i>The authors comment that six of the patients who had recurrence of PE had initial bar insertion and removal before puberty and had the bars removed before 2 years postoperatively.</i></p> <p><b>Bar removal</b></p> <ul style="list-style-type: none"> <li>• 57% (383/668) of patients had the bar removed.</li> </ul>	<p><b>Complications</b></p> <ul style="list-style-type: none"> <li>• Pneumothorax: 55% (369/668) <ul style="list-style-type: none"> <li>- with spontaneous resolution (349)</li> <li>- requiring chest tube (17)</li> <li>- requiring aspiration (3).</li> </ul> </li> <li>• Bar displacement (total): 10% (70/668).</li> <li>• Bar displacement requiring revision: 7% (50/668) <ul style="list-style-type: none"> <li>- displacement prior to use of stabilisers was introduced (16/112)</li> <li>- displacement after use of wired stabilisers (22/473)</li> <li>- displacement after use of stabilisers plus sutures around the rib and bar (1/129).</li> </ul> </li> <li>• Overcorrection: 28 (4 patients with Marfan's syndrome developed a true pectus carinatum).</li> <li>• Wound infection: 8.</li> <li>• Pneumonia: 7.</li> <li>• Pericarditis: 6.</li> <li>• Pleural effusion requiring chest tube: 5.</li> <li>• Metal allergy: 5.</li> <li>• Transient Horner's syndrome secondary to the epidural analgesia: 24% (162/668).</li> </ul>	<p>The authors state that all major complications occurred in the first 2 years of the 6-year series and some may have been attributable to the learning curve.</p>

Abbreviations used: PE, pectus excavatum; CT, computed tomography; FVC%, Forced Vital Capacity; FEV <sub>1</sub> %, Forced Expiratory Volume in one second ;FEF <sub>25-75%</sub> , Forced Expiratory Flow rate																																													
Study details	Key efficacy findings			Key safety findings	Comments																																								
<p>Nuss et al. (2008)<sup>2</sup></p> <p>Study type: <b>retrospective case series</b></p> <p>Country: USA</p> <p>Study period: not stated</p> <p>Study population: patients who had minimally invasive repair of PE</p> <p><b>n = 947</b></p> <p>Age: not stated</p> <p>Sex: not stated</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE</p> <p>Follow-up: 2 years</p> <p>Conflict of interest: none stated</p>	<p>Long-term patient satisfaction (n = 521) following bar removal:</p> <p>Excellent: 83.3%</p> <p>Good: 12.3%</p> <p>Fair: 1.7%</p> <p>Poor: 1.2%</p> <p>Failed: 1.5%</p> <p>Static pulmonary function studies showing shift to the left in patients with severe pectus excavatum (data collected up to 31 January 2006).</p> <table border="1"> <thead> <tr> <th>% predicted</th> <th>FVC% (n = 791)</th> <th>FEV<sub>1</sub>% (n = 787)</th> <th>FEF<sub>25-75%</sub> (n = 750)</th> </tr> </thead> <tbody> <tr> <td>&gt;= 100% +</td> <td>21.49%</td> <td>16.01%</td> <td>25.73%</td> </tr> <tr> <td>90-99%</td> <td>21.62%</td> <td>21.98%</td> <td>13.33%</td> </tr> <tr> <td>80-89%</td> <td>28.57%</td> <td>28.34%</td> <td>14%</td> </tr> <tr> <td>70-79%</td> <td>18.46%</td> <td>18.42%</td> <td>13.33%</td> </tr> <tr> <td>60-69%</td> <td>5.56%</td> <td>9.66%</td> <td>14.93%</td> </tr> <tr> <td>50-59%</td> <td>2.91%</td> <td>3.68%</td> <td>8.27%</td> </tr> <tr> <td>40-49%</td> <td>1.26%</td> <td>1.27%</td> <td>4.53%</td> </tr> <tr> <td>30-39%</td> <td>0.13%</td> <td>0.38%</td> <td>2.27%</td> </tr> <tr> <td>&lt; 30%</td> <td>0%</td> <td>0.25%</td> <td>3.60%</td> </tr> </tbody> </table> <p>Before surgery, most common symptoms are exertional dyspnea, chest pain with exercise, and occasionally palpitations due to:</p> <p>Cardiac compression: 88% (694/786)</p> <p>Cardiac displacement by CT: 89% (696/786)</p> <p>Mitral valve prolapsed: 15% (121/786)</p> <p>Murmurs: 32% (249/786)</p>			% predicted	FVC% (n = 791)	FEV <sub>1</sub> % (n = 787)	FEF <sub>25-75%</sub> (n = 750)	>= 100% +	21.49%	16.01%	25.73%	90-99%	21.62%	21.98%	13.33%	80-89%	28.57%	28.34%	14%	70-79%	18.46%	18.42%	13.33%	60-69%	5.56%	9.66%	14.93%	50-59%	2.91%	3.68%	8.27%	40-49%	1.26%	1.27%	4.53%	30-39%	0.13%	0.38%	2.27%	< 30%	0%	0.25%	3.60%	<p>No data reported for the larger study</p>	<p>Suspect that the 2008 study is an extension of the 2005 study (i.e. includes the 668 reported in the 2005 paper). However, this is not explicitly stated in the 2008 paper which includes no reference to the 2005 paper.</p>
% predicted	FVC% (n = 791)	FEV <sub>1</sub> % (n = 787)	FEF <sub>25-75%</sub> (n = 750)																																										
>= 100% +	21.49%	16.01%	25.73%																																										
90-99%	21.62%	21.98%	13.33%																																										
80-89%	28.57%	28.34%	14%																																										
70-79%	18.46%	18.42%	13.33%																																										
60-69%	5.56%	9.66%	14.93%																																										
50-59%	2.91%	3.68%	8.27%																																										
40-49%	1.26%	1.27%	4.53%																																										
30-39%	0.13%	0.38%	2.27%																																										
< 30%	0%	0.25%	3.60%																																										

Abbreviations used: PE, pectus excavatum; CT, computed tomography			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Park et al. (2004)<sup>3</sup></p> <p>Study type: <b>retrospective case series</b></p> <p>Country: South Korea</p> <p>Study period: Aug 1999–June 2002</p> <p>Study population: consecutive patients who had minimally invasive repair of PE.</p> <p>Redo procedures after failed Ravitch procedure (9) or sternal turnover (1).</p> <p>Severity of deformity (CT Index): 6.3 (mean), 2.5–250 (range)</p> <p><b>n = 322</b></p> <p>Age: 8 (median) 16 months–46 years (range)</p> <p>Sex: 81% male</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE.</p> <p>Follow-up: <b>not stated</b></p> <p>Conflict of interest: none stated</p>	<p><b>Operative details</b></p> <ul style="list-style-type: none"> <li>• Lateral stabilisers used: 44.4% (143/322)</li> <li>• 5-point fixation without stabiliser: 20.2% (65/322)</li> </ul> <p><b>Severity of deformity</b></p> <p>- Assessed using CT index, reported as mean index score</p> <ul style="list-style-type: none"> <li>• preoperative CT Index: 6.3 (range: 2.6–250)</li> <li>• postoperative CT index (follow-up not stated): 2.7 (range: 1.8–4.5)</li> <li>• mean individual improvement in CT index: 4.3 (range: 0.3–247).</li> </ul> <p><b>Repair results</b></p> <p>- The method of assessing results and who made the assessment was not described.</p> <ul style="list-style-type: none"> <li>• Excellent: 91% (294/322)</li> <li>• Good: 9% (28/322)</li> <li>• Fair: 1% (4/322).</li> </ul> <p>(These numbers add to more than 322, no explanation for this discrepancy is given.)</p> <p><b>Bar removal</b></p> <ul style="list-style-type: none"> <li>• 14% (44/322) of patients have had the bar removed.</li> <li>• 42 were elective removals to complete the procedure 2 years after bar insertion. In all patients, contour of the initial correction was maintained.</li> <li>• 2 were removed prematurely at 1 year due to persisting wound infection and the other was at the patients' request.</li> </ul>	<p><b>Complications: 19% (61/322)</b></p> <p>15% were early complications, 4% were late complications (<i>definition of early/late not stated</i>), and 4% were major complications.</p> <ul style="list-style-type: none"> <li>• Pneumothorax: 7% (24/322) <ul style="list-style-type: none"> <li>- with spontaneous resolution (11)</li> <li>- requiring needle aspiration (4)</li> <li>- requiring chest tube (1 tension pneumothorax)</li> <li>- requiring percutaneous catheter drainage (8).</li> </ul> </li> <li>• Bar displacement: 3% (11/322) <ul style="list-style-type: none"> <li>- major (flipped bar) (4)</li> <li>- minor (7) 3 were late complications.</li> </ul> </li> <li>• Wound seroma: 3% (10/322).</li> <li>• Pleural effusion: 3% (8/322) 1 was a late complication.</li> <li>• Pericardial effusion: 3% (8/322) 5 were late complications.</li> <li>• Pneumonia: 1% (3/322).</li> <li>• Haemothorax: 1% (3/322) all were late complications.</li> <li>• Cardiac perforation: 0.3% (1/322) – this occurred during a reoperation for a displaced bar which had been inserted in another hospital 1 year prior. There were likely adhesions on the thorax and the pectus clamp penetrated the right atrium and ventricle. The cardiac injury was repaired successfully.</li> </ul> <p><b>Reoperation: 4% (14/322)</b></p> <p>Reasons for reoperation:</p> <ul style="list-style-type: none"> <li>• bar displacement (11)</li> <li>• progressive deterioration of the contour (2)</li> <li>• skin perforation by the stabiliser (1).</li> </ul>	<p>The authors commented that they changed their stabilisation technique to address bar displacement. The first 143 patients had lateral stabilisers. Since then, 5-point fixation without a stabiliser has been routine practice.</p> <p><b>PE CT index:</b> transverse chest diameter divided by vertical chest diameter (assessed by CT scan). An index above 3.25 indicates severe deformity.</p>

Abbreviations used: PE, pectus excavatum; CT, computed tomography			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Hosie et al. (2002)<sup>4</sup></p> <p>Study type: <b>retrospective multicentre case series</b></p> <p>Country: Germany, Switzerland, Poland</p> <p>Study period: not stated</p> <p>Study population: patients who had minimally invasive repair of PE.</p> <p>Severity of deformity (PE CT index): &gt; 3.25: 74.3% &gt; 3.75: 40.3%</p> <p><b>n = 172</b></p> <p>Age: 15 (mean) 1–27 (range)</p> <p>Sex: 83% male</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE.</p> <p>Follow-up: <b>not stated</b> ('maximum of 2 years')</p> <p>Conflict of interest: none stated</p>	<p><b>Operative outcomes</b></p> <ul style="list-style-type: none"> <li>• Insertion of two bars: 9% (15/172)</li> <li>• No stabiliser used: 42% (72/172)</li> <li>• One stabiliser used: 1% (2/172)</li> <li>• Two stabilisers used: 43% (74/172)</li> </ul> <p><i>(No data on use of stabilisers for 24 patients)</i></p> <ul style="list-style-type: none"> <li>• 24 patients were referred postoperatively to an intensive care unit</li> <li>• 43 patients received an epidural block for postoperative pain control</li> </ul> <p><b>Cosmetic appearance</b></p> <p><i>Scored by surgeons from 1 (excellent to 10 (poor) (n = 124, follow-up not stated)</i></p> <ul style="list-style-type: none"> <li>• Excellent result: 59% (73/124)</li> <li>• Good result: 23% (28/124)</li> <li>• Fair result: 19% (23/124)</li> </ul> <p><i>The authors state that the patients evaluated the cosmetic result simultaneously and patient satisfaction was generally higher than the surgeons.</i></p>	<p><b>Major complications: 11% (19/172)</b></p> <ul style="list-style-type: none"> <li>• Bar displacement (6)</li> <li>• Stabiliser displacement (3)</li> <li>• Pneumonia/atelectasis (3)</li> <li>• Pleural effusion (3)</li> <li>• Infection (2)</li> <li>• Liver injury (1)</li> <li>• Pericardial effusion (1)</li> </ul> <p><b>Minor complications: 8% (14/172)</b></p> <p><i>Minor complications were defined as those not requiring a specific therapy and which did not prolong hospital stay</i></p> <ul style="list-style-type: none"> <li>• Subcutaneous emphysema (6)</li> <li>• Self-resolving pneumothorax (5)</li> <li>• Self-resolving atelectasis (3)</li> </ul>	<p>This paper was included in the original overview.</p> <p><b>PE CT index:</b> transverse chest diameter divided by anteroposterior chest diameter (assessed by CT scan). An index above 3.25 indicates severe deformity.</p>

Abbreviations used: PE, pectus excavatum; CT, computed tomography			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Castellani et al. (2008)<sup>8</sup></p> <p>Study type: <b>prospective case series</b></p> <p>Country: Austria</p> <p>Study period: April 2000–April 2006</p> <p>Study population: patients who had minimally invasive repair of PE. Two patients had one previous failed operation (Ravitch procedure and silicone-implantation)/one patient had two previous failed operations (modified-Ravitch procedures).</p> <p><b>n = 167</b></p> <p>Age: 16 (mean) 5–40 (range)</p> <p>Sex: 81% male</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE.</p> <p>Follow-up: <b>not stated</b> ('maximum of 2 years')</p> <p>Conflict of interest: none stated</p>	<p>No efficacy outcomes were reported.</p>	<p><b>Major complications: 4% (7/167)</b></p> <p><i>Major complications defined as those involving organ injury or if a significant secondary intervention was necessary.</i></p> <ul style="list-style-type: none"> <li>• Bar displacement requiring reoperation: 3.</li> <li>• Intraoperative cardiac perforation requiring emergency thoracoscopy: 1.</li> <li>• Liver piercing: 1.</li> <li>• Early infection (2 weeks postoperatively): 1 (antibiotics failed so bar was removed).</li> <li>• Recurrent local signs of inflammation: 1.</li> </ul> <p><b>Minor complications: 73% (122/167)</b></p> <p><i>Some patients had more than one complication. Seventeen cases required readmission for inpatient treatment of complications (five required reoperation).</i></p> <ul style="list-style-type: none"> <li>• Breakage of wires used to secure stabiliser and bar on the underlying rib: 48.</li> </ul> <p><i>The authors state that due to this problem, the technique was modified in the last 49 patients to use suture cords instead of wires for fixation and no further problems were encountered.</i></p> <ul style="list-style-type: none"> <li>• Pleural effusion: 28.</li> </ul> <p><i>Most were recognised incidentally during routine follow-up examinations. Eight cases required thoracocentesis with evacuation of effusions (two patients had repeated bilateral pleural effusions and required repeated thoracocentesis for 10 weeks postoperatively).</i></p> <ul style="list-style-type: none"> <li>• Pneumothorax: 15.</li> </ul> <p><i>14 cases occurred during the first postoperative week and because of incomplete gas evacuation after thoracoscopy, not pulmonary tissue damage. One case was late and caused by rupture of an emphysematous bulla which was not related to the correction of the PE.</i></p> <ul style="list-style-type: none"> <li>• Intraoperative rupture of intercostal muscles: 15.</li> </ul> <p><i>These occurred in older patients with stiffer thoracic skeletons.</i></p> <ul style="list-style-type: none"> <li>• Haematothorax or haematopneumothorax: 10.</li> </ul> <p><i>Six cases were early, four were late (three of which were caused by trauma).</i></p> <ul style="list-style-type: none"> <li>• Minor pericardial tears (no further consequences): 7.</li> <li>• Dislocation of the stabiliser plate detected during follow-up (7–21 months postoperatively): 7.</li> <li>• Dyspnoea and lung atelectasia associated with bronchial mucous plugs: 4.</li> <li>• Pain requiring readmission for pain therapy: 3.</li> <li>• Transient brachial plexus injury: 1.</li> </ul>	<p>The authors state that all major complications occurred in the first 2 years of the 6-year series and some may have been attributable to the learning curve.</p>

Abbreviations used: PE, pectus excavatum; CT, computed tomography; HRQL, health-related quality of life questionnaire			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Lam M et al. (2008)<sup>9</sup></p> <p>Study type: <b>cross-sectional survey</b> Country: Canada Study period: 2003–2006 Study population: patients who received repair of PE (Nuss procedure: 44%, Ravitch procedure: 66%).</p> <p><b>n = 43</b> Age: 16 years (mean) Sex: 91% male</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE (Nuss procedure; 44%) and open surgical repair (Ravitch procedure; 66%).</p> <p>Follow-up: <b>mean time between surgery and survey: 15 months</b></p> <p>Conflict of interest: none stated</p>	<p><b>Survey response rate: 53% (23/43)</b> - 11 Nuss patients, 12 Ravitch patients</p> <p><b>Health-related quality of life</b> - assessed by the <i>Child Health Questionnaire</i>; mean follow-up: 16 months</p> <ul style="list-style-type: none"> <li>In all domains of the Child Health Questionnaire there were no differences in mean scores between patients who had the Nuss procedure and those who had the Ravitch procedure.</li> <li>However, for the question on the 'child's perspective of change in health over the past year' Nuss patients rated their health as 'somewhat better now' and Ravitch patients rated theirs as 'about the same now' (corresponding to mean Likert scores of 1.7 and 2.8 respectively; <math>p = 0.01</math>).</li> </ul> <p><b>Physical and psychosocial quality of life</b> - assessed by the <i>Pectus Excavatum Evaluation Questionnaire</i>; mean follow-up: 16 months</p> <ul style="list-style-type: none"> <li>Nuss patients felt 'less bothered' by the appearance of their chest than Ravitch patients (corresponding to median Likert scores of 4.0 and 3.0 respectively; <math>p = 0.02</math>).</li> <li>Nuss patients experienced less frequent 'chest pain or discomfort' than Ravitch patients (corresponding to median Likert scores of 3.0 and 2.0 respectively; <math>p = 0.04</math>).</li> </ul>	<p><b>Complications</b></p> <p><b>Nuss procedure</b></p> <ul style="list-style-type: none"> <li>No complications were reported in Nuss patients.</li> </ul> <p><b>Ravitch procedure</b></p> <ul style="list-style-type: none"> <li>One patient had a wound infection after hospital discharge requiring antibiotic treatment.</li> <li>Of the 23 patients who had a retrosternal strut placed, 52% (12/23) required unplanned surgical removal or repositioning of the bar because of bar displacement 1–31 days postoperatively.</li> </ul>	<p>The number of patients who had the bar removed is not stated. It is not clear whether the survey was administered before or after bar removal.</p> <p><b>Child Health Questionnaire:</b> 87-item multidimensional generic measure of health-related quality of life that was designed to be self-completed by children aged 5 to 18 years (12 domains: physical functioning, role/social limitations (behavioural, emotional and physical), bodily pain, behaviour, mental health, self-esteem, general health perception, family activities, change in health, and family cohesion).</p> <p><b>Pectus Excavatum Evaluation Questionnaire:</b> 17-item (with Likert scales) measure of physical and psychosocial quality of life changes after surgical repair of PE (low scores indicate better outcomes).</p>

Abbreviations used: PE, pectus excavatum; CT, computed tomography; HRQL, health-related quality of life questionnaire; SD, standard deviation																																										
Study details	Key efficacy findings	Key safety findings	Comments																																							
<p>Metzelder ML et al. (2007)<sup>b</sup></p> <p>Study type: <b>cross-sectional survey</b>  Country: Germany  Study period: Feb 2002–Feb 2006  Study population: patients who had minimally invasive repair of PE.</p> <p><b>n = 45</b>  Age (at time of surgery): 14 years (mean)  Age (when survey was completed): 17 (mean); 10–24 years (range)  Sex: 65% male</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE.  Survey: 45 patients and parents (where relevant) were contacted 6 months after bar removal surgery and 40 agreed to participate in this study.</p> <p>Follow-up: <b>54 months since bar insertion (mean); 25–73 months (range)</b></p> <p>Conflict of interest: none stated</p>	<p><b>Survey response rate: 89% (40/45)</b></p> <p><b>Patient and parental satisfaction</b>  - assessed by a questionnaire with 5-point scales (scales described below for each questionnaire item), reported as mean score <math>\pm</math> SD</p> <table border="1"> <thead> <tr> <th>Questionnaire Item</th> <th>Patients</th> <th>Parents</th> </tr> </thead> <tbody> <tr> <td>General postoperative health (1 = much worse now; 5 = much better now)</td> <td>4.4 <math>\pm</math> 0.7</td> <td>4.3 <math>\pm</math> 0.6</td> </tr> <tr> <td>Extent that chest appearance interfered with social activity preoperatively (1 = extremely; 5 = not at all)</td> <td>3.6 <math>\pm</math> 1.0</td> <td>3.9 <math>\pm</math> 1.0</td> </tr> <tr> <td>Extent that chest appearance interfere with social activity postoperatively (1 = extremely; 5 = not at all)</td> <td>4.6 <math>\pm</math> 0.5</td> <td>4.4 <math>\pm</math> 0.8</td> </tr> <tr> <td>Satisfaction with postoperative appearance (1 = very dissatisfied; 5 = extremely satisfied)</td> <td>4.1 <math>\pm</math> 0.8</td> <td>4.1 <math>\pm</math> 0.8</td> </tr> <tr> <td>Preoperative self-esteem (1–10)</td> <td>6.3 <math>\pm</math> 1.2</td> <td>6.0 <math>\pm</math> 0.7</td> </tr> <tr> <td>Postoperative self-esteem (1–10)</td> <td>7.9 <math>\pm</math> 0.8</td> <td>7.5 <math>\pm</math> 0.7</td> </tr> <tr> <td>Chest looks different (1 = a lot worse now; 5 = major improvement)</td> <td>4.5 <math>\pm</math> 0.6</td> <td>4.3 <math>\pm</math> 0.7</td> </tr> <tr> <td>Going back, would have the operation again (0 = no; 5 = unsure; 10 = yes)</td> <td>9.1 <math>\pm</math> 2.7</td> <td>9.0 <math>\pm</math> 3.0</td> </tr> </tbody> </table> <p><b>Pain</b>  - assessed by a questionnaire with 5-point scale( from 1, severe pain to 5, no pain)</p> <table border="1"> <thead> <tr> <th>Mean item score <math>\pm</math> SD</th> <th>Patients</th> <th>Parents</th> </tr> </thead> <tbody> <tr> <td>Pain during hospital stay (for bar insertion)</td> <td>3.3 <math>\pm</math> 1.2</td> <td>3.3 <math>\pm</math> 1.1</td> </tr> <tr> <td>Pain interfering with day-to-day life (with bar implanted)</td> <td>4 <math>\pm</math> 0.9</td> <td>4 <math>\pm</math> 1.1</td> </tr> <tr> <td>Pain now (6 months after bar removal)</td> <td>5 <math>\pm</math> 0</td> <td>5 <math>\pm</math> 0</td> </tr> </tbody> </table>	Questionnaire Item	Patients	Parents	General postoperative health (1 = much worse now; 5 = much better now)	4.4 $\pm$ 0.7	4.3 $\pm$ 0.6	Extent that chest appearance interfered with social activity preoperatively (1 = extremely; 5 = not at all)	3.6 $\pm$ 1.0	3.9 $\pm$ 1.0	Extent that chest appearance interfere with social activity postoperatively (1 = extremely; 5 = not at all)	4.6 $\pm$ 0.5	4.4 $\pm$ 0.8	Satisfaction with postoperative appearance (1 = very dissatisfied; 5 = extremely satisfied)	4.1 $\pm$ 0.8	4.1 $\pm$ 0.8	Preoperative self-esteem (1–10)	6.3 $\pm$ 1.2	6.0 $\pm$ 0.7	Postoperative self-esteem (1–10)	7.9 $\pm$ 0.8	7.5 $\pm$ 0.7	Chest looks different (1 = a lot worse now; 5 = major improvement)	4.5 $\pm$ 0.6	4.3 $\pm$ 0.7	Going back, would have the operation again (0 = no; 5 = unsure; 10 = yes)	9.1 $\pm$ 2.7	9.0 $\pm$ 3.0	Mean item score $\pm$ SD	Patients	Parents	Pain during hospital stay (for bar insertion)	3.3 $\pm$ 1.2	3.3 $\pm$ 1.1	Pain interfering with day-to-day life (with bar implanted)	4 $\pm$ 0.9	4 $\pm$ 1.1	Pain now (6 months after bar removal)	5 $\pm$ 0	5 $\pm$ 0	<p>No safety outcomes were reported in this paper.</p>	<p>All patients had had the procedure for cosmetic reasons.</p>
Questionnaire Item	Patients	Parents																																								
General postoperative health (1 = much worse now; 5 = much better now)	4.4 $\pm$ 0.7	4.3 $\pm$ 0.6																																								
Extent that chest appearance interfered with social activity preoperatively (1 = extremely; 5 = not at all)	3.6 $\pm$ 1.0	3.9 $\pm$ 1.0																																								
Extent that chest appearance interfere with social activity postoperatively (1 = extremely; 5 = not at all)	4.6 $\pm$ 0.5	4.4 $\pm$ 0.8																																								
Satisfaction with postoperative appearance (1 = very dissatisfied; 5 = extremely satisfied)	4.1 $\pm$ 0.8	4.1 $\pm$ 0.8																																								
Preoperative self-esteem (1–10)	6.3 $\pm$ 1.2	6.0 $\pm$ 0.7																																								
Postoperative self-esteem (1–10)	7.9 $\pm$ 0.8	7.5 $\pm$ 0.7																																								
Chest looks different (1 = a lot worse now; 5 = major improvement)	4.5 $\pm$ 0.6	4.3 $\pm$ 0.7																																								
Going back, would have the operation again (0 = no; 5 = unsure; 10 = yes)	9.1 $\pm$ 2.7	9.0 $\pm$ 3.0																																								
Mean item score $\pm$ SD	Patients	Parents																																								
Pain during hospital stay (for bar insertion)	3.3 $\pm$ 1.2	3.3 $\pm$ 1.1																																								
Pain interfering with day-to-day life (with bar implanted)	4 $\pm$ 0.9	4 $\pm$ 1.1																																								
Pain now (6 months after bar removal)	5 $\pm$ 0	5 $\pm$ 0																																								

Abbreviations used: PE, pectus excavatum; CT, computed tomography			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Dzielicki et al. (2006)<sup>12</sup></p> <p>Study type: <b>retrospective case series</b></p> <p>Country: Poland</p> <p>Study period: 1999–2005</p> <p>Study population: patients who had minimally invasive repair of PE</p> <p>Redo procedures after failed conventional repair: 20 (4.3%).</p> <p>Severity of deformity (PE CT index):  ≤ 3.25: 30.2%  3.26–4.0: 48.1%  &gt; 4.0: 21.7%</p> <p><b>n = 461</b></p> <p>Age: 15 (mean), 3–31 (range)</p> <p>Sex: 79% male</p> <p>Inclusion criteria: not stated</p> <p>Technique: minimally invasive repair of PE</p> <p>Follow-up: <b>not stated</b></p> <p>Conflict of interest: none stated</p>	<p><b>Operative outcomes</b></p> <ul style="list-style-type: none"> <li>• Insertion of two bars: 17.4% (80/461)</li> <li>• Transverse sternotomy used: 7.8% (36/461)</li> <li>• Lateral stabilisers used: 1.3% (6/461)</li> <li>• Parasternal fixation of bar used: 59.7% (275/461)</li> <li>• Resection of rib cartilages: 5.9% (27/461) – these were mainly done in older patients with an asymmetric deformity</li> </ul> <p><b>Bar removal (follow-up not stated)</b></p> <ul style="list-style-type: none"> <li>• Support bar removed: 56.4% (260/461)</li> <li>• Mean date of removal: 26 months after insertion (range 22–32 months)</li> </ul>	<p><b>Mortality: 0</b></p> <p><b>Intraoperative complications: 4.1% (19/461)</b></p> <ul style="list-style-type: none"> <li>• Tear of an intercostal space: 14</li> <li>• Damage to pericardium: 4</li> <li>• Fractured sternum: 1</li> </ul> <p><b>Postoperative complications: 9.3% (43/461)</b></p> <ul style="list-style-type: none"> <li>• Bar rotation: 14 (<i>The authors note that these bar rotations occurred before 2000 when a new method of parasternal bar fixation was introduced.</i>)</li> <li>• Pleuritis exudativa and/or pneumonia: 10 (<i>Nine of these patients were readmitted to hospital during early postoperative period for pericardiac serous exudate, pneumonia and pleurisy.</i>)</li> <li>• Wound infection: 8</li> <li>• Persistent pneumothorax: 7</li> <li>• Pericarditis with fluid in pericardial sac: 4 (One patient required pericardiocentesis.)</li> </ul>	<p>No efficacy outcomes were reported (only technical details and safety outcomes).</p> <p>36 patients had a transverse sternotomy. The authors state that transverse sternotomy and insertion of a second bar were carried out mainly in older patients (&gt; 12 years) with a considerably rigid anterior chest wall.</p> <p><b>PE CT index:</b> transverse chest diameter divided by anterior chest diameter (assessed by CT scan). An index above 3.25 indicates severe deformity.</p>



Abbreviations used: PE, pectus excavatum; CT, computed tomography			
Study details	Key efficacy findings	Key safety findings	Comments
<p>Shin et al. (2007)<sup>11</sup> and Rushing et al. (2007)<sup>10</sup></p> <p>Study type: <b>retrospective case series</b> (retrospective review of a prospectively gathered database)</p> <p>Country: USA</p> <p>Study period: Jan 1987–Sept 2005</p> <p>Study population: patients who had minimally invasive repair of PE and developed an infectious complication (n = 14) or presented with signs of metal allergy (n = 19).</p> <p><b>n = 863</b></p> <p>Age: not stated</p> <p>Sex: not stated</p> <p>Inclusion criteria:</p> <ul style="list-style-type: none"> <li>Concern for metal allergy either on preoperative screening or postoperative follow-up (e.g. when fever, rash, erythema, effusion, or granuloma was noted without obtainable evidence of infection of positive cultures).</li> </ul> <p>Technique: minimally invasive repair of PE. Metal allergy diagnosed using dermal patch test, metal sensitivity disc, pathology reports and clinical outcomes.</p> <p>Follow-up: <b>not stated</b></p> <p>Conflict of interest: none stated</p>	<p>These studies only reported safety outcomes.</p>	<p><b>Postoperative infections: 2% (13/863)</b></p> <ul style="list-style-type: none"> <li>Cellulitis: four (1 day, 2 days, 2 weeks and 7 months after surgery. All cases were treated with a single course of antibiotics.)</li> <li>Stitch abscesses: three (2 weeks, 6 weeks and 2 months after surgery. All cases were treated with oral antibiotics.)</li> <li>Bar infections: six (3 weeks to 8 months after surgery. All cases were diagnosed after a wound abscess was found in contact with the bar. All abscesses were drained and antibiotics administered. Three cases resolved after antibiotics. Three patients had recurrent infections which were suppressed with long-term antibiotics but required early bar removal 3, 18 and 18 months after surgery.)</li> </ul> <p>None of the patients with infectious complications had been operated on previously for PE repair.</p> <p>There were no intraoperative complications or known breaks in sterile surgical technique.</p> <p>Seven patients had one bar inserted and six had two bars inserted.</p> <p>Two patients were operated on before the use of stabilisers. In the others, lateral stabilisers were used on both sides (n = 6) or one side (n = 5). All infections occurred on the side where the stabiliser had been placed.</p> <p><b>Suspected metal allergy on preoperative screening or postoperative follow-up: 2% (19/863)</b></p> <p>- mean follow-up 25 months (range: 1–67 months)</p> <ul style="list-style-type: none"> <li>Nine patients had history of atopy (rhinitis, or asthma), three patients had an allergy to jewellery or braces, one patient had food allergies.</li> <li>Ten patients presented with a rash and erythema, five with pleural effusion and one patient had a granuloma. Mean time to presentation of allergy was 40 days (range 5–140 days).</li> <li>Three patients who were diagnosed with metal allergy before surgery had titanium bars placed (with no allergic event after surgery).</li> <li>Three patients had stainless steel bars removed because of allergic skin breakdown. Two of these patients had titanium bars placed instead and one patient had no bar replaced with good resolution of PE and metal allergy.</li> </ul>	<p>These results are from two separate publications of safety outcomes on the same group of patients (one reported on infections and the other reported metal allergies).</p>

Abbreviations used: PE, pectus excavatum; CT, computed tomography		
Study details	Key safety findings	Comments
<p>Bouchard et al (2009)<sup>9</sup></p> <p>Study type: <b>case report</b></p> <p>Country: Canada/USA</p> <p>Study period: not stated</p> <p>Study population: cardiac injury sustained during MIRPE</p> <p><b>n = 4</b></p> <p>Age: 14, 18, 11, 17</p> <p>Sex: All male</p> <p>Inclusion criteria: see above</p> <p>Technique: minimally invasive repair of PE</p> <p>Follow-up: <b>not stated</b></p> <p>Conflict of interest: none stated</p>	<p>Case 1: 14-yr-old healthy boy with severe deformity. Given the severity of the sterna depression it was very difficult to pass the the pectus dissector across the posterior aspect of the sternum, despite the use of bilateral thoracoscopy. Despite meticulous dissection and constant communication with the anaesthesiologist, the patient became hypotensive and bradycardic. Through the right thoroscope, a cardiac tamponade was noted and on mild withdrawal of the pectus dissector, bleeding was seen. An immediate sternotomy was performed and the pericardium opened and drained following improvement of the patient's hemodynamics. The bar had entered the right atrium, traversed the tricuspid valve and created a ventricular septal defect (VSD). The heart sustained injury without arrhythmia. After controlling bleeding and adequate resuscitation, the puncture site was repaired, pacing wires placed and an intraop echocardiogram was performed that showed the VSD. The patient recovered well although he still has a severe pectus excavatum.</p> <p>Case 2: An 18-year-old male underwent Ravitch procedure at age 11 and the deformity subsequently reoccurred. He received MIRPE. A thoracoscopy revealed significantly distorted anatomy. Decision was made to place two bars. The tract for the first was created without difficulty. On withdrawal of the introducer, after making the tract for the second bar, a significant amount of bleeding was noted with a loss of end tidal CO<sub>2</sub>. An immediate left thoractomy was performed. Two actively bleeding lesions were noted in the pericardium and a tamponade was also present. Two wounds to the heart were observed: one in the right atrium and one in the right ventricle. Open cardiac massage was performed and the wounds repaired. The patient was placed on cardiac bypass for 90 minutes. The patient survived but sustained a severe hypoxic brain injury.</p> <p>Case 3: An 11-year-old male sought correction for a moderate pectus excavatum. An atrial septal defect had been repaired at 1 year of age. At surgery, right thoracoscopy revealed marked sterna compression and pericardial adhesions. Dissection to create space between the pericardium and sternum was initiated. Cardiac surgery was notified and a sternotomy performed. The dissector was discovered through the tip of the right ventricle at the point of dense fusion of the heart, pericardium and undersurface of the sternum. The dissector was removed and myocardium repaired on cardiopulmonary bypass. The patient recovered well and still has a pectus excavatum deformity.</p> <p>Case 4: A 17-year-old underwent the NUSS procedure. One month after the operation, the patient complained of pain over his stabilizer on the left side. A decision was made to modify the arc of the bend. One month after revision, he was noted to have shortness of breath. Echocardiogram showed pericardial effusion which was drained without sequellae. Six months after initial surgery he presented with pain along the entire bar without signs of infection. The bar was removed without difficulty or resistance. A sudden drop in blood pressure and cardiac arrest accompanied closure of the fascia and skin. A median sternotomy was performed and a 2cm hole in the left ventricle was observed and repaired. After aggressive resuscitation, the patient died on the operating table.</p>	

### ***Validity and generalisability of the studies***

- The studies reported on a mixture of children and adults.
- Techniques varied somewhat across studies (such as number of bars placed, stabilisation method).
- Studies varied according to the number of patients who had already received failed operations.

### **Specialist Advisers' opinions**

Specialist advice was sought from consultants who have been nominated or ratified by their Specialist Society or Royal College. The advice received is their individual opinion and does not represent the view of the society.

David Crabbe and DH Parikh (British Association of Paediatric Surgeons), John Duffy (Society for Cardiothoracic Surgery in Great Britain and Ireland), Robert Wheeler (British Association of Paediatric Surgeons) Graham Wilson (Association of Paediatric Anaesthetists of Great Britain and Ireland).

- Four Advisers perform the procedure regularly and one has performed it at least once.
- All Advisers stated that the comparator was open surgical repair (Ravitch procedure).
- The Advisers thought that adverse events included: injury to the lungs, heart and mammary artery; infection; pneumothorax; pericardial effusion; osteochondrodystrophy; pain; metal allergy; bar migration; anaesthetic complications; and bleeding.
- The Specialist Advisers reported the following anecdotal adverse events: prosthetic infection, bleeding, bar displacement, pneumothorax, pericarditis, pleural effusion, wound infection, chest infection, liver injury, residual pneumothorax, and blood in the pleural cavity.
- Three Advisers thought that there were no uncertainties about the safety of the procedure and that complication rates were well known. Another stated that the major problems with this procedure were ensuring that there was no injury to the heart when the bar is passed behind the sternum and making sure that the bar is secured in a good position to avoid migration.
- The Advisers stated that the key efficacy outcomes were cosmetic appearance and patient satisfaction.
- One Adviser commented that the association between chest wall deformities and abnormalities of respiratory and cardiac function remained unclear, despite extensive research over many years. The adviser stated that the general consensus in the UK is that pectus deformities are rarely associated with significant physiological disturbance.
- One Adviser stated that the procedure is not suitable for all people and that patient selection is crucial. Another stated that the procedure may not be as effective in older patients, especially those with a relatively stiff chest wall.

- One Adviser commented that the facilities needed for the procedure included equipment for thoracoscopy and equipment to deal with cardiac injury (which is a rare but theoretical risk). Another stated that a tertiary centre with paediatric intensive care unit facilities was needed and two stated that onsite cardiac surgery was necessary. He also said that surgeons undertaking this operation should have an established practice in thoracic or cardiac surgery and they should have performed this procedure under supervision. Another Adviser thought that training in paediatric anaesthesia and facilities for providing good-quality postoperative care and pain management (most notably thoracic epidural) were necessary.
- All Advisers thought that the procedure was likely only to be carried out in a minority of hospitals. One Adviser thought that it was unlikely to be taken up by further centres.

### **Issues for consideration by IPAC**

- None

## References

1. (2009) NICE ReBIP Nuss Registry.
2. Nuss D and Kelly RE, Jr. (2008) Minimally invasive surgical correction of chest wall deformities in children (Nuss procedure). *Advances in Pediatrics* 55:395-410.
3. Park HJ, Lee SY, Lee CS et al. (2004) The Nuss procedure for pectus excavatum: evolution of techniques and early results on 322 patients. *Annals of Thoracic Surgery* 77:289-295.
4. Hosie S, Sitkiewicz T, Petersen C et al. (2002) Minimally invasive repair of pectus excavatum--the Nuss procedure. A European multicentre experience. *European Journal of Pediatric Surgery* 12:235-238.
5. Lam MW, Klassen AF, Montgomery CJ et al. (2008) Quality-of-life outcomes after surgical correction of pectus excavatum: a comparison of the Ravitch and Nuss procedures. *Journal of Pediatric Surgery* 43:819-825.
6. Metzelder ML, Kuebler JF, Leonhardt J et al. (2007) Self and parental assessment after minimally invasive repair of pectus excavatum: lasting satisfaction after bar removal.[see comment]. *Annals of Thoracic Surgery* 83:1844-1849.
7. Nuss D. (2005) Recent experiences with minimally invasive pectus excavatum repair "Nuss procedure". *Japanese Journal of Thoracic & Cardiovascular Surgery* 53:338-344.
8. Castellani C, Schalamon J, Saxena AK et al. (2008) Early complications of the Nuss procedure for pectus excavatum: a prospective study. *Pediatric Surgery International* 24:659-666.
9. Bouchard S, Hong AR, Gilchrist BF et al. (2009) Catastrophic cardiac injuries encountered during the minimally invasive repair of pectus excavatum. *Seminars in Pediatric Surgery* 18:66-72.
10. Rushing GD, Goretsky MJ, Gustin T et al. (2007) When it is not an infection: metal allergy after the Nuss procedure for repair of pectus excavatum. *Journal of Pediatric Surgery* 42:93-97.
11. Shin S, Goretsky MJ, Kelly RE, Jr. et al. (2007) Infectious complications after the Nuss repair in a series of 863 patients. *Journal of Pediatric Surgery* 42:87-92.

12. Dzielicki J, Korlacki W, Janicka I et al. (2006) Difficulties and limitations in minimally invasive repair of pectus excavatum--6 years experiences with Nuss technique. *European Journal of Cardio-Thoracic Surgery* 30:801-804.

## Appendix A: Additional papers on placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

The following table outlines the studies (published since 2002) that are considered potentially relevant to the overview but were not included in the main data extraction table (table 2). It is by no means an exhaustive list of potentially relevant studies. Only studies with more than 50 patients or case reports of safety outcomes are included.

Article	Number of patients/follow-up	Direction of conclusions	Reasons for non-inclusion in table 2
Adam LA (2008) Erosion of the Nuss bar into the internal mammary artery 4 months after minimally invasive repair of pectus excavatum <i>Journal of Pediatric Surgery</i> 43 (2): 394–397	n = 1  4 months	Erosion of Nuss bar into the internal mammary artery	Larger studies included in table 2
Banever GT, S.H. (2003) The nuss procedure: Our experience from the first fifty Pediatric Endosurgery and Innovative Techniques 7 (3): 261–266	n = 50  Follow-up not stated	Two bars removed due to complications	Larger studies included in table 2
Barsness K, Bruny J, Janik JS, et al. (2005) Delayed near-fatal hemorrhage after Nuss bar displacement <i>Journal of Pediatric Surgery</i> 40 (11): e5–e6	n = 1  3 months	Near fatal haemorrhage	Larger studies included in table 2
Berberich T, Haecker FM, Kehrer B, et al. (2004) Postpericardiotomy syndrome after minimally invasive repair of pectus excavatum <i>Journal of Pediatric Surgery</i> 39 (11): e1–e3	n = 1  3 months	Bilateral pleural and pericardial effusion	Larger studies included in table 2
Bohosiewicz J, Kudela G, Koszutski T (2005) Results of Nuss procedures for the correction of pectus excavatum <i>European Journal of Pediatric Surgery</i> 15 (1): 6–10	n = 66  Follow-up not stated	Early results for pectus excavatum are good in most children.	Larger studies included in table 2
Boia ES (2004) The surgical treatment of pectus excavatum in children <i>Pediatric Endosurgery and Innovative Techniques</i> 8 (3): 254–259	n = 100  Follow-up not stated	Both procedures require re-evaluation with the goal of increasing surgical performance and a decrease in complications during and after surgery	Larger studies included in table 2  Mixture of interventions not all Nuss.
Brigato RR, Campos JR, Jatene	n = 20	Objective clinical	Larger studies included

FB et al. (2008) Pectus excavatum: evaluation of Nuss technique by objective methods. <i>Interactive Cardiovascular &amp; Thoracic Surgery</i> 7 (6): 1084–8	Follow-up not stated	methods are more sensitive or precise than the radiological ones by measuring the deformity in a direct manner external to the chest	in table 2
Cheng Y L, Lee SC, Huang T W et al. (2008) Efficacy and safety of modified bilateral thoracoscopy-assisted Nuss procedure in adult patients with pectus excavatum. <i>European Journal of Cardiothoracic Surgery</i> 34 (5): 1057–61	n = 96 Follow-up not stated	The modified bilateral thoracoscopy-assisted Nuss repair for adult patients could eliminate the risk of cardiopulmonary injuries	Larger studies included in table 2
Coln E, Carrasco J, Coln D (2006) Demonstrating relief of cardiac compression with the Nuss minimally invasive repair for pectus excavatum <i>Journal of Pediatric Surgery</i> 41 (4): 683–686	n = 123 Follow-up not stated	Patients with mitral valve prolapse require long-term follow-up.	Larger studies included in table 2  Atypical outcome assessment of cardiac compression
Croitoru DP, Goretsky MJ (2002) Experience and modification update for the minimally invasive Nuss technique for pectus excavatum repair in 303 patients <i>Journal of Pediatric Surgery</i> 37 (3): 437–445	n = 303 Follow-up not stated	Modifications to the procedure have reduced complications and long term results continue to be excellent	Studies with longer follow-up are included in table 2
Croitoru DP, Kelly RE, Jr., Goretsky MJ, et al. (2005) The minimally invasive Nuss technique for recurrent or failed pectus excavatum repair in 50 patients <i>Journal of Pediatric Surgery</i> 40 (1): 181–186	n = 50 Follow-up not stated	Complication rates were slightly higher than in primary repair	Larger studies included in table 2  Population with previous failed previous surgery
Fang FC, Cheng YL, Lee SC, et al. (2008) Clinical experience of Nuss procedure for pectus excavatum in adult female patients <i>Thoracic &amp; Cardiovascular Surgeon</i> 56 (5): 283–286	n = 126 Follow-up not stated	The procedure offers a high satisfaction rate and an acceptable complication rate	No efficacy data reported  Larger studies included in table 2
Fang FC, Cheng YL, Lee SC et al. (2008) Clinical experience of Nuss procedure for pectus excavatum in adult female patients. <i>Thoracic and Cardiovascular Surgeon</i> 56 (5): 283–6	n = 15 Follow-up not stated	The Nuss procedure offers a high satisfaction rate and an acceptable complication rate for PE repair in adult female patients	Larger studies included in table 2



Fonkalsrud EW (2002) Comparison of minimally invasive and modified ravitch pectus excavatum repair Journal of Pediatric Surgery 37 (3): 413–417	n = 68  Follow-up not stated	Both the Nuss procedure and modified Ravitch procedure provide excellent clinical results.	Studies with longer follow up are included in table 2  Larger studies included in table 2
Fox ME, Bensard DD, Roaten JB, et al. (2005) Positioning for the Nuss procedure: avoiding brachial plexus injury Paediatric Anaesthesia 15 (12): 1067– 1071	n = 95  Follow-up not stated	Patients are at risk of transient brachial plexus injury during the procedure	Larger studies included in table 2
Gips H, Zaitsev K, Hiss J (2008) Cardiac perforation by a pectus bar after surgical correction of pectus excavatum: case report and review of the literature Pediatric Surgery International 24 (5): 617–620	n = 1  Follow-up not stated	The procedure inadvertently culminated in perforation of the heart and lungs by the pectus bar with fatal result	Larger studies included in table 2
Hebra A (2002) Case report: Pectus carinatum as a sequela of minimally invasive pectus excavatum repair Pediatric Endosurgery and Innovative Techniques 6 (1): 41–44	n = 1  Follow-up 1 year	Careful postoperative follow up after Nuss procedure is recommended to identify patients at risk for development of a carinatum like deformity	Larger studies included in table 2
Hendrickson RJ, Bensard DD, Janik JS, et al. (2005) Efficacy of left thoracoscopy and blunt mediastinal dissection during the Nuss procedure for pectus excavatum Journal of Pediatric Surgery 40 (8): 1312–1314	n = 51  Follow-up not stated (to discharge)	2 large pneumothoraces requiring needle thoracenteses in the operating room	Larger studies included in table 2
Hoel TN, Rein KA, Svennevig JL (2006) A life-threatening complication of the Nuss procedure for pectus excavatum Annals of Thoracic Surgery 81 (1): 370–372	n = 1  Follow-up not stated	Cardiac tamponade on admission requiring needle aspiration of blood from the pericardium and bar removal	Larger studies included in table 2
Huang PM, Liu CM, Cheng YJ et al. (2008) Evaluation of intraoperative cardiovascular responses to closed repair for pectus excavatum. Thoracic and Cardiovascular Surgeon 56 (6): 353–8	n = 10  Follow-up 3 months	The data of this study supports the concept that closed repair directly contributes to hemodynamic improvement	Larger studies included in table 2
Hurme T, Savola J, Vilki V (2008) Minimally invasive repair for treating pectus excavatum – Early results. Scandinavian Journal of Surgery 97 (1): 63–70	n = 25  Follow-up not stated	MIRPE is a safe operation and gives a cosmetically good result. Thoracoscopy is needed during the operation	Larger studies included in table 2

Jo WM, Choi YH, Sohn YS, et al. (2003) Surgical treatment for pectus excavatum Journal of Korean Medical Science 18 (3): 360–364	n = 107  Follow-up not stated	Mean length of stay was 8 days and 5 patients required reoperation for bar displacement	Larger studies included in table 2
Kelly J, Shamberger RC (2007) Prospective Multicenter Study of Surgical Correction of Pectus Excavatum: Design, Perioperative Complications, Pain, and Baseline Pulmonary Function Facilitated by Internet-Based Data Collection Journal of the American College of Surgeons 205 (2): 205–21	n = 284  Follow-up not stated	Initial operative correction can be completed safely.	Studies with longer follow up are included in table 2
Kim dH, Hwang JJ, Lee MK, et al. (2005) Analysis of the Nuss procedure for pectus excavatum in different age groups Annals of Thoracic Surgery 80 (3): 1073–1077	n = 51  Follow-up not stated	The Nuss procedure is highly recommended in paediatric patients with pectus excavatum., but patient selection in adults is important.	Larger studies included in table 2
Kim HK, Choi YH, Cho YH, et al. (2007) A comparative study of pericostal and submuscular bar fixation technique in the Nuss procedure Journal of Korean Medical Science 22 (2): 254–257	n = 113  Follow-up not stated	Submuscular bar fixation results in a decrease in technique related complications	Comparison of two fixation techniques
Kosumi T, Yonekura T, Owari M, et al. (2005) Late-onset hemothorax after the Nuss procedure for funnel chest Pediatric Surgery International 21 (12): 1015–1017	n = 1  Follow-up not stated	Patients diagnosed with haemothorax on the 29th day of follow-up, managed conservatively	Larger studies included in table 2
Leonhardt J, Kubler JF, Feiter J, et al. (2005) Complications of the minimally invasive repair of pectus excavatum Journal of Pediatric Surgery 40 (11): e7–e9	n = 2  Follow-up not stated	Numerous operative and postoperative complications after Nuss procedure are feasible	Larger studies included in table 2
Metzelder ML, Ure BM, Leonhardt J, et al. (2007) Impact of concomitant thoracic interventions on feasibility of Nuss procedure Journal of Pediatric Surgery 42 (11): 1853–1859	n = 110  Follow-up not stated	The mixed procedure was feasible without intraoperative complications in all patients	Combined intervention not Nuss.
Morimoto K, Imai K, Yamada A, et al. (2008) Migration of a pectus bar into the ribs Journal of Plastic, Reconstructive & Aesthetic Surgery: JPRAS 61 (2): 225–227	n = 3  Follow-up not stated	Three different phases of bar migration into the ribs were noted	Larger studies included in table 2
Morimoto K, Imai K, Yamada A et al. (2008) Migration of a pectus bar into the ribs. Journal of Plastic, Reconstructive and	n = 3  Follow-up = 3	One case of ossification around pectus bar. One case of pectus bar migration into the ribs	Larger studies included in table 2

IP overview: placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

Aesthetic Surgery 61 (2): 225–7	years	and one case of ossification and migration to the ribs. All bars removed after 3 years.	
Muensterer OJ, Schenk DS, Praun M, et al. (2003) Postpericardiotomy syndrome after minimally invasive pectus excavatum repair unresponsive to nonsteroidal anti-inflammatory treatment European Journal of Pediatric Surgery 13 (3): 206–208	n = 1  Follow-up not stated	Postpericardiotomy syndrome treated with intravenous methylprednisolone. Pericardiocentesis was avoided	Larger studies included in table 2
Nakagawa Y, Uemura S, Nakaoka T, et al. (2008) Evaluation of the Nuss procedure using pre- and postoperative computed tomographic index Journal of Pediatric Surgery 43 (3): 518–521	n = 382  Follow-up not stated	Postoperative CT scan could provide objective evaluation of sterna elevation	Non clinical/proxy outcomes reported
Nath DS, Wells WJ, Reemtsen BL (2008) Mechanical occlusion of the inferior vena cava: an unusual complication after repair of pectus excavatum using the nuss procedure Annals of Thoracic Surgery 85 (5): 1796–1798	n = 1  Follow-up not stated	Acute occlusion of the inferior vena cava after a Nuss repair requiring bar removal	Larger studies included in table 2
Niedbala A, Adams M, Boswell WC, et al. (2003) Acquired thoracic scoliosis following minimally invasive repair of pectus excavatum American Surgeon 69 (6): 530–533	n = 2  Follow-up not stated	In both cases scoliosis slowly improved with physical therapy	Larger studies included in table 2
Nuss D (2005) Recent experiences with minimally invasive pectus excavatum repair 'Nuss procedure'. Japanese Journal of Thoracic & Cardiovascular Surgery 53: 338–44	n = 668  Follow-up 'at least 1 year'	Majority (78%) of patients reported positive cosmetic results. 57% had the bar removed.  10% bar displacement, Complications, 55% with pneumothorax (majority had spontaneous resolution).	Part of a larger study reported in table 2 (ref 2)
Obatake M (2005) Pectus excavatum repair: Review of 80 cases in 32 years Acta Medica Nagasakiensia 50 (3): 113–117	n = 16  Follow-up not stated	Mean hospital stay was 10 days	Larger studies included in table 2
Olbrecht VA, Abdullah F, Arnold MA, et al. (2008) Upper sternal depression following Lorenz bar repair of pectus excavatum Pediatric Surgery International 24 (7): 843–846	n = 8  Follow-up 24 months	Following a 2nd procedure no patient has experienced bar displacement or recurrence of sterna wall depression	Larger studies included in table 2
Olbrecht VA, Arnold MA, Nabaweesi R, et al. (2008)	n = 107	The procedure can be performed safely and	No efficacy outcomes

IP overview: placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

Lorenz Bar Repair of Pectus Excavatum in the Adult Population: Should it be Done? Annals of Thoracic Surgery 86 (2): 402–40	Follow-up not stated	effectively in adults	reported
Ong CC, Choo K, Morreau P, et al. (2005) The learning curve in learning the curve: a review of Nuss procedure in teenagers ANZ Journal of Surgery 75 (6): 421–424	n = 78  Follow-up not stated	The Nuss procedure gives good results even in teenagers	Larger studies included in table 2
Park HJ, Chung WJ, Lee IS, et al. (2008) Mechanism of bar displacement and corresponding bar fixation techniques in minimally invasive repair of pectus excavatum Journal of Pediatric Surgery 43 (1): 74–78	n = 725  Follow-up not stated	Mechanism-based bar fixation techniques seem to be effective in preventing bar displacement	Non clinical/proxy outcomes reported.
Park, H J. (2007) Technical innovations in the minimally invasive approach for treating pectus excavatum: A paradigm shift through six years' experience with 630 patients. Innovations: Technology and Techniques in Cardiothoracic and Vascular Surgery 2 (1) 25–28.	n = 630  Follow-up not stated	New techniques for Nuss procedure support that it is safe and efficacious in all morphological types of PE	Same patients are reported on in Park et al. 2008 in table 2.  The study objective is to assess technical differences between the original technique and a minor variation.
Paya K (2003) Asymmetric pectus carinatum as sequela of minimally invasive pectus excavatum repair Pediatric Endosurgery and Innovative Techniques 7 (3): 319–322	n = 1  Follow-up not stated	Asymmetric pectus carinatum resulting from fast growth during puberty	Larger studies included in table 2
Petersen C, Leonhardt J, Duderstadt M, et al. (2006) Minimally invasive repair of pectus excavatum – shifting the paradigm? European Journal of Pediatric Surgery 16 (2): 75–78	n = 84  Follow-up not stated	Complication rates are similar to other series and the decrease with the surgeon's experience	Larger studies included in table 2
Pilegaard HK, Licht, PB (2009) Can absorbable stabilizers be used routinely in the Nuss procedure? European Journal of Cardio-Thoracic Surgery 35 (4): 561–4	n = 507  Follow-up 6 weeks	Absorbable stabilisers may be used for minimal invasive surgery for pectus excavatum but they are more vulnerable and break easier than metal stabilisers	Studies with longer follow up are available in table 2 and absorbable stabilisers represent a significant modification of the technique

Pilegaard HK, Licht PB (2008) Routine use of minimally invasive surgery for pectus excavatum in adults.[see comment] Annals of Thoracic Surgery 86 (3): 952–956	n = 475  Follow-up not stated	Minimally invasive repair of pectus excavatum can be performed safely in adults.	Studies with longer follow-up are included in table 2
Raff GW, Wong MS (2008) Sternal plating to correct an unusual complication of the Nuss procedure: erosion of a pectus bar through the sternum Annals of Thoracic Surgery 85 (3): 1100–1101	n = 1  Follow-up 21 weeks	Factors that may have contributed to this complication include Marfan syndrome, older age at operation, and previous Ravitch procedure.	Larger studies included in table 2
Saitoh C (2002) Allergy to pectus bar for funnel chest [19] Plastic and Reconstructive Surgery 110 (2): 719–721	n = 1  3 months	Pleural effusion owing to bar allergy. Bar removed	Larger studies included in table 2
Saxena AK, Castellani C, Hollwarth ME (2007) Surgical aspects of thoracoscopy and efficacy of right thoracoscopy in minimally invasive repair of pectus excavatum Journal of Thoracic & Cardiovascular Surgery 133 (5): 1201–1205	n = 160  Follow-up not stated	Complications primarily relating to thoracoscopy were found in 16 patients.	Larger studies included in table 2
Schaarschmidt K, Kolberg-Schwerdt A, Lempe M, et al. (2005) Extrapleural, submuscular bars placed by bilateral thoracoscopy – a new improvement in modified Nuss funnel chest repair Journal of Pediatric Surgery 40 (9): 1407–1410	n = 57  Follow-up not stated	Extrapleural bar position is feasible in more than 90% of modified Nuss repairs	Larger studies included in table 2
Schwabegger AH, Jeschke J, Del Frari B (2008) A rounded dissector to reduce complications in the minimally invasive repair (Nuss) of pectus excavatum in adolescents and adults. Thoracic and Cardiovascular Surgeon 56 (2): 118–20	n = 21  Follow-up not stated	As a result of experiencing such complications in four cases, a new highly rigid dissector with a round cross-section was developed and its advantages are presented	Larger studies included in table 2
Swanson JW, Colombani PM (2008) Reactive pectus carinatum in patients treated for pectus excavatum Journal of Pediatric Surgery 43 (8): 1468–1473	n = 2  Follow-up not stated	Examination of the chest particularly in the first 6 postoperative months is paramount	Larger studies included in table 2
Torre M, Jasonni V, Asquasciati C et al. (2008) Absorbable stabilisation of the bar in minimally invasive repair of pectus excavatum. European Journal of Pediatric Surgery 18 (6): 407–9	Non Randomised Controlled Trial  n = 208  Follow-up not stated	LactoSorb stabiliser is safe and effective for stabilising the bar in pectus surgery	Larger studies included in table 2  Comparison of two techniques

Vegunta RK, Pacheco PE, Wallace LJ, et al. (2008) Complications associated with the Nuss procedure: continued evolution of the learning curve American Journal of Surgery 195 (3): 313–317	n = 7  Follow-up not stated	Seven complications described, the denominator number of patients treated is not described	Larger studies included in table 2
Yang MH, Cheng YL, Tsai CS, et al. (2008) Delayed cardiac tamponade after the nuss procedure for pectus excavatum: a case report and simple management Heart Surgery Forum 11 (2): E129–E131	n = 1  6 months	Delayed cardiac tamponade treated by pericardiocentesis and bar removal	Larger studies included in table 2
Zallen GS, Glick PL (2004) Miniature access pectus excavatum repair: Lessons we have learned Journal of Pediatric Surgery 39 (5): 685–689	n = 52  Follow-up not stated	Authors feel that the Nuss procedure is safer than the open technique	Larger studies included in table 2  No efficacy outcomes reported
Zeng Q, Lai JY, Wang XM et al. (2008) Costochondral changes in the chest wall after the Nuss procedure: ultrasonographic findings. Journal of Pediatric Surgery 43 (12): 2147–50	n = 95  Follow-up not stated	The Nuss procedure created significant stress and strain over the deformed cartilages	Larger studies included in table 2
Zganjer M, Zupancic B, Popovic L (2006) A 5-year experience of a minimally invasive technique for correction of pectus excavatum in Croatia Acta Medica (Hradec Kralove) 49 (2): 105–107	n = 75  3 months to 3 years	Pneumothorax in 12 patients and pneumonia in 6.	Larger studies included in table 2
Zoeller GK, Zallen GS, Glick PL (2005) Cardiopulmonary resuscitation in patients with a Nuss bar – a case report and review of the literature. [Review] [16 refs] Journal of Pediatric Surgery 40 (11): 1788–1791	n = 1  Follow-up not stated	Fatal cardiac event before bar removal. Paramedics felt they were unable to deliver effective cardiac compressions	Larger studies included in table 2

## Appendix B: Related NICE guidance for placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

Guidance	Recommendations
Interventional procedures	<p data-bbox="432 584 1107 651"><b>Minimally invasive placement of pectus bar. NICE interventional procedures guidance 3 (2003)</b></p> <p data-bbox="432 685 1262 1137">1.1 The evidence of the safety and efficacy of minimally invasive placement of pectus bar reviewed by the Interventional Procedures Advisory Committee was not adequate to support the use of this procedure without special arrangements for consent and for audit or research. Clinicians should ensure that the uncertainty about the procedure's safety and efficacy is understood by the parent or carer and where possible the child, and involve the child appropriately in arrangements for informed consent. The clinician should provide them with clear written information. Use of the information for the public, produced by NICE, is recommended. Clinicians should inform the clinical governance leads in their Trusts and ensure that appropriate arrangements are in place for clinical audit or research.</p> <p data-bbox="432 1144 1262 1301">1.2 All those who have the procedure should be entered, subject to their consent, onto the Registry maintained at the Wessex Regional Centre for Paediatric Surgery, Southampton General Hospital. The Registry's Surgical Co-Directors are Mr Robert Wheeler and Mr David Weeden.</p> <p data-bbox="432 1308 1254 1462">1.3 It is recommended that minimally invasive placement of pectus bar be referred to the Institute's Review Body, which should liaise with the Registry and prepare an analysis of its results for the Committee to consider. Further guidance will then be issued by the Institute.</p>

## Appendix C: Literature search for placement of pectus bar for pectus excavatum (also known as MIRPE or the Nuss procedure)

Database	Date searched	Version/files	No. retrieved
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	23/10/08	Issue 4, 2008	2
Database of Abstracts of Reviews of Effects – DARE (CRD website)	23/10/08	N/A	2
HTA database (CRD website)	23/10/08	N/A	2
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	23/10/08	Issue 4, 2008	6
MEDLINE (Ovid)	23/10/08	1950 to October Week 3 2008	34
MEDLINE In-Process (Ovid)	23/10/08	October 22, 2008	41
EMBASE (Ovid)	23/10/08	1980 to 2008 Week 42	42
CINAHL (Search 2.0, NLH)	23/10/08	1981 to present	13
Current Contents (CBIB)	21/10/08	1995 to date	17

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

1	Surgical Procedures, Minimally Invasive/ (9664)
2	(minimally adj3 invasive).tw. (16762)
3	Thoracic Surgical Procedures/ (2048)
4	Thoracoscopy/ (4588)
5	thoroscop\$.tw. (6269)
6	exp Endoscopy/ (189053)
7	endoscop\$.tw. (96382)
8	MIRPE.tw. (17)
9	Nuss.tw. (129)
10	(pectus adj3 bar\$.tw. (39)
11	or/1-10 (243756)



12	Funnel Chest/ (1280)
13	(chest adj3 (funnel or deform\$ or sunken)).tw. (1093)
14	pectus excavatum.tw. (927)
15	or/12-14 (2099)
16	11 and 15 (253)
17	Animals/ (4366113)
18	Humans/ (10754031)
19	17 not (17 and 18) (3277268)
20	16 not 19 (251)
21	200210\$.ed. (44532)
22	200211\$.ed. (40555)
23	200212\$.ed. (45692)
24	2003\$.ed. (872073)
25	2004\$.ed. (821080)
26	2005\$.ed. (618802)
27	2006\$.ed. (664823)
28	2007\$.ed. (795440)
29	2008\$.ed. (567412)
30	or/21-29 (4470409)
31	20 and 30 (178)
32	200802\$.ed. (58144)
33	200803\$.ed. (58071)
34	200804\$.ed. (61650)
35	200805\$.ed. (53212)
36	200806\$.ed. (55838)
37	200807\$.ed. (59646)
38	200808\$.ed. (58777)
39	200809\$.ed. (61584)
40	200810\$.ed. (26607)
41	or/32-40 (493529)
42	31 and 41 (34)