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CARDIOPULMONARY OUTCOMES AND QUALITY OF LIFE POST-SURGERY IN PECTUS EXCAVATUM: A NARRATIVE REVIEW

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Abstract: INTRODUCTION Pectus excavatum is a congenital chest wall deformity with significant implications for cardiopulmonary function due to its compressive effects on the heart and lungs. The deformity, varying in severity, often leads to reduced cardiac output and compromised pulmonary capacity, resulting in exercise intolerance and fatigue. Surgical intervention is commonly indicated for patients with severe cardiopulmonary and psychological impacts, with the Nuss and Ravitch procedures as primary corrective methods. Diagnostic imaging, alongside cardiopulmonary assessments, guides the decision-making process, with both physiological and psychosocial improvements being anticipated outcomes of successful correction. **OBJETIVE** The primary objective of this review was to evaluate the impact of surgical correction of pectus excavatum on cardiopulmonary function and quality of life, focusing on outcomes across age groups and degrees of deformity severity. **METHODS** This is a narrative review which included studies in the MEDLINE – PubMed (National Library of Medicine, National Institutes of Health), COCHRANE, EMBASE and Google Scholar databases, using as descriptors"Pectus Excavatum" OR "Cardiopulmonary Function" OR "Surgical Correction" OR "Quality of Life" OR "Thoracic Deformities" in the last years. **RESULTS AND DISCUSSION** Surgical correction of pectus excavatum demonstrates significant improvements in cardiac and pulmonary function, notably in increased stroke volume, diastolic filling, and exercise capacity. Pulmonary outcomes reveal enhancements in lung volumes and efficiency, particularly in pediatric patients. Age at surgery influences recovery and peak functional improvement, with younger patients achieving more rapid and pronounced results. Quality of life and psychosocial health show notable gains post-surgery, including improved self-esteem and

social engagement. Although complications such as bar displacement and infection occur, they are generally manageable with proper preoperative planning and procedural precision, yielding high rates of patient satisfaction. **CONCLUSION** Pectus excavatum surgery substantially benefits patients with severe deformities, offering improvements in cardiopulmonary function and quality of life. Early intervention yields the best outcomes, with sustained gains in cardiac and respiratory performance and enhanced mental well-being. Despite the possibility of complications, careful patient selection and post-surgical support minimize risks. Advances in surgical approaches and rehabilitation strategies will continue to optimize outcomes for both pediatric and adult patients, establishing surgical correction as an effective intervention for addressing the multifaceted impacts of pectus excavatum.
Keywords: Cardiopulmonary outcomes; Pectus excavatum surgery; Quality of life improvement; Surgical correction of thoracic deformities; Pediatric and adult cardiopulmonary function.

INTRODUCTION

Pectus excavatum, a congenital deformity characterized by a sunken sternum, remains the most common anterior chest wall malformation. The deformity varies in severity and is generally assessed using indices such as the Haller Index, which quantifies the degree of sternal depression relative to the thoracic cavity width[1]. In cases where the Haller Index surpasses a critical threshold, surgical correction is often indicated, especially when associated with cardiopulmonary compromise[1]. The classification of pectus excavatum severity guides therapeutic decisions and underscores the clinical relevance of comprehensive preoperative assessments, as the condition ranges from mild cosmetic concerns to significant physiological impairment[2]. The anatomical implications of pectus excavatum are not limited to skeletal alterations; rather, the deformity often disrupts the structural integrity of the entire thoracic cavity, thereby compressing the underlying cardiac and pulmonary structures[2].

From an epidemiological perspective, pectus excavatum affects approximately one in every 300–400 live births, with a noted male predominance, further supporting a potential genetic predisposition[3]. The etiology remains multifactorial, involving both genetic and environmental components, though recent studies have identified associations with connective tissue disorders such as Marfan and Ehlers-Danlos syndromes[3]. Familial clustering and genetic linkage studies have highlighted the heritability of this deformity, with affected individuals often presenting at younger ages and with more severe manifestations[4]. While isolated cases of pectus excavatum are most common, the deformity also appears in syndromic contexts, suggesting a complex interplay of genetic factors[4].

The pathophysiological mechanisms underpinning cardiopulmonary impairment in pectus excavatum are largely attributable to the physical compression exerted on the heart and lungs[5]. The depressed sternum limits thoracic expansion during inspiration, thereby reducing pulmonary capacity and impeding effective ventilation, especially under exertion[5]. Furthermore, the compression of the right ventricle can compromise cardiac output, as the altered chest anatomy restricts diastolic filling[6]. This constraint on cardiovascular function may result in diminished exercise tolerance, chronic fatigue, and in severe cases, right-sided heart strain[6]. The physiological impact of these limitations underscores the need for surgical intervention in cases where cardiopulmonary function is demonstrably impaired[7].

Clinically, pectus excavatum presents with a spectrum of symptoms that reflect the degree of cardiopulmonary involvement, ranging from mild dyspnea to marked exercise intolerance and palpitations[7]. Adolescents and young adults with severe deformities frequently report limitations in physical activity, often accompanied by non-specific symptoms such as fatigue and chest pain[8]. These functional limitations are compounded by psychological distress, as the visible deformity contributes to social self-consciousness and, in some cases, depressive symptoms[8]. For individuals facing significant psychosocial burdens, surgical correction offers not only physical relief but also psychological benefits that improve quality of life[9].

The psychological impact of pectus excavatum cannot be underestimated, particularly in adolescents who may experience stigma and body image concerns[9]. Research has documented a strong correlation between pectus excavatum severity and psychosocial distress, with many affected individuals reporting feelings of embarrassment and social isolation[10]. Surgical correction has thus become a dual-purpose intervention, addressing both physiological and psychological domains[10]. Consequently, the assessment of surgical candidacy often includes considerations of mental health and quality of life, as these factors significantly influence postoperative satisfaction and long-term outcomes[11].

Diagnostic assessment of pectus excavatum is multifaceted, involving imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) to quantify the extent of sternal depression and evaluate adjacent structures[11]. Pulmonary function tests (PFTs) and echocardiography are also essential in evaluating the impact of the deformity on respiratory and cardiac function, respectively[12]. Advanced imaging modalities provide detailed anatomical insights, enabling clinicians to determine the potential benefits of surgical intervention and predict postoperative improvements in cardiopulmonary capacity[12]. The selection of imaging techniques is tailored to the individual, taking into account age, symptomatology, and specific clinical findings[13].

Indications for surgical repair of pectus excavatum extend beyond cosmetic concerns, particularly in cases where functional limitations are evident[13]. Key criteria include documented cardiopulmonary compromise, refractory symptoms, and psychological distress, with the aim of achieving both structural and functional correction[14]. The decision to proceed with surgery is often guided by a multidisciplinary evaluation, incorporating the perspectives of cardiologists, pulmonologists, and mental health professionals to ensure a holistic approach[14]. This multifaceted assessment is essential to optimize outcomes, as pectus excavatum surgery involves significant physiological restructuring that necessitates careful planning and coordination[15].

The primary surgical techniques for pectus excavatum correction include the Nuss and Ravitch procedures, each with distinct indications and approaches to sternal remodeling[15]. The Nuss procedure, a minimally invasive method, involves the insertion of a metal bar to elevate the sternum, whereas the Ravitch technique requires a more invasive approach, involving cartilage resection and sternal osteotomy[16]. Both techniques have demonstrated efficacy in restoring chest wall contour and alleviating cardiopulmonary symptoms, with the choice of procedure often influenced by patient age, deformity severity, and surgeon expertise[16]. Advances in surgical technology and postoperative care have further refined these procedures, enhancing their safety and effectiveness[17].

Historically, pectus excavatum surgery has evolved to address both structural and functio-

nal outcomes, with contemporary techniques achieving high rates of success in symptom relief and thoracic remodeling[17]. In particular, innovations in minimally invasive methods have reduced recovery times and minimized postoperative complications, making surgical correction a feasible option for a broader range of patients[18]. These advancements reflect a growing understanding of the anatomical and physiological intricacies associated with pectus excavatum, as well as a commitment to improving patient outcomes through refined surgical strategies[18]. In recent years, there has been increasing interest in the cardiopulmonary outcomes of pectus excavatum surgery, as evidence accumulates regarding the long--term benefits of sternal correction[19]. Studies have shown improvements in both cardiac function and pulmonary efficiency, particularly in patients with severe deformities who experience substantial relief postoperatively[19]. While research continues to elucidate the full spectrum of surgical outcomes, the current body of literature supports the role of pectus excavatum surgery as a transformative intervention with meaningful impacts on cardiopulmonary health[20].

OBJETIVES

The primary objective of this review was to evaluate the impact of surgical correction of pectus excavatum on cardiopulmonary function and quality of life, focusing on outcomes across age groups and degrees of deformity severity.

SECUNDARY OBJETIVES

1. To explore postoperative improvements in right and left ventricular performance and overall exercise tolerance.
2. To assess pulmonary function changes, including lung capacity and respiratory efficiency, following corrective surgery.
3. To analyze the influence of age at the time of surgery on short- and long-term cardiopulmonary and psychological outcomes.
4. To investigate postoperative complications, such as bar displacement and pneumothorax, and their management.
5. To evaluate the psychosocial benefits of pectus excavatum surgery on self-esteem, social interactions, and mental health.

METHODS

This is a narrative review, in which the main aspects of the impact of surgical correction of pectus excavatum on cardiopulmonary function and quality of life, focusing on outcomes across age groups and degrees of deformity severity in recent years were analyzed. The beginning of the study was carried out with theoretical training using the following databases: PubMed, sciELO and Medline, using as descriptors: "Pectus Excavatum" OR "Cardiopulmonary Function" OR "Surgical Correction" OR "Quality of Life" OR "Thoracic Deformities" in the last years. As it is a narrative review, this study does not have any risks.

Databases: This review included studies in the MEDLINE – PubMed (National Library of Medicine, National Institutes of Health), COCHRANE, EMBASE and Google Scholar databases.

The inclusion criteria applied in the analytical review were human intervention studies, experimental studies, cohort studies, case--control studies, cross-sectional studies and literature reviews, editorials, case reports, and poster presentations. Also, only studies writing in English and Portuguese were included.

RESULTS AND DISCUSSION

The impact of pectus excavatum on cardiac function, particularly in individuals with severe deformities, has been widely documented, illustrating how the chest wall's abnormal shape compresses the heart and reduces cardiac output[121]. Studies consistently show that the inward pressure on the right ventricle restricts diastolic filling, diminishing stroke volume and ultimately impairing systemic circulation under both resting and exertional conditions[21]. When surgical correction is undertaken, there is typically a marked improvement in right ventricular function and cardiac output, with postoperative evaluations indicating increased diastolic filling capacity and improved ventricular compliance[21]. Such outcomes are critical in young patients and athletes, where exercise intolerance due to pectus excavatum poses limitations on physical capacity and overall quality of life[22].

Right and left ventricular performance post-surgery demonstrates significant improvement, as both the Nuss and Ravitch procedures allow for increased thoracic space and alleviate the mechanical constraints on the heart[22]. Left ventricular function, while less commonly affected than the right, also shows improvement in severe cases where the deformity has influenced overall hemodynamic stability[23]. Studies utilizing echocardiography and cardiac MRI have highlighted these postoperative changes, which often translate into enhanced exercise tolerance and reduced symptoms of fatigue and dyspnea[23]. Importantly, the degree of cardiopulmonary improvement appears closely tied to the preoperative severity of the deformity, with patients exhibiting higher Haller Indices reporting the most substantial gains following surgical correction[24].

Pulmonary function tests conducted before and after surgical correction reveal a consistent pattern of improvement in vital capacity, forced expiratory volume, and total lung capacity, particularly in patients with moderate to severe deformities[24]. The compression of lung tissue and limited expansion capacity characteristic of pectus excavatum are significantly relieved postoperatively, allowing for enhanced pulmonary ventilation[25]. In the pediatric population, where lung tissue is more adaptable, the improvement is even more pronounced, leading to increased exercise performance and respiratory efficiency[25]. However, in older patients with long-standing deformities, the degree of improvement is often less, underscoring the importance of early intervention to maximize pulmonary recovery[26].

Age at the time of surgery is a critical factor influencing both immediate and long-term cardiopulmonary outcomes, with younger patients generally experiencing faster recovery and greater improvement[26]. Pediatric patients who undergo corrective surgery often demonstrate near-normal cardiopulmonary function in postoperative assessments, highlighting the benefits of addressing the deformity during formative years[27]. In contrast, adults tend to show reduced plasticity in chest wall mechanics, and while functional improvements are documented, the recovery trajectory is often slower, and peak outcomes may be more limited compared to younger counterparts[27]. The benefits of early surgical intervention extend beyond physiology, as psychological outcomes are similarly enhanced when pectus excavatum is addressed during childhood or adolescence[28].

Long-term cardiovascular outcomes post-surgery also reflect a reduction in arrhythmias and improvements in heart rhythm regularity, particularly in cases where preoperative cardiac monitoring identified ectopic activity associated with sternal compression[28]. These benefits extend into adulthood for pediatric patients, with follow-up studies indi-

cating a lasting impact on heart health and reduced risk of cardiopulmonary complications later in life[29]. Further, the expansion of chest wall compliance contributes to more effective cardiac mechanics, reducing the risk of long-term cardiac strain in cases of severe preoperative restriction[30]. Postoperative assessments of blood pressure regulation have also shown positive outcomes, with a notable reduction in cases of exercise-induced hypertension, a common finding in symptomatic individuals prior to surgical intervention[30].

The role of postoperative thoracic compliance and expanded pulmonary gas exchange capacity has been central to the observed improvements in exercise performance, as documented through VO_2 max testing and peak exercise testing[31]. Athletes and active individuals with severe deformities have reported substantial improvements in exercise tolerance following surgery, and these gains are corroborated by objective measurements of lung ventilation efficiency and oxygen uptake[31]. Such findings underscore the physiological significance of structural correction in enhancing both passive and active cardiopulmonary function[32]. Additionally, rehabilitation programs tailored to individual needs have been shown to optimize these benefits, with structured physical therapy facilitating lung expansion and aiding respiratory muscle strength recovery[32].

Patient quality of life and psychosocial outcomes have also shown marked improvements following surgical correction, addressing the mental health impacts of pectus excavatum that often accompany the physical symptoms[33]. Reports indicate that patients experience significant gains in self-esteem and social interactions, with a notable decrease in symptoms of social withdrawal and depression, particularly among adolescents[33]. Furthermore, quality of life surveys consistently reveal high postoperative satisfaction, largely due to the alleviation of symptoms and the improvement in body image post-correction[34]. These findings highlight the role of psychological well-being in the assessment of surgical outcomes, as the impact of the deformity extends beyond physiological constraints[34].

Postoperative complications remain a critical consideration, with the most common issues being bar displacement, infection, and, occasionally, pneumothorax in Nuss procedures[35]. While these complications can be managed effectively, their occurrence underscores the importance of patient selection and the consideration of individual anatomical and physiological factors in surgical planning[35]. Comparative studies between the Nuss and Ravitch procedures indicate that while minimally invasive approaches are associated with faster recovery, open techniques like Ravitch are often more effective in complex deformities that require extensive remodeling[36]. Despite these differences, both approaches are generally well-tolerated and associated with high rates of surgical success and low long-term complication rates[36].

For adult patients, particularly those undergoing minimally invasive procedures, the risk of recurrence and hardware-related complications necessitates careful long-term follow-up, as these individuals often have stiffer chest wall mechanics that can predispose them to re-deformity after hardware removal[37]. Advances in surgical techniques, such as custom-shaped implants and bioabsorbable supports, aim to reduce these risks and improve outcomes in adult populations[37]. Further, patient-reported outcomes post-surgery emphasize the importance of comfort and body image improvements, with many patients noting substantial benefits in physical appearance that contribute positively to their overall satisfaction and life quality[38].

The influence of age, severity of deformity, and psychosocial support on outcomes suggests that a comprehensive, individualized approach is essential for optimizing surgical success in pectus excavatum patients[38]. Tailored rehabilitation programs that focus on respiratory muscle function and gradual reconditioning are particularly beneficial for patients experiencing persistent limitations post-surgery[39]. Additionally, early identification of factors that could predict long-term success, such as preoperative functional status and baseline cardiopulmonary function, remains a focus of ongoing research[39]. Emerging evidence supports that patients with concurrent deformities, such as scoliosis, may require specialized approaches to address compounded structural constraints and achieve optimal functional recovery[40].

The current landscape of pectus excavatum surgery reflects a refined understanding of its impact on cardiopulmonary health, emphasizing that correction yields benefits not only in alleviating physical symptoms but also in enhancing mental and emotional well-being[40]. Non-surgical treatments are also being explored for mild cases, focusing on physical therapy and posture correction as methods to improve chest wall mechanics in patients without severe functional impairment[41]. Although these conservative treatments are less impactful than surgical intervention, they offer an alternative for patients with minimal symptoms or those contraindicated for surgery, expanding the scope of treatment options[41].

CONCLUSION

Pectus excavatum surgery offers substantial improvements in both cardiopulmonary function and quality of life for patients with severe deformities. The benefits of surgical intervention are particularly significant in younger patients, where early correction facilitates optimal functional recovery and minimizes long-term complications. Postoperative assessments demonstrate marked enhancements in cardiac output, respiratory capacity, and exercise tolerance, affirming the value of structural correction in restoring physiologic capacity. Psychological outcomes are equally noteworthy, as patients frequently report gains in self-esteem and social interactions, underscoring the holistic impact of surgical correction beyond the physical. Complications, while present, are generally manageable, with proper patient selection and procedural planning playing crucial roles in minimizing risks. For adults and those with complex deformities, the choice of surgical approach, coupled with tailored rehabilitation, further contributes to successful outcomes.

Future directions in pectus excavatum treatment may include enhanced surgical techniques and individualized rehabilitation protocols that maximize long-term benefits for both young and adult patients. Continued research into conservative management options for mild cases will also be valuable, providing a range of interventions that accommodate diverse clinical presentations and patient needs. Ultimately, pectus excavatum surgery stands as a transformative intervention that addresses the complex interplay of physical and psychological dimensions, offering patients a path to improved health and quality of life.

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