

Peer Review File

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Review Comments

Reviewer A

Comment 1: The authors discussed the trends for NUSS procedure: 3D printing and implant customization, sternal elevation and chest wall remodeling, and implant fixation with bridges. As the authors point out, the most serious problem is cardiac impairment when an introducer passes between the sternum and pericardium. The authors review the methods for avoiding injury, for example, crane-technique, vacuum bell, and sternal lift. A new index may help decide the number of implant bars. Lateral bridges may be useful when pectus bars must be placed closely together. Finally, we believe this paper will be informative for readers and worthy of acceptance.

Reply 1: [We thank the Reviewer for his/her attentive comments.](#)

Reviewer B

Comment 1: Toselli and co-workers present a review of recent technical modifications that they consider a paradigm shift (lines 50-51) comparable to the paradigm shift caused by the introduction of the Nuss-procedure (line 46).

Neither does this reviewer agree with this assumption nor this he feel this comparison to be appropriate.

Reply 2: [We thank the Reviewer for his/her comment. We see that it might be an excess on our behalf. Certainly, the introduction of the Nuss procedure has changed the natural history of chest wall malformations uniquely. Our intention with this](#)

comment was to reinforce the importance of the numerous modifications done and proposed to the original technique that transformed it into a safer, easier, more effective, and less painful surgery.

We have removed this last remark and replaced it as follows: “In this article, we provide an in-depth discussion of the most relevant innovative concepts related to the treatment of chest wall malformations; including 3D printing and implant customization, compulsive sternal elevation, complete thoracic remodeling as a goal of repair, and implant fixation with bridges.”

Comment 2: Concerning the 3d-technology, the line of argument is not convincing. The authors cite very small studies and their own one. They fail to acknowledge the methodological shortcomings of the included studies that severely impede generalisability of their results. For example, reference 6 describes a propensity-score matching that is not reported at all (the standards described in DOI: <https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/s12874-020-00994-0>) and relies on chest x-rays for postoperative Haller indices. That is sloppy, albeit peer-reviewed, clinical science, but not a paradigm shift.

Reply 2: We appreciate the Reviewer’s comment. We appreciate his/her remarks on reference 6 and we added that the study design and that the Haller index was measured using x-rays in the postop period.

In general, we agree with the Reviewer that studies about the use of 3d technology lack generalizability. On one hand, the reader will require technology that, although it is becoming more affordable by the day, not everyone has access to it yet. On the other hand, it is difficult to find concrete, useful endpoints that might prove the utility of changing the current manufacturing processes. However, we believe that as technology advances faster every day, 3d technology will spread and more and better studies will be available.

Thus, we added a comment at the end of this section: “However, studies with objective, measurable endpoints and larger cohorts are still necessary to ascertain the benefits of the implementation of 3d technology in chest wall malformations.”

Comment 3: With regard to sternal elevation, the authors still sell their technique as the favourite one, raising criticism of the vacuum bell without providing evidence for their statements (lines 122-125). Moreover, the shortcomings of the crane technique, as raised by the group of Erik de Loos (DOI: 10.1016/j.xjtc.2021.05.028) are not mentioned at all.

Reply 3: We thank the Reviewer for this comment. As the Reviewer pointed out, at the end of this section we express our opinion and state it clearly (“In our own practice”). However, to better clarify that in this statement we are sharing our experience, we added it literally (“Alternatively, we believe that the vacuum bell might only be used as a second-best complementary choice since, in our experience, it can provoke subcutaneous emphysema and petechiae, and retraction lasts for a few minutes before it is necessary to apply suction again.”).

Regarding the reference provided, we appreciate the Reviewer for sharing it. We have read it with interest and find that the study is supportive of the probable utility of the crane and shows its feasibility clearly. We understand that the Reviewer might refer to the need to invest in a crane or the comment on being able to achieve less correction in more severe patients. In this last case, the authors didn’t attempt to duplicate sternal attachments or evaluated other attachment methods (Lewin clamp or the new screw form Primemed). We added this reference and these comments in this section in blue (“In 2021, de Loos et al. reported a quantitative analysis of the degree of superficial

correction achieved with a crane attached to the sternum by a wire suture in 30 patients undergoing MIRPE (1). They used an optical scanner to compare external pectus depth before and after sternal lifting and found that it decreased by 78% (IQR 63,100). Although they concluded that the technique might be effective in providing a safer retrosternal passage, they found less degree of correction in more severe cases. Further studies are warranted to determine whether a different attachment element such as the Lewin clamp or the new Screw developed by Dr. Park or the duplication of the attachment elements are effective in improving these findings.”).

Comment 4: The same is true for the complete chest wall remodelling section. As Dr. Nuss himself recently noted (DOI: 10.5090/jcs.23.034), half of the patients in the large Norfolk experience did not need more than one bar to sufficiently correct the deformity. This aspect is not addressed at all.

Reply 4: Thank you for this comment. Although we acknowledge the relevance of Dr. Nuss’ reference, it should be noted that he has also mentioned in recent meetings that his center is introducing two bars in most cases nowadays. Thus, the difficulty lies again in what is our current expectation in terms of chest wall remodeling: if a high percentage of the sternum is sunken, are we content with raising the lower end only? In punch or banana sternums, are we satisfied with putting one bar at the tip of the sternum with the risk of rotation it has or do we prefer crossed bars? As the mean age of patients undergoing repair is currently between 14 and 17 in most studies, should we expect the same degree of safety and effectiveness that we had when repairing prepubertal children with one bar? We believe not, and we feel this has been expressed in the manuscript.

However, indeed, it is still a matter of debate in our community and although this is a narrative review for which we were invited, all sides of the story should be represented to avoid conceptual bias. For these eye-opening remarks, we are grateful. Thus, we included the following comment at the end of this section: “All this being said, there is still debate in the community of chest wall specialists. As Dr. Nuss himself commented in a letter to the editor recently, further studies showing the benefits and safety of the use of multiple bars are warranted for this concept to gain wider popularity (1).”

Comment 5: This is also the case in the following section on implant fixation, the author's own, small, experience is put forward, but not the rather large cohort by the Park-group.

Reply 5: We thank the Reviewer for this remark and for providing this important reference for inclusion. Truly our own small experience is certainly shadowed by Dr. Park's impressive one. We included his reference and commented it: “In 2023, Dr. Kim reported a large cohort of cases with pectus excavatum and carinatum focusing on their stabilization system (2). They included 497 cases with the bridge technique, having adopted this approach over the hinge plate technique in all patients since 2022 in search of complete chest wall remodeling with zero rate of bar displacement.” We also came across a large study by Vinh et al. (3) comparing 560 cases undergoing bridge stabilizations to 1200 patients with other stabilization techniques, being bilateral stabilization the best approach in terms of bar dislocations.

Comment 6: Except for figures 1 and 5, the authors opted to use old, already published, ones to support their point.

Reply 6: Thank you. Although figure 2 was also unpublished previously, the idea behind requesting reprints is to reinforce the concept of this manuscript being a review, thus revisiting already published material. However, we changed figure 4 and resubmitted a new one.

Comment 7: As it has not escaped this reviewer's notice that the newest publications, except reference 2, are only from the authors' group whereas other newer works relevant for the points that they wanted to put forward, were not mentioned (for example, DOI: 10.5090/jcs.22.136).

Reply 7: Thank you for the reference. It has been included for the reader's benefit.

Comment 8: Therefore, it is unclear for this reviewer, what this review would add to the literature.

Reply 8: We have done our best to satisfy this Reviewer's insightful and detailed observations and we think they have certainly improved our original manuscript. We hope the Reviewer agrees with us and may consider it now acceptable for publication.

Reviewer C

Comment 1: This manuscript addresses the novel techniques and future developments in minimally invasive pectus repair. However, I believe that this article contains information that is already well-known and does not represent the latest surgical techniques. There are already many reports on preoperative simulations using 3D printers. It is very regrettable, but it will be rejected for the reasons mentioned above that.

Reply 1: We would like to thank the Reviewer for his/her time in reading our manuscript. We would like to point out that this is a narrative review for request, not an original article, and that we simply did our best to comply with the invited editors' proposed subject, thus revisiting publications on the latest trends in minimally invasive pectus repair.

Reviewer D

Comment 1: The author has devoted significant effort to provide a comprehensive and detailed review of the latest surgical techniques for correcting pectus excavatum. I believe this article deserves approval for several key reasons.

Completeness and Timeliness:

The article provides a thorough overview of the latest surgical techniques, demonstrating a deep commitment to research and staying updated on the most current information. The comprehensiveness of the work is crucial for an overall understanding of the available options for patients with pectus excavatum.

Clarity and Engaging Writing:

The clarity of presentation and the quality of writing are remarkable. Technical terminology is presented in an accessible manner, making the article suitable for a broad audience,

Clinical Relevance and Practical Applicability:

The author has demonstrated commendable attention to the clinical relevance of the presented techniques, providing detailed information on their practical point of view.

Reply 1: We are honored by this Reviewer's words and we sincerely hope we merit such praise for our work.

Reviewer E

Comment 1: The authors summarized the history of development for MIRPE, or so-called Nuss procedure. Although they followed the history, it merely presents papers of limited numbers of authors.

Reply 1: We thank the Reviewer for this comment. Although we approached this manuscript as a narrative review, not a metanalysis, we would be open to adding relevant references if the Reviewer would like to share them with us. We have already added a few that other Reviewer considered of importance (1,2,4). We hope this inclusions provide satisfaction for this Reviewer.

References:

1. de Loos ER, Daemen JHT, Coorens NA, Maessen JG, Vissers YLJ, Hulsewé KWE. Sternal elevation by the crane technique during pectus excavatum repair: A quantitative analysis. *JTCVS Tech.* 2021;9(C):167–75.
2. Heekyung Kim, M.D., Gongmin Rim, M.D., Hyung Joo Park, M.D. PDD. Technical Advancement of Pectus Bar Stabilization in Chest Wall Deformity Surgery: A 10-Year Trend and Appraisal with 1,500 Patients. *J Chest Surg.* 2023;56(4):238–9.
3. Vinh VH, Khanh HQ, Binh NH, Khoi N Van. Pectus excavatum repair using bridge fixation system. *Asian Cardiovasc Thorac Ann.* 2019;27(5):374–80.
4. Nuss D. Commentary: Technical Advancement of Pectus Bar Stabilization in Chest Wall Deformity Surgery: A 10-Year Trend and Appraisal with 1,500 Patients. *J Chest Surg.* 2023;56(4):238–9.
5. Alvarez-Garcia N, Ardigo L, Bellia-Munzon G, Martinez-Ferro M. Close Examination of the Bar Removal Procedure: The Surgeons' Voice. *Eur J Pediatr Surg.* 2018;28(5):406–12.

Comment 2: Furthermore, their choice of references is biased. For instance, they refer to Park's group as an innovator of total-chest wall remodeling, many other authors refer to this issue.

Reply 2: Thank you for this comment. If the Reviewer would shed some light on these other references, we would be open to inclusion. However, we would like to express that we aimed to illustrate new trends in MIRPE with the most paradigmatic references; we didn't do a metanalysis.

Comment 3: The authors emphasize the importance of multiple-bar fixation. But this reviewer emphasizes the usage of multiple bars—in particular when they are connected—restricts the movement of the thorax, making patients uncomfortable.

Reply 3: Thank you for this comment. In this point we might disagree with the Reviewer, that the benefits shown by the current evidence of multiple bar fixation outweigh their disadvantages with zero displacement rates allowing for a safe

disposition of the bars in any intercostal space or direction without fear of rotation (2). Also, it has not come to our attention evidence showing an increase in the discomfort rate of pectus patients undergoing different stabilization systems. We would be grateful for such information.

- Ref.: 1. de Loos ER, Daemen JHT, Coorens NA, Maessen JG, Vissers YLJ, Hulsewé KWE. Sternal elevation by the crane technique during pectus excavatum repair: A quantitative analysis. *JTCVS Tech.* 2021;9(C):167–75.
2. Heekyung Kim, M.D., Gongmin Rim, M.D., Hyung Joo Park, M.D. PDD. Technical Advancement of Pectus Bar Stabilization in Chest Wall Deformity Surgery: A 10-Year Trend and Appraisal with 1,500 Patients. *J Chest Surg.* 2023;56(4):238–9.
 3. Vinh VH, Khanh HQ, Binh NH, Khoi N Van. Pectus excavatum repair using bridge fixation system. *Asian Cardiovasc Thorac Ann.* 2019;27(5):374–80.
 4. Nuss D. Commentary: Technical Advancement of Pectus Bar Stabilization in Chest Wall Deformity Surgery: A 10-Year Trend and Appraisal with 1,500 Patients. *J Chest Surg.* 2023;56(4):238–9.
 5. Alvarez-Garcia N, Ardigo L, Bellia-Munzon G, Martinez-Ferro M. Close Examination of the Bar Removal Procedure: The Surgeons' Voice. *Eur J Pediatr Surg.* 2018;28(5):406–12.

Comment 4: In general, this author believes this review article isn't up to the bar to be published in GTD.

Reply 4: We regret our first manuscript wasn't up to the Reviewer's expectations. We hope the current explanations and further modifications might be grounds for him/her to change his/her mind.

Reviewer F

Comment 1: Line 52 lists new trends. It would be convenient if they came in the order in which they will be presented in the text. So 3D printing would come first, sternal elevation second, etc...

Reply 1: We thank the Reviewer for this comment. We have made the modifications mentioned.

Comment 2: In line 87 it is stated that the 3D printing approach facilitates the process and avoids the creation of scars forming scratches and notches on the implant...

The meaning was not clear. Is the authors' concerned with the surgical scar? Or with the formation of fibrosis/ossification that makes it difficult to remove the bars? Are these processes caused by irregularities resulting from the customization of the bars? It would be convenient to explain more clearly and cite references in this section.

Reply 2: Thank you for this observation. We aimed to explain how prebent customized bars avoid the need to manually bend the implant, thus, prevent the formation of the resultant notches and scratches produced by the bender. This might facilitate what the Reviewer perfectly explained as “formation of fibrosis/ossification that makes it difficult to remove the bars”, leading to a harder, less smooth bar removal process. In a survey performed to the CWIG members in 2016 on complications related to bar removal process (5), a 26.9% of the respondents reported bleeding due to severe adhesions in the bar tunnel. Although evidence linking ossifications and fibrous tissue formation when the bar has scratches is lacking, we believe we can safely associate bleeding and bar scratches as a result.

We added this reference and further explained this concept.

5. Alvarez-Garcia N, Ardigo L, Bellia-Munzon G, Martinez-Ferro M. Close Examination of the Bar Removal Procedure: The Surgeons' Voice. *Eur J Pediatr Surg.* 2018;28(5):406–12.

Comment 3: The subtitle of line 90 is sternal elevation. But in line 97 the authors describe "several strategies" to avoid injuries during dissection of the retrosternal tunnel.

Certainly, the Crane maneuver is the most recommended, but not all surgeons use it. I would like to suggest that the authors evaluate the possibility of including among the strategies that aim to avoid injuries the dissection of the retrosternal tunnel from the left to the right side, avoiding the use of the thoracic introducer (1).

Reply 3: We appreciate the reference; it has been included in the corresponding section.

Comment 4: In line 115, the authors mention the use of the vacuum bell and the Crane maneuver as similar maneuvers. This is not appropriate.

It should be noted that the vacuum bell's ability to elevate the sternum is very limited, whereas a properly performed Crane maneuver actually causes a very effective sternal elevation.

Reply 4: Thank you for this comment. As mentioned in the manuscript, we also think that the Crane is superior to the vacuum bell for sternal elevation for the reasons mentioned in the text. However, as shown in this same review process, not everybody agrees. Thus, this being a narrative review on the subject, although we express our point of view on the matter, we avoid taxative affirmations that haven't been demonstrated with randomized controlled trials or high-quality comparative studies between techniques.

Comment 5: In line 126 it would be convenient to improve the sentence about Notrica's statement, to make it clear that we are talking about Crane's maneuver.

Reply 5: We have clarified Dr. Notrica's sentence.

Comment 6: In line 170 it is written that the crossed bar technique must be performed with multiple implants... Perhaps the authors want to say that along with the 2 crossed bars it may be necessary to use one more upper bar, the so-called "XI" scheme. It would be convenient to exclude the term "multiple" bars and make the authors' intention clearer.

Reply 6: Thank you for this observation. We have made the modifications suggested in blue in the manuscript.

Comment 7: In line 191, the authors exemplify the advantages of bridges, giving as an example the possibility of introducing an implant into the second intercostal space!

Although I completely agree that the bridges represent a great advance for MIRPE, I suggest that it be explained that, as a rule, bars should not be implanted in the second intercostal space...

Reply 7: Thank you for this comment. Although we are aware that when using lateral traditional stabilizers it may be dangerous to introduce implants in the second intercostal space, half of our patients receive an implant in this space. Our experience of zero implant rotation with the bridge system provides us the confidence to do so. As this Reviewer brings this subject up, we can see how this can be a controversial new issue so we have modified this statement as follows: “These last three experiences might support the introduction of an implant as high as the second intercostal space without fear of bar rotation and compression of the great vessels or the airway in that area, improving the extent of remodeling in a cephalocaudal direction. However, further studies are warranted showing evidence that this technical aspect is safe and useful.”

Reference

1. Tedde ML, Togoro SY, Eisinger RS, Okumura EM, Fernandes A, Pêgo-Fernandes PM, Campos JRM. Back to the future: a case series of minimally invasive repair of pectus excavatum with regular instruments. *J Bras Pneumol.* 2019;45(1):e20170373. doi: 10.1590/1806-3713/e20170373.