OPERATIVE CORRECTION OFPECTUS EXCAVATUM
DEFORMITY IN CHILDREN BY THE ELASTICITY CRITERIA
OF THE STERNOCOSTAL COMPLEX

This report presents the results of the operative correction of the pectus excavatum deformity in 54 children aged from 5 to 15 years. In relation to the elasticity degree and age of the patient there was performed of the pectus excavatum deformity by method of D. Nuss in modification with application of a metal plate of the own construction. At normal elasticity (degree 1) of the anterior sternocostal complex in 27 (50.0%) patients is executed operative intervention by method of D. Nuss, with good result in 26 (96.3%) and satisfactory in 1 (3.7%) patient. At moderate degree of elasticity (II-degree) in 15 (27.8%) patients there was performed procedure of D. Nuss in modification of our clinic. The correction of the pectus excavatum deformity was carried out by chondrotomy of the deformed ribs and placement of the metal plate under the sternocostal complex. The good results were noted in 13 (86.7%) patients, satisfactory - in 2 (13.3%). At the hypoplastic sternocostal complex (degree III) the deformation was removed by "T"-shaped or cross sternotomy with chondroresection of some ribs and then placement of the metal plate of D. Nuss under sternocostal complex. The good results were found in 9 (75%), satisfactory in 1 (8.3%) and unsatisfactory in 2 (16.7%) patients. Thus, the less elasticity of the sternocostal complex and older age of child, there is more traumatic operative intervention and worse long-term results of treatment.

Keywords: Children, thorax, pectus excavatum deformity, elasticity, thoracoplasty

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Introduction

The deformation of the thorax has various forms, the overwhelming majority of them is the pectus excavatum (90%) and keeled chest (8%) deformity (Abdrahmanov, Tazhin, Anashev, 2010; Urmonas and Kondrashin, 1983). The prevalence of the pectus excavatum deformity according to the various authors fluctuates from 0.06 up to 2.3% (Urmonas and Kondrashin, 1983). The treatment of children and adolescents with pectus excavatum remains to be significant and not to be resolved completely problem of the children orthopedics. This is confirmed by the high percent of unsatisfactory results of operative correction of pectus excavatum deformity, which are found in more than 20% cases (Vinogradov, 1999; Mirzakarimov, 2010). Besides, in some cases, despite of good functional results, after operative correction of pectus excavatum deformity during the growing of children the atypical deformations of the chest are progressing and forming (Haje, Hareke and Bowen, 1999; Sadler, 2000). While having diversity of various methods for operative correction of pectus excavatum deformity the cosmetic effect seems not to be resolved problem completely. Especially in this direction the researches have been performed by the known children's surgeon D. Nuss who performs operative correction of the deformed sternocostal complex without resection of the costal cartilages and sternotomy. According to the author’s data the results of the 10-year-experience of treatment of the pectus excavatum deformity the
number of the unsatisfactory results accounted for 8% (Nuss, Kelly, Croitoru, and Katz, 1998; Hebra, Swoveland, Egbert et al., 2000). This method of thoracoplasty induced great interest among all orthopedists and children's surgeons. However, in the data of the literature accessible to us, many authors emphasize that the frequency of unsatisfactory results after operation by the method of D. Nuss reaches 21% (Razumovskiy and Pavlov, 2005).

Though the majority of the authors use the method of thoracoplasty by D. Nuss with the purpose of elimination of the pectus excavatum deformity, the orthopedic features of treatment remain without appropriate attention. It is quite logical, that the performance of the same method of thoracoplasty at different types and severity of the pectus excavatum deformity in the patients of various age groups leads to the predispositions for occurrence of various postoperative complications which quite often result in unsatisfactory results of treatment at the long-term period. In our opinion, one of the causes of appearance of significant quantity of unsatisfactory results of thoracoplasty by the method D. Nuss may be it performance without taking into account of the elasticity of the sternocostal complex in children of various age. For the resolving of this task we carried out investigations with use of our criteria, developed for sternocostal complex elasticity in 54 patients with pectus excavatum deformity.

The purpose of work was to improve results of operative correction of the pectus excavatum deformity in children.

**Materials and methods**

In the Clinic of Scientific Research Institute of Traumatology and orthopedics of the Ministry of Health 54 patients with pectus excavatum deformity at the age from 5 to 15 years were operated during the period from 2007 to 2011. All patients were known about their cosmetic impairment and so, they had moral degradation. Because, patients and their parents were given their consent to perform the operative intervention, notably, they completed out the act about occurrence of any complaints during the operation.

These children were divided into three groups in relation to the degree of sternocostal complex elasticity. All patients were performed treatment with use of criteria of elasticity (patent No.DGU02466) including the following parameters: the test of auto-correction, difference of chest excursion at a deep inspiration and expiration, "torsion" of the breast bone and the angle of steepness of the deformed ribs. In order to study of the breast bone torsion and steepness angle of the deformed ribs we performed multispiral computed tomography on the basis of the faculty of radiation diagnosis and oncology of Tashkent Medical Academy. On the basis of these criteria and the degree of sternocostal complex elasticity there were formed groups of the patients. For operative correction of the sternocostal complex we used our developed (2010) and made by firm ChM (Poland) metal plates.

**Results and discussion**

The test of auto-correction is one of the reliable anthropometric (Rebeis, Samano, Dias et al., 2004) criteria of sternocostal complex. This test is performed in a deep inspiration, and the patient keeping inhaled air creates the increased pressure in the chest in order to correct deformation and strains anterior wall of the chest (Figure1 a), b)). The groups were made on the basis of the degree of the deformation correction. It is known, that in the preschool age in the patients with pectus excavation deformity the bone part of the chest is especially elastic. Therefore in this age group the anterior wall of the chest, especially area of sternocostal complex is elastic and compliable.

With age because of increased quantity of coarse collagen fibers the cartilaginous part is gradually loses its elasticity and becomes firm. In such cases the test of auto-correction
becomes negative and weakly positive. According to the criteria of the test of auto-correction we differ three stages: stage I - if correction of deformation achieved more than by 80% from the initial condition, stage II - if the patient can be removed from 60 up to 80% from the initial situation, stage III - if the removal of deformation is achieved less than 60% of initial state. So stage I was established in 27 (50%), stage II - in 17 (31.5 %) and stage III - in 10 (18.5%) children.

The excursion of the thorax is also one of reliable parameters of the criteria of elasticity. In the standing position, circle of the child chest was measured twice at the deep of inspiration and at the state of complete expiration with use of a centimetric tape. The difference between meanings of a deep inspiration and expiration was determined in percentages. If the difference between these two parameters was more than 10% from a circle of the chest at inspiration, it indicated about sufficient elasticity of the chest. Difference less than 10% - up to 5% we considered as the average degree of elasticity, if the difference is less than 5% - then in this case the chest was considered as hypoelastic. By these criteria the patients were divided into three groups: in 28 (51.8%) patients the difference was more than 10% from initial (stage 1 - normoelastic chest), in 15 (27.8%) this difference was from 5 up to 10% (stage II of elasticity), in 11 (20.4%) children it made less than 5% (stage III, hypoelastic).

The results of multispiral computer tomography (MSCT) allowed visualization of topographeo-anatomic condition of the thoracic organs. In this case it was possible to obtain information about the state of sternocostal complex and thoracic organs with indirect images about the morphological structures of the sternocostal complex and its parts (breast bone, cartilaginous part of the ribs) in different planes. On the horizontal slice the angle of breast bone torsion was measured (Figure 2).

In pectus excavatum the breast bone with the adjacent cartilaginous parts of the ribs in the frontal plane rotates along its axis in the left or right party of a body. The increase of a torsion degree of the breast bone provides occurrence of the asymmetric deformations. According to the angle size of the breast bone torsion the patients also were divided into 3 groups: I - light degree torsion - up to 15°. These children had good elasticity of the sternocostal complex. Group 2 included the patients with II - moderate degree of the
breast bone torsion from 16º to 30º. The third group comprised of the patients with III - heavy degree of the breast bone torsion, with angle of torsion more than 30º.

![Figure 2](image)

**Figure 2. Patient female S. 16-year-old**
The pectus excavatum deformity, subcompensated stage and asymmetric formed. The breast bone torsion on the right side is 37.0º

Out of 54 children 27 (50 %) had mild degree of the breast bone torsion, in 15 (27.8 %) the moderate degree of torsion was established, in others 12 (22.2 %) the heavy degree was established.

As a rule the breast bone torsion is accompanied by formation of the deformed protruded ribs of the anterior wall of the chest. Such deformations visualize on the MSCT and in the horizontal plane. These protrusions of the chest on the side of the breast bone torsion are usually depending on the size of angle of the high of the ribs have the sharp form and more blunt on the opposite part. The angle of the steepness of the deformed ribs (Figure 3.) is differed by volume and not symmetric more often in the patients with pectus excavatum deformity.

According to the criteria of angle of the steepness of the deformed ribs we classified three degrees: degree 1 - when the angle of the steepness of the deformed ribs was from 180º to 120º; degree II - from 120º to 90º, when the angle of steepness of the deformed ribs was less than 90º, then it is considered as severe form of deformation - degree III. By these criteria the patients were distributed as follows: in 24 (44.4%) children the angle of steepness of the deformed ribs was from 180º to 120º, that corresponded to the first degree of deformation, in 20 (37.0%) there was established the second degree of deformation (from 120º to 90º), in 10 (18.6%) patients the angle of steepness was less than 90º (degree III). In 17 (31.5%) children the angle of steepness of the deformed ribs was more marked on the right side, and at others 37 (68.5%) on the left.

At the heavy degree of the breast bone torsion and asymmetric deformation of the ribs of the third degree (11 - 20.4% of cases), during operative correction technical difficulties occurred more often.

At the end of investigation, summarizing the data of the developed criteria, the elasticity of the anterior sternocostal complex was determined for which the computer program was developed. The distribution of 54 children with pectus excavatum deformity by the
criteria of deformation of the sternocostal complex (test of auto-correction, CE, BBT, angle of the steepness of the deformed ribs) and degrees of elasticity of the chest were presented in Table 1.

**FIGURE 3. PATIENT MALE J, 16-YEAR-OLD**
The pectus excavatum deformity, subcompensated stage and asymmetric formed. The angle of the steepness of the deformed ribs on the right side is 82.7° and 89.2° on the left.

![Image](image_url)

**TABLE 1. DISTRIBUTION OF THE CHILDREN WITH PECTUS EXCAVATUM DEFORMITY BY CRITERIA FOR DEFORMATION OF THE STERNOCOSTAL COMPLEX AND ELASTICITY DEGREE OF THE CHEST (N=54)**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Light degree of elasticity of the chest (n=27)</th>
<th>Moderate degree of elasticity (n=15)</th>
<th>Severe degree of hypoelastic chest (n=12)</th>
<th>Totally</th>
</tr>
</thead>
<tbody>
<tr>
<td>(TA) Test of auto-correction</td>
<td>27 (50.0%)</td>
<td>17 (31.5%)</td>
<td>10 (18.5%)</td>
<td>54 (100%)</td>
</tr>
<tr>
<td>(CE) Excursion of the chest</td>
<td>28 (51.8%)</td>
<td>15 (27.8%)</td>
<td>11 (20.4%)</td>
<td>54 (100%)</td>
</tr>
<tr>
<td>(BBT) Breast bone torsion</td>
<td>27 (50.0%)</td>
<td>15 (27.8%)</td>
<td>12 (22.2%)</td>
<td>54 (100%)</td>
</tr>
<tr>
<td>Angle of the steepness of the deformed ribs</td>
<td>24 (44.4%)</td>
<td>20 (37.0%)</td>
<td>10 (18.6%)</td>
<td>54 (100%)</td>
</tr>
</tbody>
</table>

The table shows, that summarizing all parameters of criteria of deformation of the sternocostal complex in 27 (50.0%) children we establish elastic thorax, in 15 (27.8%) moderate elasticity was determined, and in 12 (22.2%) the hypoelastic thorax is established.

Depending on a degree of elasticity of the sternocostal complex the method of operative correction was chosen. In 27 (50.0%) patients with normal elasticity of sterno complex (as a rule they are children in the age under 10 years), there was carried out thoracoplasty by method of D. Nuss with application of a metal plate. At the moderate degree of elasticity in 15 (27.8%) children correction of the pectus excavatum deformity was performed by chondrotomy of the deformed ribs with stabilization of the corrected sternocostal complex with plate. In the third group of the patients the pectus excavatum deformity was corrected by "T"-shaped or transversal sternotomy and subperichondrial resection of
the ribs and stabilization of the corrected sternocostal complex with plate too. The duration of immobilization period was 2.5-3.7 years in relation to character and rate of growth of the patient.

The long-term results of the operated patients were investigated in 37 (68.5%) out of common number of operated children during the period of follow-up from 2 till 4 years. In the other 17 (31.5%) patients there were studied nearest postoperative results.

The results of operative correction we have estimated as good, satisfactory and unsatisfactory;

- The good result is considered when the patient does not show the complaints and the good cosmetic effect, complete restoration of the functions of pulmonary-cardiovascular system has been obtained;

- The satisfactory result is considered when there is a periodic pain sensation in the field of operative intervention, intercostals pain, and light inflammatory reaction in the area postoperative wound on the basis of good cosmetic result.

- The unsatisfactory result is when there is noted sinking deeply of sternocostal complex looking-like pectus excavatum of degree 1, that is, the relapse of deformation is of mild degree.

In 27 (50.0%) children with sufficient elasticity of the sternocostal complex there was performed real thoracoplasty by D. Nuss (Fonkalsrud, 2003; Nuss, Croitoru, Kelly et al., 2002). In the postoperative period at the department of resuscitation and intensive therapy the patients were during 24 hours. Temperature of a body preserved on the subfebrile values (37.0 +0.20С), in this group of the patients general health state and physical activity faster were restored relatively more rapid. On the second day these patients were permitted to sit, drainage tubes were usually removed on the second day after operation because discharges from the pleural cavity, as a rule, were poor.

For anesthesia there were used non narcotic substances. Children began to do respiratory gymnastics by inflating the spheres on the third day after operation.

The good result was obtained in 26 (96.3%) children, thus pectus excavatum was eliminated with a good relief without a relapse and complaints of the patient. In one (3.7%) patient the satisfactory result was achieved.

In 15 (27.8%) patients with moderate degree of elasticity (more often they are children at the age of from 11 up to 15 years) with the purpose of reduction of resistance of the sternocostal complex the thoracoplasty by D. Nuss was performed with modification (Rudakov, 1988). During alignment of the anterior wall of the chest in these patients there was performed chondrotomy in the cartilaginous parts of some ribs through small incisions in the skin (from 1 to 2.5 cm) in several places on the border with pectus excavatum, then there was performed turning of a plate by 180º degrees along the frontal axis of a body. The postoperative period in these patients was without complications, in the department of resuscitation and intensive therapy they were for 2 days. Temperature of a body in early postoperative period rose to 38.0º and was gradually normalized on the third day after operation. From the second day these patients were sitting on the bed. There was used combined analgesia with narcotic and not narcotic substances. Intraoperative blood lose was in volume to 50 ml. The drainage tubes were removed on the 2-3 days after operation. From the third day they were activated, performing respiratory gymnastics. The good result in this group of patients was obtained in 13 (86.7%) children, they have good relief in the area of sternocostal complex, and recurrences were absent. In 2 (13.3%) cases there were received satisfactory results. In
these patients there were noted insignificant periodic pain sensations in the area of postoperative wound and skin extensions because of rough keloid scars. The unsatisfactory results were not found.

The hypoelastic chest was established in 12 (22.2%) patients. These were children of 14-15 years old. These patients were performed thoracoplasty in modification, i.e. the elimination of deformation was carried out by "T"-shaped or transversal sternotomy with chondro-resection of some ribs (chondroresection was usually performed at the level of the IV, V, VI and VII ribs) then the plate of D.Nuss was established under sternocostal complex. The operative intervention of this group was more traumatic than in the previous groups and was often performed with technical difficulties. Intraoperative blood loss was more than 100 ml. Therefore this category of the patients after operation was in the department of resuscitation and intensive therapy for about 5 days. The patients were performed therapy for maintenance of homeostasis, prolonged analgesia, therapy with antibiotics, vitamins, as well as there were prescribed medicines for improvement of the function of cardiovascular and respiratory systems. In the early postoperative period in this category of patients there was noted marked hyperthermic reaction of he body, achieving 38.0±0.50°C, with gradual reduction to normal parameters. The patients were activated with the help of the doctor or parents from the 3-4 days. Drainage tubes were removed on the 3-4 day after operation with the subsequent performance of respiratory gymnastics. The therapeutic physical exercises and respiratory loadings were performed with use of nebulizer with solution of sodium carbonate 4%-50.0 ml, prednisolone 30 mg-1.0 ml, euphilline 2.4%-10.0 ml. The good result was obtained in 9 (75%) children. The satisfactory result was noted in 1 (8.3%) case. The unsatisfactory results were received in 2 (16.7%) cases. In our opinion this was connected with incomplete compensation of the resistant force of the plate placed in the sternocostal complex, that is, the relapse of deformation. These patients underwent repeated operative intervention.

Intra- and postoperative results of the operative correction of the patients with pectus excavatum are presented in Table 2.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Totally</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Normal elasticity (n=27)</td>
<td>Moderate degree of</td>
<td>Hypo elastic (n=12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>elasticity (n=15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>26 (96.3%)</td>
<td>13 (86.7%)</td>
<td>9 (75%)</td>
<td>48 (88.9)</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>1 (3.7%)</td>
<td>2 (13.3%)</td>
<td>1 (8.3%)</td>
<td>4 (7.4%)</td>
</tr>
<tr>
<td>Unsatisfactory</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>2 (16.7%)</td>
<td>2 (3.7%)</td>
</tr>
<tr>
<td>Totally</td>
<td>27 (50%)</td>
<td>15 (27.8%)</td>
<td>12 (22.2%)</td>
<td>54 (100%)</td>
</tr>
</tbody>
</table>

The Table 2 shows the results of operative intervention depend on a degree of elasticity of the anterior sternocostal complex and become worse with the reduction of elasticity of the anterior sternocostal complex. The rate of restoration and improvement of the patient state was directly proportional to volume of operative intervention. The duration of operative intervention in thoracoplasty by method of D. Nuss (group 1 of the patients) made 25±2.5 minutes, at modified method of D. Nuss, (groups 2-3) it made more than an hour - 72±9.4 minutes (p > 0.001).

Because of strong pain syndrome in the postoperative period in the patients from groups 2-3 the ventilation function of the lungs was limited and worsened, the need of the body in oxygen was not supplied, this was expressed by slowing of physical activation of the
patient, as a result the patients received treatment in the department of resuscitation and intensive therapy for a longer period, 3.4±0.8 days.

At an easy degree of elasticity the pectus excavatum deformity is easily corrected without negative effect on the internal organs of the thorax. And at the moderate and hypoelastic thorax the elimination of deformation is carried out with the certain difficulties and with additional interventions. In these cases the possibility of the occurrence of intraoperative complications is increased. Certainly, resection of the ribs and sternotomy help to remove deformation but break the structure of the anterior wall of the chest which can be complicated by infringement of the relief on the anterior wall of the chest or secondary deformations. We believe that presence of breast bone torsion and marked steepness of the deformed ribs are the contributing factors to occurrence of the secondary deformations.

Conclusion

As our results show, that with the maturation of the age of patients their sterno-costal complex is became as a rigid. So, in such moment the correction of the PE deformity without sternotomy or cartilages resection is impossible.

The results of the performed operative interventions and their comparative analysis show that thoracoplasty by D. Nuss due to pectus excavatum deformity is required when the sternocostal complex is still elastic. The worse elasticity of the sternocostal complex there are more and more often complications and relapses of the deformation after the thoracoplasty.

The results obtained of the comparative characteristic in three groups of the patients indicate that “with age” of the sternocostal complex in the pectus excavatum loses the elasticity, the latter is difficult for correction; the elimination of the deformation is carried out with some difficulties and complications.

Thus, the operative intervention at pectus excavatum deformity should be performed with taking into account elasticity of the sternocostal complex that contributes to the easy performance of the correction and provides good cosmetic and functional results.

Recommendations:

1. The assessment of the degree of the anterior sternocostal complex elasticity is carried out by the using of the anthropometric parameters and instrumental investigations, which are based on the criteria as test of auto-correction, different measures of excursion of the chest in deep inspiration and expiration; breast bone torsion and angle of the steepness of the ribs deformed.

2. The operative correction of the pectus excavatum deformity should be carried out with taking into account elasticity of the anterior sternocostal complex.

3. If the operative intervention will perform in view of a degree of elasticity of the anterior sternocostal complex, it can be warranty to allow creating a good cosmetic relief of the anterior wall of the thorax, reducing quantity of intra- and postoperative complications and promoting early physical activation of the patients.

References


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