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Surgical interventions for treating pectus excavatum.
Cochrane Database of Systematic Reviews 2014, Issue 10. Art. No.: CD008889.
DOI: [10.1002/14651858.CD008889.pub2](https://doi.org/10.1002/14651858.CD008889.pub2).

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TABLE OF CONTENTS

HEADER	1
ABSTRACT	1
PLAIN LANGUAGE SUMMARY	2
BACKGROUND	3
OBJECTIVES	4
METHODS	4
RESULTS	6
Figure 1.	7
DISCUSSION	8
AUTHORS' CONCLUSIONS	8
ACKNOWLEDGEMENTS	8
REFERENCES	9
CHARACTERISTICS OF STUDIES	11
ADDITIONAL TABLES	12
APPENDICES	13
CONTRIBUTIONS OF AUTHORS	14
DECLARATIONS OF INTEREST	14
SOURCES OF SUPPORT	14
DIFFERENCES BETWEEN PROTOCOL AND REVIEW	14
INDEX TERMS	14

[Intervention Review]

Surgical interventions for treating pectus excavatum

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Editorial group: Cochrane Cystic Fibrosis and Genetic Disorders Group

Publication status and date: New, published in Issue 10, 2014.

Citation: de Oliveira Carvalho PE, da Silva MVM, Rodrigues OR, Cataneo AJM. Surgical interventions for treating pectus excavatum. *Cochrane Database of Systematic Reviews* 2014, Issue 10. Art. No.: CD008889. DOI: [10.1002/14651858.CD008889.pub2](https://doi.org/10.1002/14651858.CD008889.pub2).

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ABSTRACT

Background

Pectus excavatum is characterized by a depression of the anterior chest wall (sternum and lower costal cartilages) and is the most frequently occurring chest wall deformity. The prevalence ranges from 6.28 to 12 cases per 1000 around the world. Generally pectus excavatum is present at birth or is identified after a few weeks or months; however, sometimes it becomes evident only at puberty. The consequence of the condition on a individual's life is variable, some live a normal life and others have physical and psychological symptoms such as: precordial pain after exercises; impairments of pulmonary and cardiac function; shyness and social isolation. For many years, sub-perichondrial resection of the costal cartilages, with or without transverse cuneiform osteotomy of the sternum and placement of a substernal support, called conventional surgery, was the most accepted option for surgical repair of these patients. From 1997 a new surgical repair called, minimally invasive surgery, became available. This less invasive surgical option consists of the retrosternal placement of a curved metal bar, without resections of the costal cartilages or sternum osteotomy, and is performed by videothoracoscopy. However, many aspects that relate to the benefits and harms of both techniques have not been defined.

Objectives

To evaluate the effectiveness and safety of the conventional surgery compared with minimally invasive surgery for treating people with pectus excavatum.

Search methods

With the aim of increasing the sensitivity of the search strategy we used only terms related to the individual's condition (pectus excavatum); terms related to the interventions, outcomes and types of studies were not included. We searched the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, Embase, LILACS, and ICTPR. Additionally we searched yet reference lists of articles and conference proceedings. All searches were done without language restriction.

Date of the most recent searches: 14 January 2014.

Selection criteria

We considered randomized or quasi-randomized controlled trials that compared traditional surgery with minimally invasive surgery for treating pectus excavatum.

Data collection and analysis

Two review authors independently assessed the eligibility of the trials identified and agreed trial eligibility after a consensus meeting. The authors also assessed the risk of bias of the eligible trials.

Main results

Initially we located 4111 trials from the electronic searches and two further trials from other resources. All trials were added into reference management software and the duplicates were excluded, leaving 2517 studies. The titles and abstracts of these 2517 studies were independently analyzed by two authors and finally eight trials were selected for full text analysis, after which they were all excluded, as they did not fulfil the inclusion criteria.

Authors' conclusions

There is no evidence from randomized controlled trials to conclude what is the best surgical option to treat people with pectus excavatum.

PLAIN LANGUAGE SUMMARY

Surgical treatments for pectus excavatum

Pectus excavatum is characterized by a depression (sunken appearance) of the anterior (front) chest wall (sternum and lower costal cartilages); it is the most common chest wall defect. The frequency ranges from 6.28 to 12 cases per 1000 around the world. It is generally regarded as a genetic condition, based on the fact that it is usually present in several members of the same family and is often associated with other genetic diseases; however, its causes remain in debate. To what degree the disorder affects the individual's life is variable, some will live a normal life and others can have physical and psychological symptoms such as: precordial pain after exercises; problems with pulmonary and cardiac function; shyness and social isolation.

Many types of non-surgical treatments have been tried, among them there are physical and respiratory exercises and different methods or devices to put pressure on the elevated parts of the chest wall or do traction in the depressed parts. Despite these different options of conservative treatment, the widespread treatment is that of surgical correction. For many years the surgical correction was based on the resections of the deformed costal cartilages (which aim to extend the ribs forward and contribute to the elasticity of the walls of the thorax (area between abdomen and neck)) and the placement of a support behind of the externum to move it forward. Since 1997 a new surgical technique became available, the externum is displaced forward by the placement of a metal bar behind it, the bar is placed by video-assisted throat surgery and the costal cartilage is resected. However, there is a debate if one surgery is better (reach a better result with less complications) than the other. To clarify this question we performed a systematic review, but, no trials were eligible for inclusion. We conclude that, there is no evidence to decide what is the best surgical procedure to treat pectus excavatum.

BACKGROUND

Description of the condition

Pectus excavatum or funnel chest, is characterized by a depression of the sternum and the lower costal cartilages, the depression starts at the manubriosternal articulation and increases toward the xiphoid which is angulated forward and depressed until very close to the spine resulting in a funnel-shaped thorax (Head 1950). Often pectus excavatum has an asymmetric shape with the right side deeper than the left side, in such cases the sternum is rotated counter-clockwise (Ravitch 1977). The grade of depression can vary from small and almost imperceptible, to very large, which is the typical case. Many different indexes have been proposed for grading the depression, generally these indexes consider the distance between the sternum and the spine (Haller 1987; von der Oelsnitz 1981; Welch 1980). Despite many attempts to classify pectus excavatum in an objective manner, there are no universally accepted classifications (Welch 1989). Recently Lawson proposed a new classification based on the cross-sectional area of the thorax determined by computed tomography scans (Lawson 2006). The diagnosis of pectus excavatum is done by physical examination, noting the presence of the deformity, the subjective classification (mild, moderate, severe) and shape (symmetric or asymmetric) (Haller 1987; von der Oelsnitz 1981; Welch 1980). Currently, the Haller index is the most utilised index to quantify pectus excavatum and to indicate and evaluate the results of surgery (Haller 1987).

Pectus excavatum is the most frequently occurring chest wall deformity (Welch 1989). The prevalence of pectus excavatum in the UK has been reported to be 7.9 per 1000 individuals (Clark 1962); while in Turkey 7.68 cases per 1000 (considering pectus excavatum and carinatum) were reported in children from 6 to 15 years old (Yucesan 1993). Furthermore, in Manaus, Brazil, a prevalence of 12.75 cases per 1000 children (from 11 to 14 years old) has been reported (Westphal 2009).

Pectus excavatum is generally considered a congenital condition, based on the observation that it is usually present in several members of the same family and is frequently associated with other congenital diseases (Creswick 2006; Denk 1945; Welch 1989). In most cases it is present at birth or is noticed after few weeks or months (Ravitch 1977; Shamberger 1988); however, sometimes, in approximately 5% of cases, the pectus excavatum becomes evident only at puberty (Shamberger 1988). Despite the acceptance of its congenital nature, the etiology of the pectus excavatum remains in debate (Creswick 2006; Kotzot 2009; Nakaoka 2009; Shamberger 1995). Several theories have been postulated to explain it, such as:

1. diaphragmatic abnormalities such as: abnormal traction of the sternum proposed by Woillez in 1860 (Ravitch 1977); the presence of diaphragmatic substernal ligament (Brown 1939); a short central tendon (Lester 1957);
2. skeletal abnormalities: overgrowth of the sternum (proposed by Ebstein in 1882) (Denk 1945); of the ribs (proposed by Flesch in 1873) (Ravitch 1977); of the costal cartilages (Sanger 1963); and decreased biomechanical stability of the costal cartilages caused by a collagen disturbance (Feng 2001);
3. injuries in cartilaginous growth plates between the osseous segments of the growing sternum (Haje 1999).

Some people with pectus excavatum can live a normal life and others have physical and psychological symptoms. Clinically pectus

excavatum is well-tolerated in infancy, although older children may complain of pain in the area of the deformed cartilage or precordial pain after exercises (Shamberger 1995). Impairments of pulmonary function (Weg 1967) and cardiac function have been detected in young adults (Beiser 1972; Bevegard 1962; Haller 1970; Shamberger 1988). There are also several reports of psychological impairment such as shyness and social isolation (Ravitch 1977; Sutherland 1958).

The German doctor Wilhelm Ebstein nominate this condition as, "trichterbrust" (funnel chest), in the final of XIX century, since then diverse types of non-surgical treatments for pectus excavatum have been tried, among them there are: physical and respiratory exercises, different devices with the aim of exercising pressure under elevated parts or traction on the depressed (Denk 1945; Haje 1992; Haje 2009). Recently a new device to apply suction under the depressed parts have been proposed (Haecker 2006).

Description of the intervention

Since Meyer first attempted to correct pectus excavatum in 1911, conventional surgical techniques have changed considerably (Ravitch 1977). For several years now, with some small variations, the accepted principles for surgical correction of pectus excavatum have been:

1. sub-perichondrial resection of the costal cartilages to displace the sternum forward (Brown 1939);
2. transverse cuneiform osteotomy of the sternum to correct its concavity (Brown 1939) (for some patients this is not necessary);
3. the placement of a substernal support to stabilize the sternum in its new position. Different strategies have been proposed to achieve this objective, e.g. the placement of a bone (rib or tibia) (Dailey 1952), metal bar (Paltia 1959), or synthetic mesh (May 1961).

The minimally invasive surgery has been more recently introduced to correct pectus excavatum; this involves the placement of a curved metallic bar without any skeletal resection or sternum osteotomy (Nuss 1998). Since the first Nuss publication, this minimally invasive technique has become very popular and consists of the placement of a retrosternal curved metal bar, without skeletal resection and performed by videothoracoscopy (Nuss 1998).

How the intervention might work

The interventions should correct the deformity; improve quality of life, cardiac and pulmonary functions; be safe; and avoid recurrence.

Why it is important to do this review

Pectus excavatum is a disease that causes physical and psychological impairments. Treatment is invasive, painful, and expensive and can have long-term consequences. Many questions related to both procedures remain in debate like, impact in the quality of life, cardiac and pulmonary functions, acute and late postoperative complications. In the presence of this debate we proposed to conduct a systematic review of the literature comparing the results of conventional surgery with minimally invasive surgery in people with pectus excavatum considering safety and effectiveness.

OBJECTIVES

To evaluate the effectiveness and safety of conventional surgery as compared to minimally invasive surgery in people with pectus excavatum.

METHODS

Criteria for considering studies for this review

Types of studies

Prospective randomized or quasi-randomized trials.

Types of participants

People at any age with pectus excavatum undergoing surgical correction.

Types of interventions

Conventional surgery, that consist of sub-perichondrial resection of any costal cartilages with or without sternum osteotomy and, with or without placement of any kind of retrosternal support, compared with minimally invasive surgery, that consists of placement of a retrosternal curved metal bar without skeletal resection (any removal of costal cartilage or any kind of sternum osteotomy).

Types of outcome measures

Primary outcomes

1. Quality of life (QoL) - we considered QoL in its broader definition that encompasses overall QoL, symptoms and side effects that may or may not reflect or affect QoL. Data from either the patient or another person by proxy ([Fayers 2007](#))
 - a. the generic health-related quality of life questionnaires, the Child Health Questionnaire CHQ-CF87 (child version), and CHQ-PF50 (parent version)
 - b. Keith and Schallock's quality of life model ([Schallock 1989](#))
 - c. aesthetic appearance post-surgery (body image functioning attributable to pectus excavatum) ([Lawson 2003](#))
 - d. patient reported outcomes (PROs)
 - e. or any other validated questionnaire
2. Pulmonary function
 - a. maximum voluntary ventilation (MVV)
 - b. forced expiratory volume measured over one second (FEV₁)
 - c. vital capacity (VC)
 - d. forced vital capacity (FVC)
 - e. as otherwise assessed by the investigators
3. Cardiac function (we will consider the echocardiographic method, transthoracic or transesophageal)
 - a. left ventricular ejection fraction (LVEF)
 - b. right ventricular ejection fraction (RVEF)
 - c. left ventricular end-diastolic volume (LVEDV)
 - d. right ventricular end-diastolic volume (RVEDV)
 - e. as otherwise assessed by the investigators

Secondary outcomes

1. Exercise test
 - a. maximal oxygen consumption (VO₂max)
 - b. as otherwise assessed by the investigators

2. Recurrence - recurrence were analysed only after the first intervention (for surgical techniques that place an internal sub-sternal support for a limited time, the assessment of recurrence should be performed before and after the withdrawal of that support)
 - a. quantitative measure (Haller or other quantitative index assessed by investigators)
 - b. qualitative measure if it was assessed by investigators
3. Adverse effects related to the surgical procedures
 - a. intra-operative complications (myocardial, pericardial, pleural, pulmonary and diaphragmatic injuries, unexpected bleeding or pneumothorax)
 - b. post-operative complications (pericardial effusion, pleural effusion, pneumothorax, wound seroma, infection, bar migration)
 - c. late post-operative complications (aesthetic result, restrictive chest wall deformity, erosion of the sternum, vascular injury, cardiac injury, chronic chest pain, recurrence and allergy to the device, pulmonary or cardiac impairment)
 - d. any other unexpected adverse effect not stated here

We planned to analyse each parameter listed under each individual outcome separately.

Search methods for identification of studies

In the structure of the search strategy we considered only the health condition (funnel chest) ([Khan 2001](#)).

Electronic searches

The Cochrane Central Register of Controlled Trials (CENTRAL) was searched using exploded MeSH headings and keywords ([Appendix 1](#)). The following databases were also searched ([Appendix 1](#)).

1. [PubMed](#) (from 1940 to January 2014)
2. [Ovid Embase](#) from 1974 to January 2014
3. [Cochrane Central Register of Controlled Trials](#) (CENTRAL) Issue 6 of 12, June 2014
4. [LILACS](#) (Latin American and Caribbean Health Sciences) from 1980 to January 2014
5. [ICTRP International Clinical Trials Registry Platform](#) from 2007 to June 2014

There were no restrictions on the basis of date or language of publication, date of the last search:14 January 2014.

Searching other resources

The bibliographies of all retrieved and relevant publications identified by these strategies were searched for further studies and we contacted experts in the field.

Data collection and analysis

We traced references mentioning conventional surgery and minimally invasive surgery from articles identified and we planned to include those that met the pre-specified criteria, we documented the reasons for exclusion of any article from the selection process. Thereafter, we planned to assess studies fulfilling the inclusion criteria. We planned to independently review articles for inclusion before reconciliation of any discrepant selections.

Selection of studies

We selected studies as described in chapter 7 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2008a).

1. Merge search results using reference management software, and remove duplicate records of the same report.
2. Examine titles and abstracts to remove obviously irrelevant reports.
3. Retrieve full text of the potentially relevant reports.
4. Link together multiple reports of the same study.
5. Examine full-text reports for compliance of studies with eligibility criteria.
6. Correspond with investigators, where appropriate, to clarify study eligibility.
7. Make final decisions on study inclusion and proceed to data collection.

Two review authors (de Oliveira Carvalho PE and da Siva MVM) independently selected potentially eligible studies based on the screening of titles and abstracts. Full copies of potentially eligible studies were obtained. Two review authors (de Oliveira Carvalho PE and da Siva MVM), acting independently, decided on inclusion or exclusion, based on predefined inclusion and exclusion forms. Disagreements were resolved by discussion. If this didn't result in consensus, the third author's opinion was decisive. We documented the reasons for excluding any article from selection.

Data extraction and management

We planned to extract details of eligible studies and summarized them using a data extraction sheet specific to this review constructed according chapter 7 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2008a). This summary contain the baseline characteristics of the intervention and control group participants and include (where available) their number, age, gender, ethnicity, surgery type and main outcome measures, the length of the follow-up and numbers of dropouts (Table 1). Two review authors (de Oliveira Carvalho PE and da Siva MVM) were intended to independently extract all data regarding the interventions studied. Disagreements were planned to be solved by discussion, if this didn't result in consensus a third author's opinion would be decisive.

We planned to analyse each parameter listed under each individual outcome separately. In reference to time-periods to be reported, we planned to record when participants were analysed before the correction, and report data in the immediate post-operative period (until 30 days after the procedure) and in the late post-operative period (until three years after the procedure). When the internal support behind the sternum is removed, we planned to report data in the immediate period after (until 30 days) and for the later period (to one year after the removal). We will accept any variation in the technique of conventional surgery and all of them will be analysed in combination, if appropriate, we will separate them in subgroup analyses.

Assessment of risk of bias in included studies

Two authors (de Oliveira Carvalho PE and da Silva MVM) were designated to assessed each study independently. We planned to resolve any disagreements by consensus, or with consultation with a third party. We planned to calculate interrater agreement for key

bias indicators (e.g. allocation concealment, incomplete outcome data) using the kappa statistic (Cohen 1960). We planned to assess the quality of the studies and presented a summary of the risk of bias for each included study utilizing the Cochrane Collaboration's tool for assessing risk of bias (Higgins 2008b):

- was the allocation sequence adequately generated?;
- was the allocation adequately concealed?;
- was knowledge of the allocated intervention adequately prevented during the study?;
- were incomplete outcome data adequately addressed?;
- were reports of the study free of suggestion of selective outcome reporting?;
- was the study apparently free of other problems that could put it at a high risk of bias?

We planned to judge all domains as having either a low, unclear or high risk of bias and to generate a 'risk of bias graph' figure and 'risk of bias summary' figure.

Measures of treatment effect

We planned to express dichotomous data as risk ratios (RR); risk difference (RD) and the number needed to treat (NNT) with corresponding 95% confidence intervals (CI). For continuous data we planned to present differences in means with corresponding 95% CIs or standardized mean differences (MD) when the studies assess the same outcome but measure it in a variety of ways (e.g. different questionnaires for quality of life assessment).

Unit of analysis issues

Given the surgical nature of the interventions, we didn't consider cross-over trials to be a suitable trial design. Similarly, we didn't consider cluster randomized trials to be appropriate as there could be other factors at a particular trial site, e.g. the skill of the surgeon, which could affect outcome.

Dealing with missing data

We planned to obtain relevant missing data from authors, and carefully performed evaluation of important numerical data such as screened, randomized participants as well as intention-to-treat (ITT), as-treated and per protocol (PP) populations. We investigated attrition rates, for example dropouts, losses to follow up and withdrawals and critically appraised issues of missing data and imputation methods (e.g. last-observation-carried-forward (LOCF) (Higgins 2008c)).

Assessment of heterogeneity

We planned first assess statistical heterogeneity using the I^2 statistic which examines the percentage of total variation across studies due to heterogeneity rather than to chance (Higgins 2003). Values of I^2 under 40% indicate a low level of heterogeneity and justify use of a fixed-effect model for meta-analysis. Values of I^2 between 30% and 60% are considered moderate and a random-effects model can be used. Values of I^2 higher than 75% indicate a high level of heterogeneity; in this case meta-analysis is not appropriate. We will consider whether statistical, methodological and clinical heterogeneity are present (Deeks 2008).

Assessment of reporting biases

We planned to use funnel plots to assess for the potential existence of small study bias. There are numerous possible explanations for the asymmetry of a funnel plot (Sterne 2002) and we carefully interpreted results (Lau 2006). However, we recognised that if the number of eligible studies is small (less than 10) the results are likely to be inconclusive (Sterne 2008).

Data synthesis

In the absence of heterogeneity we planned to use a fixed-effect model for meta-analysis, if statistical heterogeneity is moderate, a random-effect model would be used (Deeks 2008). In the presence of substantial statistical heterogeneity between studies we planned to present a qualitative summary (O'Rourke 1989).

Subgroup analysis and investigation of heterogeneity

We planned the following subgroup analyses:

1. age (child, adolescent and adult);
2. sex;
3. conventional surgery with retrosternal bar compared with conventional surgery without retrosternal bar;
4. pectus excavatum classification (pectus severity index);
5. isolated pectus excavatum compared to pectus excavatum associated to other congenital disease.

Sensitivity analysis

We planned to perform sensitivity analyses (on primary outcomes only) in order to explore the influence of the following factors on effect size:

1. excluding unpublished studies;
2. taking account of risk of bias (excluding trials classified as high risk), as specified above;
3. excluding studies using the following filters: diagnostic criteria (e.g. clinician classification or Haller index); source of funding (industry versus other); country.

We also planned to test the robustness of the results by repeating the analysis using different measures of effect size (RR, odds ratio, etc.) and different statistical models (fixed-effect and random-effects models) (Deeks 2008).

RESULTS

Description of studies

We did not identify any randomized controlled trials comparing conventional surgery with minimally invasive surgery for people with pectus excavatum. After screening and reading the full text articles, we excluded all of them.

Results of the search

Following our search strategy, we initially identified 4111 potentially eligible trials and in an additional Google Internet search we identified a further two trials. We used reference management software to remove all duplicate references. After which, 2515 trials remained, these were evaluated by reading the title and abstract to find eligible trials, finally we selected eight trials for the full text analysis (Boehm 2004; Brigato 2006; Coelho 2009; Fox 2007; Kelly 2007; Nasr 2010; Pan 2009; ZENG Qi 2005) (Figure 1). However, none of the trials were eligible for inclusion.

Figure 1. Study flow diagram.

Included studies

There were no included trials.

Excluded studies

After the evaluation of the full text of the final potentially eligible eight identified trials, all trials were ultimately excluded. Three trials were prospective but they were not randomized ([Boehm 2004](#); [Coelho 2009](#); [Kelly 2007](#)); four trials compared the interventions analyzed in this review (conventional surgery with minimally invasive surgery) but they were retrospective and not randomized ([Brigato 2006](#); [Fox 2007](#); [Pan 2009](#); [ZENG Qi 2005](#)). The remaining Nasr study was a meta-analysis of retrospective studies ([Nasr 2010](#)).

Risk of bias in included studies

There were no included trials.

Effects of interventions

There were no included trials. Therefore, all planned analyses were not possible including subgroup analyses, sensitivity analyses and assessment of heterogeneity and reporting bias.

DISCUSSION

Summary of main results

We did not locate any prospective randomized controlled trials that could be included. Therefore, we cannot draw conclusions about the effectiveness and safety of conventional surgery compared with minimally invasive surgery for patients with pectus excavatum.

Overall completeness and applicability of evidence

Many questions related to pectus excavatum such as the etiology, pathophysiology, and the impact on cardiopulmonary function and QoL remain in debate. The clinical presentation of this condition is widely variable, some individuals with pectus excavatum experience normal life, independent of the condition, and others are very symptomatic. Surgical correction has been used for many years, this review looked at conventional surgery compared with minimally invasive surgery; however, no trials fulfilled the pre-specified inclusion criteria.

Quality of the evidence

There were no randomized controlled clinical trials eligible for inclusion.

Potential biases in the review process

We made every attempt to locate all trials comparing conventional surgical repair with minimally invasive surgical repair without language restriction, and we carefully followed each step of the protocol.

Agreements and disagreements with other studies or reviews

We did not locate trials that fulfilled the pre-specified eligibility criteria of this review. Consequently, we were not able to draw conclusions about our pre-specified primary and secondary outcomes; however, three non-randomized studies have concluded that surgery improves body image ([Coelho 2009](#); [Kelly 2007](#); [Pan 2009](#)). One review, with 19 included studies, concluded that surgery improves cardiopulmonary function ([Jayaramakrishnan 2013](#)) and another review, which included eight retrospective studies and one non-randomized prospective study concluded that the rate of re-operation, post-operative pneumothorax and hemothorax were higher with the Nuss procedure as compared to the conventional procedure ([Nasr 2010](#)).

AUTHORS' CONCLUSIONS

Implications for practice

Pectus excavatum is a prevalent condition with psychological and fiscal consequences for the affected individuals. For many years surgical repair has been the most widely used treatment option for people with this condition; however, surgery is invasive, painful and can lead to permanent sequels. There is currently no evidence from randomized controlled trials to help clinicians decide which is the better surgical intervention in relation to outcomes such as quality of life and cardiac and pulmonary function.

Implications for research

This review highlights the need for a adequately-powered prospective randomized controlled trial. The primary outcomes assessed should include quality of life and both cardiac and pulmonary function tests.

ACKNOWLEDGEMENTS

We would like to thank Tracey Remington, Nikki Jahnke and Natalie Hall from the Cochrane Cystic Fibrosis & Genetic Disorders Group.

Evidence Based Health Actions Group from the Marília Medical School (FAMEA-ASBE).

REFERENCES

References to studies excluded from this review

Boehm 2004 {published data only}

Boehm RA, Muensterer OJ, Till H. Comparing minimally invasive funnel chest repair versus the conventional technique: an outcome analysis in children. *Plastic & Reconstructive Surgery* 2004;**114**(3):668-73.

Brigato 2006 {published data only}

Brigato RB. Pectus excavatum: comparative evaluation of the surgical techniques of Robicsek and Nuss [Pectus excavatum: avaliação comparativa das técnicas operatórias de Robicsek e Nuss/]. <http://bases.bireme.br/cgi-bin/wxislind.exe/iah/online/?IscScript=iah/iah.xis&src=google&base=LILACS&lang=p&nextAction=lnk&expSearch=156015&indexSearch=ID> (accessed 24 October 2014):127p.

Coelho 2009 {published data only}

Coelho Mde S, Silva RF, Bergonse Neto N, Stori Wde S Jr, dos Santos AF, Mendes RG, et al. Pectus excavatum surgery: sternochondroplasty versus Nuss procedure. *Annals of Thoracic Surgery* 2009;**88**(6):1773-9.

Fox 2007 {published data only}

Fox JP, Schnell JL, Adams TA Jr, Hilton WM, Seyfer AE. Pectus excavatum: comparison of nonprosthetic repairs using multiple techniques. *Plastic and Reconstructive Surgery* 2007;**119**(3):33e-39e.

Kelly 2007 {published data only}

Kelly RE Jr, Cash TF, Shamberger RC, Mitchell KK, Mellins RB, Lawson ML, et al. Surgical repair of pectus excavatum markedly improves body image and perceived ability for physical activity: multicenter study. *Pediatrics* 2008;**122**(6):1218-22.

Kelly RE Jr, Mellins RB, Shamberger RC, Mitchell KK, Lawson ML, Oldham KT, et al. Multicenter study of pectus excavatum, final report: complications, static/exercise pulmonary function, and anatomic outcomes. *Journal of the American College of Surgeons* 2013;**217**(6):2080-9.

* Kelly RE Jr, Mellins RB, Shamberger RC, Mitchell KK, Lawson ML, Oldham KT, et al. 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* 2007;**205**(2):205-16.

Lawson ML, Mellins RB, Paulson JF, Shamberger RC, Oldham K, Azickhan RG, et al. Increasing severity of pectus excavatum is associated with reduced pulmonary function. *Journal of Pediatrics* 2011;**159**(2):256-61.

Nasr 2010 {published data only}

Nasr A, Fecteau A, Wales PW. Comparison of the Nuss and the Ravitch procedure for pectus excavatum repair: a meta-analysis. *Journal of Pediatric Surgery* 2010;**45**(5):880-6.

Pan 2009 {published data only}

PAN Zheng-xia, WU Chun, HE Ling, LI Hong-bo, Li Young-gang. Pectus excavatum: Nuss procedure vs modified Ravitch procedure. *Acta Academie Medicinae Militaris Tertiae* 2009;**31**(14):1378-80.

ZENG Qi 2005 {published data only}

Zeng Qi, Zhang Na, Fan Mǎo-huai, He Yan-ru. Comparisson of Nuss procedure and Ravitch procedure. *Chinese Journal of Pediatric Surgery* 2005;**26**(8):397-400.

Additional references

Beiser 1972

Beiser GD, Epstein SE, Stampfer M, Goldstein RE, Noland SP, Levitsky S. Impairment of cardiac function in patients with pectus excavatum, with improvement after operative correction. *New England Journal of Medicine* 1972;**287**(6):267-72.

Bevegard 1962

Bevegard S. Postural circulatory changes at rest and during exercise in patients with funnel chest, with special reference to factors affecting the stroke volume. *Acta Medica Scandinavica* 1962;**171**:695-713.

Brown 1939

Brown AL. Pectus excavatum (funnel chest). *Journal of Thoracic and Cardiovascular Surgery* 1939;**9**:164-84.

Clark 1962

Clark JG, Grenville-Mathers R. Pectus excavatum. *British Journal of Diseases of the Chest* 1962;**56**:202-5.

Cohen 1960

Cohen J. A coefficient of agreement for nominal scales. *Educational and Psychological Measurement* 1960;**20**:37-46.

Creswick 2006

Creswick HA, Stacey MW, Kelly RE Jr, Gustin T, Nuss D, Harvey H, et al. Family study of the inheritance of pectus excavatum. *Journal of Pediatric Surgery* 2006;**41**(10):1699-703.

Dailey 1952

Dailey JE. Repair of funnel chest using sub-sternal osteoperiosteal rib graft strut; report of a case with four year follow-up. *JAMA* 1954;**150**(12):1203-4.

Deeks 2008

Deeks JJ, Higgins JPT, Altman DG. Analysing data and undertaking meta-analyses. In: Higgins JPT, Green S editor(s). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.0.1. Cochrane Collaboration, 2008. [www.cochrane-handbook.org]

Denk 1945

Denk W, Kuns H. Cirugía [Cirugía]. In: M. Kirschner, O. Nordmann editor(s). Cirugía del thorax. Segunda. Vol. **Quinto**, Barcelona: Editorial Labor S. A., 1945:141-7.

Fayers 2007

Fayers PM, Machin D. Quality of Life: The assessment, analysis and interpretation of patient-reported outcomes. second edition. Chichester UK: John Wiley & Sons Ltd, 2007.

Feng 2001

Feng J, Hu T. The biomechanical, morphologic, and histochemical properties of the costal cartilages in children with pectus excavatum. *Journal of Pediatric Surgery* 2001;**36**(12):1770-6.

Haecker 2006

Haecker FM, Mayr J. The vacuum bell for treatment of pectus excavatum: an alternative to surgical correction? [The vacuum bell for treatment of pectus excavatum: an alternative to surgical correction?]. *Eur J Cardiothorac Surg*. 2006;**29**(4):557-61.

Haje 1992

Haje, SA, Bowen, JR. Preliminary results of orthotic treatment of pectus deformities in children and adolescents. *Journal of Pediatric Orthopaedics* 1992;**12**:795-800.

Haje 1999

Haje SA, Harcke HT, Bowen JR. Growth disturbance of the sternum and pectus deformities: imaging studies and clinical correlation. *Pediatric Radiology* 1999;**29**(5):334-41.

Haje 2009

Haje SA, Haje DP. Orthopaedic approach to pectus deformities: 32 years of studies [Abordagem ortopédica das deformidades pectus: 32 anos de estudos]. *Revista Brasileira de Ortopedia* 2009;**44**(3):191-8.

Haller 1970

Haller JA, Peters GM, Mazur D. Pectus excavatum. A 20 year surgical experience. *Journal of Thoracic and Cardiovascular Surgery* 1970;**60**(3):375-83.

Haller 1987

Haller JA Jr, Kramer SS, Lietman SA. Use of CT scans in selection of patients for pectus excavatum surgery: a preliminary report. *Journal of Pediatric Surgery* 1987;**22**(10):904-6.

Head 1950

Jerome R Head. A Textbook of Surgery. In: Frederick Christopher editor(s). The Thoracic Wall, Pleura and Lung. 5. Philadelphia: W B Saunders Company, 1950:842.

Higgins 2003

Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003;**327**(7414):557-60.

Higgins 2008a

Higgins JPT, Deeks JJ. Selecting studies and collecting data. In: Higgins JPT, Green S editor(s). Cochrane Handbook for

Systematic Reviews of Interventions. Chichester (UK): John Wiley & Sons, 2008:151-85.

Higgins 2008b

Higgins JPT, Altman DG. Assessing risk of bias in included studies. In: Higgins JPT, Green S editor(s). Cochrane Handbook for Systematic Reviews of Interventions. Chichester (UK): John Wiley & Sons, 2008:187-241.

Higgins 2008c

Higgins JPT, Deeks JJ, Altman DG. Chapter 16: Special Topics in statistics. In: Higgins JPT, Green S editor(s). Cochrane Handbook for Systematic Reviews of Interventions. Chichester (UK): John Wiley & Sons, 2008:481-529.

Jayaramakrishnan 2013

Jayaramakrishnan K, Wotton R, Bradley A, Naidu B. Does repair of pectus excavatum improve cardiopulmonary function?. *Interactive Cardiovascular and Thoracic Surgery* 2013;**16**(6):865-70.

Khan 2001

Khan KS, ter Riet G, Glanville J, Sowden AJ, Kleijnen J. Undertaking systematic reviews of research on effectiveness: CDR's guidance for those carrying out or commissioning reviews. CDR report Number 4. 2nd Edition. York: NHS Center for Reviews and Dissemination, University of York, 2001.

Kotzot 2009

Kotzot D, Schwabegger AH. Etiology of chest wall deformities-a genetic review for the treating physician. *Journal of Pediatric Surgery* 2009;**44**(10):2004-11.

Lau 2006

Lau J, Ioannidis JPA, Terrin N, Schmid CH, Olkin I. The case of the misleading funnel plot. *BMJ* 2006;**333**(7568):597-600.

Lawson 2003

Lawson ML, Cash TF, Akers R, Vasser E, Burke B, Tabangin M, et al. A pilot study of the impact of surgical repair on disease-specific quality of life among patients with pectus excavatum. *Journal of Pediatric Surgery* 2003;**38**(6):916-8.

Lawson 2006

Lawson ML, Barnes-Eley M, Burke BL, Mitchell K, Katz ME, Dory CL, et al. Reliability of a standardized protocol to calculate cross-sectional chest area and severity indices to evaluate pectus excavatum. *Journal of Pediatric Surgery* 2006;**41**(7):1219-25.

Lester 1957

Lester CW. The etiology and pathogenesis of funnel chest, pigeon breast, and related deformities of the anterior chest wall. *Journal of Thoracic Surgery* 1957;**34**(1):1-10.

May 1961

May AM. Operation for pectus excavatum using stainless steel wire mesh. *Journal of Thoracic and Cardiovascular Surgery* 1961;**42**:122-4.

Nakaoka 2009

Nakaoka T, Uemura S, Yano T, Nakagawa Y, Tanimoto T, Suehiro S. Does overgrowth of costal cartilage cause pectus excavatum? A study on the lengths of ribs and costal cartilages in asymmetric patients. *Journal of Pediatric Surgery* 2009;**44**(7):1333-6.

Nuss 1998

Nuss D, Kelly RE Jr, Croitoru DP, Katz ME. A 10-year review of a minimally invasive technique for the correction of pectus excavatum. *Journal of Pediatric Surgery* 1998;**33**(4):545-52.

O'Rourke 1989

O'Rourke K, Detsky AS. Meta-analysis in medical research; strong encouragement for higher quality in individual research efforts. *Journal of Clinical Epidemiology* 1989;**42**(10):1021-4.

Paltia 1959

Paltia V, Parkkulainen KV, Sulamaa M, Wallgren GR. Operative technique in funnel chest; experience in 81 cases. *Acta Chirurgica Scandinavica* 1959;**116**(2):90-8.

Ravitch 1977

Mark M. Ravitch. Congenital deformities of the chest wall and their operative correction. Philadelphia: W. B. Saunders Company, 1977.

Sanger 1963

Sanger PW, Taylor FH. Deformities of the anterior wall of the chest. *Surgery, Gynecology and Obstetrics* 1963;**116**:515-22.

Schalock 1989

Schalock RL, Keith KD, Hoffman K, Karan OC. Quality of life: its measurement and use. *Mental Retardation* 1989;**27**(1):25-31.

Shamberger 1988

Shamberger RC, Welch KJ. Cardiopulmonary function in pectus excavatum. *Surgery, Gynecology and Obstetrics* 1988;**166**(4):383-91.

Shamberger 1995

Robert C. Shamberger, W. Hardy Hendren III. Congenital deformities. In: F. Griffith Pearson, Jean Deslaurie, Robert J Ginsberg, Clement A. Hiebert, Martin F. McKneally, Harold C. Urschel editor(s). Thoracic Surgery. 1st Edition. New York: Churchill Livingstone, 1995:1189-97.

Sterne 2002

Sterne JA, Jüni P, Schulz KF, Altman DG, Bartlett C, Egger M. Statistical methods for assessing the influence of study characteristics on treatment effects in 'meta-epidemiological' research. *Statistics in Medicine* 2002;**21**(11):1513-24.

Sterne 2008

Sterne JAC, Egger M, Moher D. Chapter 10: Addressing reporting biases. Cochrane Handbook for Systematic Reviews of Interventions. Chichester: John Wiley & Sons, 2008:297-333.

Sutherland 1958

Sutherland ID. Funnel chest. *Journal of Bone and Joint Surgery. British Volume* 1958;**40-B**(2):244-51.

von der Oelsnitz 1981

von der Oelsnitz G. [Anomalies of the chest (author's transl)]. *Zeitschrift für Kinderchirurgie* 1981;**33**(3):229-36.

Weg 1967

Weg JG, Krumholz RA, Harkleroad LE. Pulmonary dysfunction in pectus excavatum. *American Review of Respiratory Disease* 1967;**95**(5):936-45.

Welch 1980

Welch KJ. Pediatric Surgery. In: T. M. Holder, K. W. Ashcraft editor(s). Chest wall deformities. Philadelphia: W. B. Saunders Company, 1980.

Welch 1989

Welch KJ, Shamberger RC. Chest wall deformities. In: Thomas W. Shields editor(s). General Thoracic Surgery. 3rd Edition. Philadelphia: Lea & Febiger, 1989:515-23.

Westphal 2009

Westphal FL, Lima LC, Lima Neto JC, Chaves AR, Santos Júnior VL, Ferreira BL. Prevalence of pectus carinatum and pectus excavatum in students in the city of Manaus, Brazil. *Jornal Brasileiro de Pneumologia* 2009;**35**(3):221-6.

Yucesan 1993

Yucesan S, Dindar H, Olcay I, Okur H, Kiliçaslan S, Ergoren Y, et al. Prevalence of congenital abnormalities in Turkish school children. *European Journal of Epidemiology* 1993;**9**(4):373-80.

* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
Boehm 2004	A prospective clinical trial but the interventions were chosen by the doctors considering the severity of the pectus excavatum.
Brigato 2006	A retrospective study of a series of cases that underwent different surgical techniques.

Surgical interventions for treating pectus excavatum (Review)

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Study	Reason for exclusion
Coelho 2009	A comparison of two series of cases.
Fox 2007	A retrospective study of a series of cases underwent to different surgical techniques.
Kelly 2007	A prospective clinical trial, not randomized, the choice of the intervention was done by discussion between the doctor, patients and their relatives.
Nasr 2010	Not a primary study, it is a review.
Pan 2009	An analysis of a series of cases that had included patients who underwent conventional surgical correction and patients who underwent minimally invasive repair.
ZENG Qi 2005	A retrospective analysis of a series of cases that had included patients who underwent conventional surgical correction and patients who underwent minimally invasive repair.

ADDITIONAL TABLES

Table 1. Data extraction form for characteristics of included studies *(Continued)*

Study identification	
Methods	<p>Study design:</p> <p>Method of randomization:</p> <p>Concealment of allocation:</p> <p>Blinded- No () Single () Double () Triple () Unclear ()</p> <p>Power calculation:</p> <p>Number of patients randomized:</p> <p>Number of patients analyzed:</p> <p>Number of patients excluded after randomization:</p> <p>Number of patients withdraws and reasons:</p> <p>Intention to treat analysis:</p>

Table 1. Data extraction form for characteristics of included studies *(Continued)*

Source of funding:		
Not stated () Industry () Other ()		
Description:		
Participants	Country: Location:	Number of centers:
	No:	Age: Sex:
	Inclusion criteria:	
	Exclusion criteria:	
	Pectus excavatum classification:	
	<ul style="list-style-type: none"> Pectus severity index () Haller index () Other () 	
	Description:	
	<ul style="list-style-type: none"> Subjective classification: 	
	symmetric, asymmetric, mild, moderate, severe	
	Description:	
Interventions	Minimally invasive repair:	
	conventional surgical repair:	
Outcomes	Primary outcome:	
	Secondary outcomes:	
Adverses effects		
Notes	Add any additional relevant information:	

APPENDICES

Appendix 1. Search strategies

[Cochrane Central Register of Controlled Trials](#) CENTRAL

"Funnel Chest" OR Funnel Chest OR Pectus Excavatum OR Funnel Breast OR Funnel Breasts OR Sunken Sternum OR Trichterbrust OR Cobbler's chest OR Sunken chest

PubMed

"Funnel Chest"[Mesh] OR Funnel Chest OR Pectus Excavatum OR Funnel Breast OR Funnel Breasts OR Sunken Sternum OR Trichterbrust OR Cobbler's chest OR Sunken chest

Ovid Embase

"Funnel Chest" OR Funnel Chest OR Pectus Excavatum OR Funnel Breast OR Funnel Breasts OR Sunken Sternum OR Trichterbrust OR Cobbler's chest OR Sunken chest

LILACS (Latin American and Caribbean Health Sciences)

"Funnel Chest" OR Funnel Chest OR Pectus Excavatum OR Funnel Breast OR Funnel Breasts OR Sunken Sternum OR Trichterbrust OR Cobbler's chest OR Sunken chest

ICTRP International Clinical Trials Registry Platform

"Funnel Chest" OR Funnel Chest OR Pectus Excavatum OR Funnel Breast OR Funnel Breasts OR Sunken Sternum OR Trichterbrust OR Cobbler's chest OR Sunken chest

CONTRIBUTIONS OF AUTHORS

Paulo Eduardo de Oliveira Carvalho: designing and coordinating the review, providing a methodological perspective, appraising quality of papers, assessing risk of bias in included studies, analysis of data, writing the protocol and review, will update the review.

Marcus Vinicius Muriano da Silva: undertaking searches, screening searches results, organizing retrieval of papers, screening retrieved papers against eligible criteria, appraising quality of papers, assessing risk of bias in included studies, extracting data from papers, writing to the authors of papers for additional information, providing additional data about papers, obtaining and screening data from unpublished studies, writing the review.

Olavo Ribeiro Rodrigues: providing a clinical perspective, analysis of data, writing the review.

Antonio José Maria Catâneo: providing a clinical perspective, analysis of data, writing the review.

DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- Evidence Based Health Actions Group from Marília Medical School - FAMEMA, Brazil.
- Botucatu Medical School from São Paulo State University UNESP, Brazil.

External sources

- No sources of support supplied

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

No

INDEX TERMS

Medical Subject Headings (MeSH)

*Thoracic Surgery, Video-Assisted [adverse effects]; Funnel Chest [*surgery]; Osteotomy [adverse effects] [*methods]; Randomized Controlled Trials as Topic

MeSH check words

Humans