doi: 10.67071/3093-9038-2026-25-06-137-140

MODERN APPROACHES TO DIAGNOSIS AND SURGICAL CORRECTION OF CHEST WALL DEFORMITIES IN PEDIATRIC PRACTICE

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Abstract Background. Chest wall deformities in children represent a common pathology, including pectus excavatum, pectus carinatum, and their combined forms. Besides cosmetic defects, severe deformities can lead to functional disorders of the cardiopulmonary system and psychological problems significantly reducing patients› quality of life. In recent years, significant evolution has occurred in understanding the pathophysiological mechanisms, diagnostic approaches, and surgical correction methods for this pathology.

Objective. To optimize the diagnostic and treatment tactics for various types of chest wall deformities in children by developing a differentiated approach to selecting the surgical correction method considering anatomical, functional, and age characteristics to improve immediate and long-term treatment outcomes.

Materials and Methods: Results of examination and treatment of 215 patients aged 4 to 17 years with chest wall deformities who underwent surgical treatment from 2016 to 2023 were analyzed. The diagnostic algorithm included clinical examination, anthropometric measurements, index-based assessment of deformities, functional tests of respiratory and cardiovascular systems, and radiological diagnostic methods (chest radiography, computed tomography, magnetic resonance imaging). By deformity type, patients were distributed as follows: pectus excavatum – 164 (76.3%) children, pectus carinatum – 41 (19.1%), mixed forms – 10 (4.6%).

Results. Depending on the type and degree of deformation and patient age, various surgical correction methods were applied: minimally invasive Nuss procedure – in 148 (68.8%) patients; open thoracoplasty with resection of the costal-cartilaginous complex – in 27 (12.6%); modified Ravitch thoracoplasty – in 16 (7.4%); corrective thoracoplasty using compression-distraction systems – in 19 (8.8%); combined techniques – in 5 (2.3%). Intraoperative complications were observed in 12 (5.6%) patients, early postoperative complications – in 18 (8.4%). Among long-term results: excellent – 167 (77.7%), good – 34 (15.8%), satisfactory – 11 (5.1%), unsatisfactory with deformity recurrence – 3 (1.4%). Functional indicators of the respiratory system improved by an average of 15.6±3.8% in severe pectus excavatum. Subjective satisfaction with the cosmetic result was noted in 92.1% of patients.

Conclusion. The study demonstrates the effectiveness of a differentiated approach to selecting the surgical correction method for chest wall deformities in children. The developed diagnostic and treatment algorithm, based on objective criteria for assessing the type and degree of deformation, patient age, and functional disorders, allows optimizing the choice of surgical tactics and achieving high functional and aesthetic treatment outcomes.

Keywords: *chest wall deformities, pectus excavatum, pectus carinatum, Nuss procedure, minimally invasive thoracoplasty, children, Haller index, computer modeling.*

Relevance. Chest wall deformities are one of the most common pathologies of the musculoskeletal system in children, occurring with a frequency of 1:300-1:400 newborns, with a predominance of pectus excavatum (PE), which accounts for about 90% of all cases [1]. According to the World Health Organization, the incidence of various chest wall deformities in the general population ranges from 0.6 to 2.3%, with the ratio between boys and girls being approximately 4:1 [2]. Pectus carinatum (PC) is less common - in a ratio of 1:5 to PE, however, in recent years there has been a tendency towards an increase in the incidence of this pathology [3].

Chest wall deformities in children present not only an aesthetic problem but also a serious medical condition, as severe deformities can lead to significant functional impairment of the cardiopulmonary system. Patients with severe forms of PE experience a reduction in vital capacity to 20-30% of the predicted value, impaired respiratory mechanics, cardiac compression with the development of mitral valve prolapse, and abnormal heart rhythms and conduction [4]. In addition to physiological impairments, chest wall deformities have a significant psychological impact on children, especially during adolescence, leading to decreased self-esteem, social isolation, depression, and limited physical activity [5].

The etiopathogenesis of chest wall deformities remains a subject of debate. Modern research points to the multifactorial nature of this pathology with a genetic predisposition (up to 37% of pa-

tients have a family history of chest wall deformities), impaired growth and development of cartilage tissue, and connective tissue dysplasia [6]. The association with hereditary syndromes (Marfan, Ehlers-Danlos, Noonan, etc.) confirms the genetic nature of many cases of chest wall deformities [7].

The diagnosis of chest wall deformities has evolved significantly from simple visual assessment to sophisticated computer modeling and functional diagnostic methods. Modern methods allow not only to determine the type and severity of deformity but also to quantify its impact on cardiopulmonary function. The Gizycka index for PE and the symmetry index for CDH have become standardized tools for assessing the severity of deformity and indications for surgical correction [8].

Surgical treatment of chest wall deformities in children has also undergone significant development – from traumatic open procedures with costal cartilage resection (the Ravitch procedure) to minimally invasive techniques using metal fixators (the Nuss technique for PE) and compression-distraction systems for CDH [9]. Despite significant progress, the optimal age for correction, the surgical technique depending on the type and severity of deformity, and the prevention of complications and recurrence remain controversial [10].

Of particular relevance is the development of a personalized approach to surgical correction using computer modeling and 3D printing of individual implants. Such technologies improve the accuracy of correction, reduce the risk of complications, and achieve optimal functional and aesthetic results [11]. Thus, despite significant progress in understanding the pathophysiology and development of surgical techniques for correcting chest deformities, many aspects of this problem remain insufficiently studied, which necessitates the development of a differentiated approach to the diagnosis and treatment of various forms of pathology to improve the outcomes and quality of life of patients.

Purpose of the study: optimization of treatment and diagnostic tactics for various types of chest deformities in children by developing a differentiated approach to the choice of surgical correction method, taking into account anatomical, functional and age-related characteristics to improve immediate and long-term treatment results.

Materials and methods. A retrospective and prospective analysis of the examination and treatment results of 215 patients aged 4 to 17 years with chest deformities who underwent surgical treatment between 2016 and 2023 was conducted. Inclusion criteria: the presence of chest deformity of grades II–III, age from 4 to 17 years, informed consent of parents or legal representatives for inclusion in the study.

Patient age distribution: 4-7 years – 23 (10.7%), 8–12 years – 94 (43.7%), 13–17 years – 98 (45.6%). Boys predominated among the examined children – 174 (80.9%) patients. The distribution of chest wall deformity type was as follows: pectus excavatum (PC) – 164 (76.3%) children, carinatum carinatum (PC) – 41 (19.1%), and mixed forms – 10 (4.6%).

The diagnostic algorithm included the following methods:

Clinical examination with anthropometric measurements and photo documentation.

Calculation of index indicators: Gizhitskaya index for VCHD (ratio of minimum anterior-posterior size of the chest to transverse), correction index for KDGK (ratio of maximum anterior-posterior size to transverse).

Functional studies: spirometry, electrocardiography, echocardiography, exercise stress test.

Diagnostic imaging methods: chest X-ray in two projections, computed tomography with 3D reconstruction in 187 (87.0%) patients, magnetic resonance imaging in 28 (13.0%) patients with suspected compression of internal organs.

According to the severity of the deformation, the patients were distributed as follows: grade I (Gizytskaya index>0.7) – 19 (8.8%) children, grade II (Gizytskaya index 0.5-0.7) – 118 (54.9%), grade III (Gizytskaya index <0.5) – 78 (36.3%).

Functional disorders of the cardiorespiratory system were detected in 143 (66.5%) patients: a decrease in vital capacity of the lungs (VC) by 10-15% in 67 (31.2%) children, by 16-25% in 51 (23.7%), more than 25% in 25 (11.6%); cardiac disorders (mitral valve prolapse, rhythm and conduction disorders) in 78 (36.3%) patients.

Indications for surgical correction were determined based on a comprehensive assessment of the degree of deformation (Gizytskaya index <0.7 for PVDGK, pronounced asymmetry for KDGK), the presence of functional disorders of the cardiorespiratory system, psycho-emotional problems and aesthetic indications.

Results. Depending on the type, degree of deformation and age of the patient, various methods of surgical correction were used:

1. Minimally invasive thoracoplasty according to Nuss – in 148 patients (68.8%) with PE;

2. Open thoracoplasty with resection of the costochondral complex – in 27 patients (12.6%) with severe asymmetric deformity;

3. Modified thoracoplasty according to Ravitch – in 16 patients (7.4%) with recurrent and complex forms of PE;

4. Corrective thoracoplasty using compression-distraction systems – in 19 patients (8.8%) with CDH;

5. Combined techniques – in 5 patients (2.3%) with mixed forms of deformity.

Preoperative planning included computer modeling of correction in 93 (43.3%) patients, which allowed for an individualized approach to selecting the size and shape of fixation elements, especially for asymmetric and complex deformities.

The following criteria were taken into account when analyzing surgical results: intraoperative and postoperative complications, the degree of deformity correction based on index parameters, the dynamics of functional parameters, the patient's subjective assessment of the cosmetic result, and the duration of the rehabilitation period.

Intraoperative complications were noted in 12 (5.6%) patients: pneumothorax – 7 (3.3%) cases, intercostal vessel damage – 3 (1.4%), pericardial perforation – 1 (0.5%), and hemopericardium – 1 (0.5%). Early postoperative complications were registered in 18 (8.4%) patients: seroma – 7 (3.3%), hemothorax – 3 (1.4%), migration of the fixing plate – 2 (0.9%), postoperative pneumonia – 4 (1.9%), wound infection – 2 (0.9%).

The average hospital stay was 7.2 ± 2.3 days for minimally invasive procedures and 12.5 ± 3.1 days for open procedures. The duration of postoperative analgesia was 3.8 ± 1.2 days for the Nuss procedure and 5.2 ± 1.6 days for open procedures.

Long-term results were monitored in 201 patients (93.5%) over periods ranging from 1 to 7 years. Recurrence of deformity was noted in 3 patients (1.4%), requiring repeat surgical correction. Overcorrection was observed in 4 patients (1.9%) using the minimally invasive Nuss technique. Removal of fixing elements was performed 2 to 3 years after the initial surgery in 164 patients (76.3%).

According to the space and functional results of treatment, patients were distributed as follows: excellent results - 167 (77.7%), good - 34 (15.8%), satisfactory - 11 (5.1%), unsatisfactory - 3 (1.4%).

Respiratory function improved by an average of 15.6±3.8% in severe PE. Normalization of electrocardiographic parameters was noted in 63 (80.8%) of 78 patients with baseline impairments. Subjective satisfaction with the cosmetic result was noted in 92.1% of patients.

An analysis of the results showed that minimally invasive thoracoplasty according to Nuss is most effective for uncomplicated symmetrical grades II-III pelvic deformities in children over 8 years of age. For severe asymmetric deformities, recurrences, and combined forms, open procedures remain optimal, allowing for more precise correction. With CDH, the best results were achieved using compression-distraction systems with individualized modeling.

Conclusion. The study demonstrates the effectiveness of a differentiated approach to selecting a surgical correction method for chest wall deformities in children. The developed diagnostic and treatment algorithm, based on objective criteria for assessing the type and severity of deformity, patient age, and functional impairment, allows for the optimization of surgical tactics and the achievement of high functional and aesthetic treatment outcomes.

Table 1. Comparative characteristics of the results of various methods of surgical correction

Indicator	Nuss operation (n=148)	Open thoracoplasty (n=27)	Operation Ravich (n=16)	Compression-distraction systems (n=19)	Combined methods (n=5)
Intraoperative complications (%)	4,7	7,4	12,5	5,3	0
Early postoperative complications (%)	8,1	11,1	12,5	5,3	0
Average length of hospital stay (days)	6,8±1,9	13,2±2,8	14,1±3,2	7,6±2,1	10,2±2,4
Good cosmetic result (%)	94,6	81,5	75,0	89,5	80,0
Functional improvement (%)	87,2	74,1	68,8	73,7	80,0
Relapses (%)	0,7	3,7	0	5,3	0

Minimally invasive thoracoplasty techniques are optimal for most patients with PE, providing good cosmetic results with less trauma and shorter hospitalization and rehabilitation periods. However, for complex asymmetric deformities, recurrences, and mixed forms, open procedures with costochondral resection remain relevant, allowing for more precise correction.

Preoperative computer modeling significantly improves the effectiveness of surgical interventions, especially for complex deformities, allowing for a more personalized approach and reducing the risk of complications. The introduction of 3D technologies and the production of custom-made fixation elements represents a promising direction for the further development of surgical correction of chest wall deformities.

Early detection and timely correction of functionally significant chest wall deformities in children helps prevent the development of serious cardiorespiratory disorders and psychological problems, significantly improving patients' quality of life. The optimal age for surgical correction of severe deformities is 8-14 years, when the chest retains sufficient flexibility and the risk of recurrence is minimal.

Further improvements in diagnostic methods and surgical treatment of chest wall deformities, the development of new biocompatible materials for fixation elements, and the advancement of minimally invasive technologies will contribute to further improvements in the treatment of this pathology in children.

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