Editorial

Pectus excavatum revision surgery: a complex challenge requiring centralization of expertise

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With increasing awareness of pectus excavatum among patients and healthcare providers, the demand for surgical correction and thus unfortunately also complex revision surgeries has surged (1). Although primary repairs often achieve the desired outcomes, revision procedures continue to be necessary and present significant challenges, carrying increased risks and complications (2,3). The recent study by Shawwaf and colleagues [2024] "Revision after prior failed pectus excavatum repair: higher risks and greater complications than primary surgery" underscores the need to optimize outcomes at the time of primary surgical correction (3). This editorial comments on the complexities of revision surgery, focusing on patient-specific factors and highlighting the essential role of specialized pectus centers in improving outcomes and minimizing complications.

Young versus adult patients

Age is a critical factor concerning complications and determines the surgical approach and expected outcomes for both primary and revision procedures (4). As the skeletal system matures with age the increased rigidity of the chest wall complicates the Nuss procedure, which relies on anterior chest wall flexibility (5). Despite these technical challenges, the Nuss procedure is increasingly performed in adult patients due to its less invasive nature compared to the modified Ravitch technique (6). Though the Nuss procedure has proven to be safe and feasible in this group, higher age *per se* seems to increase the general risk of complications and chronic pain (4). The patient cohort presented by Shawwaf *et al.*, with a relatively high median age of 33 years [standard deviation (SD) =10], consisted of 50% recurrent cases following minimally invasive repair of pectus excavatum (MIRPE). This underscores a paradigm shift from open repair towards MIRPE, reducing chronic pain or recurrence due to osteotomy non-union or malunion, which are common after open procedures (3,7,8). In contrast, although the less invasive character of MIRPE can be considered as an advantage, the altered biomechanical action and high reaction forces of the adult

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chest wall predispose to intercostal muscle stripping which can lead to chronic pain by nerve or rib pinching when bars migrate in the chest. The placement of at least two bars or a hybrid procedure to partially alleviate the high forces is advocated for addressing this cause of chronic pain in adult patients. Persistent postoperative pain often necessitates the consultation of a pain specialist or even early bar removal in this patient group.

Bar dislocations are also more likely in adults due to the increased rigidity of the anterior chest wall. However, dislocations are not significantly more reported in these patients, largely because the use of multiple bars helps mitigate the risk by distributing the forces more evenly (4). The literature confirms that multiple bars are commonly used in adults, with some studies reporting this practice in up to 70% of cases, while only 4% of young patients in our initial cohort required two bars (4,9,10). Recently, there has moreover been a clear trend towards using multiple bars in case of severe deformities, not just in adults, with two-bar techniques being more common than a three-bar or XI-bar configuration (11,12). In the study by Shawwaf *et al.*, 69% of revision cases involved patients who had originally received a single bar with severe deformities (mean Haller index of 4.4±1.8) overrepresented, likely contributing to the high revision rate (3). These complex cases might have benefited from multiple-bar techniques during the primary surgery. Conversely, the retrospective study by Skrzypczak *et al.* [2024], relying on propensity matching based on the Haller Index and age, reports a higher incidence of complications when two bars are used (13). However, since the Haller Index does not capture morphological features like steepness or asymmetry, this finding may reflect selection bias with patients with more severe deformities disproportionally assigned to the two-bar group. Adding to this discussion, Nuss D [2023], the pediatric surgeon who introduced the Nuss procedure that bears his name, recently shared his perspective on the placement of single versus multiple bars (14). He emphasizes that while many centers now routinely use two bars, alternative single-bar stabilization techniques, such as combining left-sided stabilizer placement with pericostal sutures on the contralateral side, can mitigate displacement risks in appropriately selected cases. This underscores the importance of patient-tailored surgical planning. While a multiple-bar approach remains critical for ensuring stability in patients with more severe deformities, weighing the risks of additional bar placement against the potential benefits in less complex cases is equally essential.

While pediatric patients, with their more flexible chest wall, are more responsive to correction, they may be at higher risk of recurrence when bars are removed prematurely or before sufficient maturity of the chest wall. Shawwaf *et al.* recommend bar removal after three years, a practical guideline echoed by other experts but based largely on clinical experience (3,15,16). Prolonging the bar´s presence to prevent recurrence carries risks, such as bar-related pain. The lack of substantial prospective comparative research on the optimal duration for leaving the Nuss bar in place across different age groups highlights the need for future investigation.

The importance of following current standards

The success of pectus excavatum surgical correction hinges on strict adherence to current standards and techniques (17). As previously emphasized, achieving optimal outcomes in the primary procedure is key to preventing recurrences and the subsequent need for revision surgeries. Recent insights highlight the importance of employing sternal elevation techniques to ensure proper bar placement and minimize complications such as major vessel injury and intercostal muscle stripping (18-20).

In revision procedures, identifying the cause of failure in the primary surgery is as essential as avoiding the repetition of mistakes during the revision. Critical factors include proper bar length, positioning (with optimal entry and exit points—i.e., not too lateral), fixation, and the number of bars. Techniques like medial stabilizer positioning, Hammock stitches or the bridge stabilization method proposed by Park *et al.* provide additional bar stability (8,11,21). Shawwaf *et al.* also presented an algorithm for the optimal redo approach, which varies according to the type of primary repair (3). Surgeons must account for altered anatomy, scar tissue and intrathoracic adhesions, and any underlying medical issues when performing revisions. While most patients undergo revision surgery due to recurrence or insufficient correction, a subset does so primarily for chronic pain. Although standardized criteria for indicating revision surgery for persisting postoperative pain are lacking, Shawwaf *et al.* report a drop in chronic pain from 53% preoperatively to 9% postoperatively (3). However, when pain is the dominant issue, referring patients to a specialized pain management team may be a safer first step as post-surgical improvement of the initial pain complaint is not guaranteed, especially in cases where no burdensome symptoms are present.

While Shawwaf *et al.*'s patient cohort focused on older patients, those operated on at a young age using an open technique may face unique challenges, such as developing acquired asphyxiating thoracic dystrophy (i.e., Jeune's syndrome), which complicates revision procedures (3). Further research is needed to determine the optimal timing for initial surgery, and consensus on a minimum age requirement could help prevent complications linked to operating too early. The article "*Pectus Excavatum*: *Consensus and Controversies in Clinical Practice*" addressed key issues in pectus excavatum care, including the minimum age for surgery, as the first step towards an international guideline for this patient population (22). In this study, 75% of participants agreed that patients should not be surgically treated before the age of 12 years old in straightforward cases. Although this study did not delve into the reasoning behind selecting this age criterium, this choice likely reflects concerns about minimizing the risk of recurrence or acquired asphyxiating thoracic dystrophy which are both crucial for achieving optimal outcomes in pectus excavatum correction.

The need for specialized care in multidisciplinary teams

Across many publications, there is consensus that pectus excavatum management requires a multidisciplinary approach involving preoperative assessments by surgeons, cardiologists, pulmonologists, and pediatricians, alongside psychological support and genetic counseling where connective tissue disorders are suspected (22-24). Additionally, both recommended diagnostic tools and thorough documentation—preferably with advanced 3D imaging—are essential for optimizing outcomes (17,22,24). Surgeons managing pectus excavatum patients must be skilled in all treatment options, including conservative approaches, to provide the full spectrum of care (24). Surgical interventions should be performed by experienced teams with particular expertise in advanced perioperative care, including techniques like intercostal nerve cryoablation (17). In line with NICE guidelines, teams must have experience in both cardiac and thoracic surgery to handle potential complications such as cardiac or pulmonary injury (23). Postoperative care should be delivered by a dedicated team, including pain management specialists and physiotherapists (22).

High-volume centers consistently demonstrate superior outcomes, particularly in reducing complication rates. While Dunning *et al.* recommend a minimum annual caseload of 20 surgical corrections, our research suggests that an optimal institutional volume of 73 procedures per year is associated with a plateauing complication rate (24,25). While this benchmark may not be achievable for all centers, it serves as an aspirational target for optimizing expertise and patient outcomes. Each country should interpret these findings in the context of its local healthcare infrastructure, resources, and case availability. Flexibility in applying such benchmarks is essential to ensure that specialized care is accessible and effective across diverse settings. Notably, Shawwaf *et al.* reported that 16% of their patients had undergone multiple previous surgeries to correct their deformity (3). However, it must be noted that the number of surgeons who should perform these 73 cases per institution is still to be guessed. Additionally, even in experienced hands, revision surgeries carry a higher risk of serious complications, morbidity, and mortality. This makes a compelling case for these complex procedures to be performed in specialized centers only with 24/7 access to experienced surgical teams and comprehensive facilities for managing complications (24).

Conclusions

Shawwaf *et al.* should be commended for their thorough analysis of a large cohort undergoing complex revision surgeries. Their findings underscore the critical need for centralization of revisional pectus excavatum care in specialized centers capable of delivering a multidisciplinary approach to managing these challenging cases. However, the most crucial takeaway is the imperative to optimize primary surgery by integrating the latest advancements to reduce the necessity for revisions. Ultimately, the complexity of pectus excavatum care highlights the urgent need for consensus statements and the development of international guidelines to ensure that patients consistently receive the highest standard of care.

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