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INTERMEDIATE RESULTS OF CONSERVATIVE TREATMENT OF PECTUS EXCAVATUM AND CARINATUM DEFORMITY

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Background. The intermediate results of conservative treatment of chest deformities are presented.
Aims. To evaluate the interim results of conservative treatment of chest deformities.
Materials and methods. Starting from August 2023, 63 patients have been prescribed conservative therapy for chest deformities at the Kidney Children's Clinic and the N.M. Kuraev Children's Hospital in Makhachkala. Of these, 38 children with VDGK, 25 with CDGK. Vacuum bell therapy was performed for VDGK, and dynamic compression system was performed for CDGK. Of the 38 children with HCV, 14 patients were excluded from the follow-up, as 8 patients voluntarily stopped treatment, and 6 patients were lost from observation. Thus, 24 patients continued treatment with VC. Of the 25 children with CDHK, 6 patients were excluded from observation, as 4 patients were lost from observation, and 2 patients voluntarily stopped treatment. DCS treatment was continued in 19 patients.
Results. The effectiveness of conservative treatment of VDGK was assessed by measuring the depth of deformation, calculating the Haller index and GVR on computed tomography before and during treatment. The deformation depth decreased at each subsequent visit. In addition to lifting the sternocostal skeleton, there was also a thickening of the pancreas according to computed tomography. Early good cosmetic results are usually noticeable in children with CDHA. At the first stage of treatment, there are still 13 patients with a duration of wearing DCS from 4 to 12 months. 3 patients with CDHC have completed treatment with recovery. There were no complications when wearing VC and DCS. Conclusion: it is important to remember that the key to successful conservative treatment of chest deformities is therapeutic discipline, motivation and parental help. The use of conservative methods for the treatment of chest deformities can be considered as an alternative treatment method for patients with "soft" chest who prefer non-invasive treatment. A mandatory component of conservative treatment for chest deformities is regular physical education and sports, exercises to strengthen the muscles of the back, chest and abs, breathing exercises, and not just wearing a device.
***Keywords**: vacuum bell, dynamic compression system, funnel-shaped chest deformity, keel-shaped chest deformity.*

Background. Excavity pectus excavatum (EPC) is the most common deformity of the anterior chest wall, characterized by depression of the sternum with involvement of the sternocostal cartilages and ribs. Most cases of EPC may be idiopathic or may be associated with connective tissue diseases, neuromuscular diseases, and other genetic disorders [1]. Chest deformities are progressive and may change during growth, especially during puberty. For a long time, the methods for correcting EPC were highly traumatic open surgeries. More than 30 methods and their modifications are known. Some of these surgeries were: the Ravich operation (1947), the N.I. Kondrashin operation (1968), and the Paltia operation (1958). The Ravich and Kondrashin operations were performed without the use of special fixators, thereby not supporting the sternum, which increased the recurrence rate [2]. In 1998, D. Nuss proposed minimally invasive thoracoplasty, which remains the gold standard in the treatment of PE to this day, as it reduces the duration of the operation and provides a good cosmetic result [3]. However, the implementation and installation of a retrosternal plate during the Nuss procedure has potential risks of complications, such as heart injury, pneumothorax, hemothorax, plate displacement, diaphragmatic rupture, and severe pain in the postoperative period. These risks led to the development of non-invasive methods for correcting PE. In 1992, German engineer Eckart Clobe, who suffered from PE, made and used a homemade vacuum bell at the age of 36, achieving positive results [4]. In 2005, the vacuum bell was presented and described as an alternative treatment method for some patients with PE who prefer non-invasive treatment [5-6].

Carinatum deformity of the sternum (CD) is characterized by protrusion of the sternum and adjacent costal cartilages [7-8]. It occurs 2-4 times less frequently than pectus excavatum [9]. This pathology can also be corrected using the Ravitch procedure, but a minimally invasive thoracoplasty according to Abramson (reverse Nuss procedure) is preferable [10] [11-12]. The disadvantages of these operations, such as pain, hospitalization, postoperative scars, and pneumothorax, led to the development of

Table 1. Characteristics of patients with VC

24 patients with VC		Quantity	
		abs.	%
VDGK form	Symmetrical	17	71
	Asymmetrical	7	29
Age	Up to 7 years (from 1 g)	6	25
	7-11 years old	7	29
	12-17 years old	11	46
Gender	Boy	15	63
	Girl	9	37

external corsets for the correction of CD. Corset therapy has been used since the 1970s, but only became popular after the introduction of the dynamic compression system in 2008 [7, 13].

Objective. To evaluate the intermediate results of conservative treatment of chest deformities.

Materials and methods. Since August 2023, 63 patients have been prescribed conservative therapy for chest wall deformities at the Kidney Children's Clinic and the N.M. Kuraev Children's Children's Clinical Hospital in Makhachkala. Of these, 38 children had pectus excavatum (PE) and 25 had cholangitis (CD). For PE, therapy was performed with a vacuum bell (VB), and for CD, with a dynamic compression system (DCS). The inclusion criteria for conservative treatment were patients with a "soft" chest, regardless of age. Of the 38 children with PPE, 14 were excluded from follow-up, as 8 patients discontinued treatment voluntarily, and 6 were lost to follow-up. This demonstrates the importance of carefully selecting a treatment method based on patient characteristics and their motivation. Thus, 24 patients continued VB treatment. The baseline patient characteristics are presented in Table 1.

Table 1 shows that symmetrical forms of PE and male children predominated. The youngest patient with PE was 1 year old and was prescribed a device for respiratory distress (shortness of breath).

In most patients, chest wall deformity was asymptomatic, although 6 patients experienced cardiopulmonary symptoms (shortness of breath, chest pain, fatigue).

The duration of VK use during the analysis period is presented in Figure 1.

Of the 25 children with CDH, 6 patients were excluded from follow-up because 4 were lost to follow-up, and 2 patients voluntarily discontinued treatment. Nineteen patients continued treatment with DKS. Table 2 shows the type of deformity, age category, and gender of the patients.

Table 2 shows that asymmetrical forms of CGD and male children predominated.

Patients with CDGK presented only cosmetic complaints.

Characteristics of devices and treatment protocol

VK and DKS are manufactured by Ortezdeti (Russia).

The VK consists of several parts: a silicone ring, a viewing lens, a hand pump attachment, and a hand pump. VKs are available in several sizes (11, 12.5, 14, 16, 17, 19, and 23 cm in diameter,

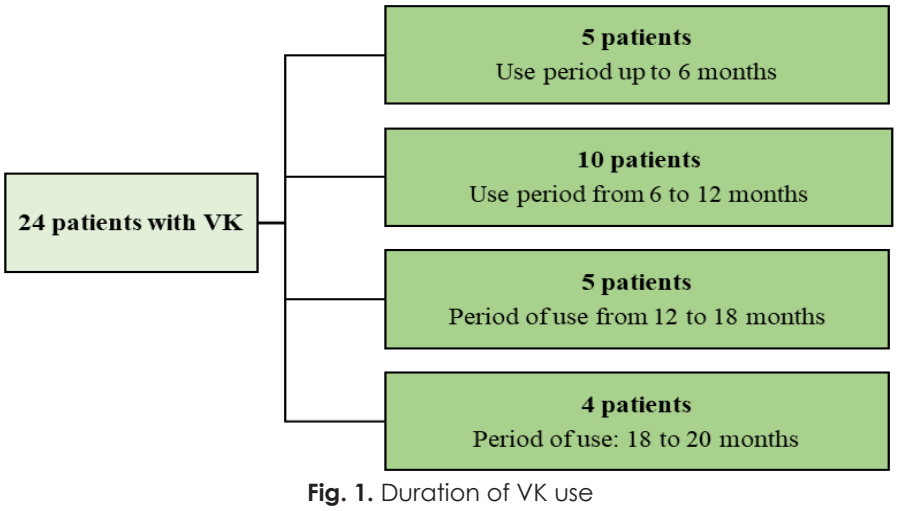


Fig. 1. Duration of VK use

Table 2. Characteristics of patients with DKS

19 patients with DKS		Quantity	
		abs.	%
Form of KDGK	Symmetrical	5	26
	Asymmetrical	14	74
Age	7-11 years (from 10 years)	3	16
	12-17 years old	16	84
Gender	Boy	14	74
	Girl	5	26

respectively), as well as women's sizes, which take into account the anatomical structure of the female body. The appropriate device size is selected based on the patient's age, depth, and width of the infundibulum. Before treatment with VK, the depth of the deformity was assessed, and the Haller index and sternovertebral distance (SVD) were calculated using computed tomography to assess the dynamics of treatment results. During the first visit, all patients were examined. In addition to the physical examination, a chest CT/X-ray, ECG, echocardiography, cardiologist consultation, spirometry, orthopedic consultation, and genetic consultation (if syndromic forms are suspected) were performed. Following a follow-up examination, the initial placement of the VC was performed under the supervision of the attending physician (during an in-person appointment). The VC was positioned so that the center of the window was positioned over the deepest point of the deformity. After application to the chest wall, negative pressure was created in the VC using a hand pump to lift the sunken sternum forward. The recommended duration of daily treatment depended on the patient's age. The minimum time of use of the bell for children was 5-6 hours per day, and for adolescents, 10-12 hours per day. Subsequently, parents kept a diary in which they recorded the depth of the deformity once every two weeks (in the morning before the VC placement) and provided a monthly photo report. Routine examinations were performed for all patients every three months, including clinical assessments and an assessment of the depth of the deformity.

The DKS is a brace with an anterior compression plate. The plate can be moved laterally to correct both symmetrical and asymmetrical deformities. Using the DKS gradually returns the sternum to its normal position, providing greater wearing comfort and less pain. During the initial outpatient clinic visit, all patients were assessed for chest height, keel width, and thoracic asymmetry, based on which a custom-made brace was manufactured and fitted. Patients initially wore the brace 20-22 hours a day (stage I). After the chest had stabilized after 20-22 hours of wearing the DKS, patients were transitioned to wearing the brace only during the day or at night (stage II - consolidation of the results). Routine examinations were also performed for all patients every 3 months.

In addition to conservative treatment, patients with chest deformities were recommended to exercise, perform exercises to strengthen the muscles of the back, chest and abdomen, and do breathing exercises in the device.

Results. The effectiveness of conservative treatment of PVD was assessed by measuring the depth of deformation, calculating the Haller index and GVR using computed tomography before and during treatment, which is presented in Table 3.

At the time of analysis, all 24 patients were still undergoing treatment. The depth of deformity decreased with each subsequent visit. In addition to elevation of the sternocostal framework, thickening of the subcutaneous fat was also noted on CT scan. Figure 2 shows some intermediate results of conservative treatment of PVD.

Table 3. Indicators of patients with PVD before and during treatment with a vacuum bell

Indicators	Average value	
	Before treatment	During the treatment period
Depth of deformation	2 см	0,9 см
Haller index	3,9	3,2
GVR	5,7 см	7 см
PZK	0,6 см	1,5 см

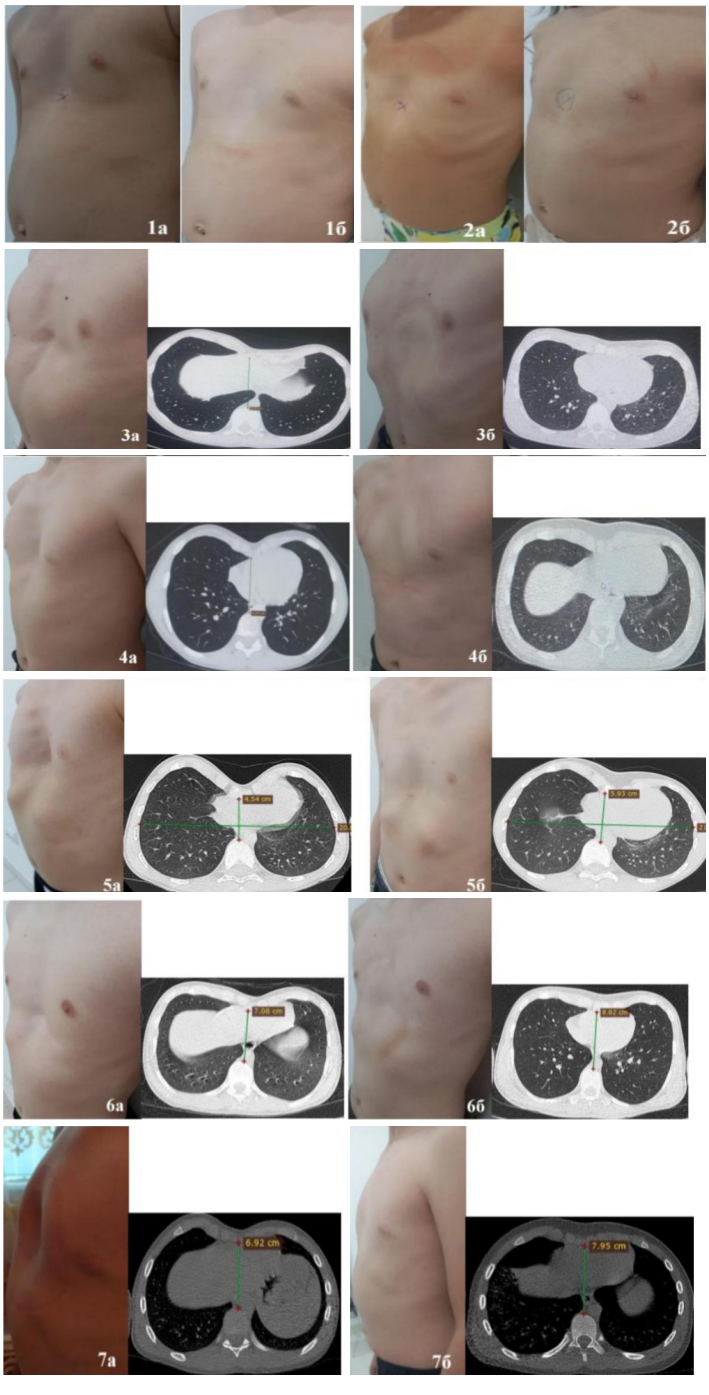


Fig. 2. Intermediate results of conservative treatment of PVD:
1a – depth of deformation before treatment - 1.4 cm, 1b – depth of deformation after 1 year 2 months - 0.7 cm;
2a – depth of deformation before treatment - 1.3 cm, 2b – depth of deformation after 1 year 7 months - 0.4 cm;
3a – depth of deformation before treatment - 2.1 cm with MSCT, 3b – depth of deformation after 1 year 2 months - 0.8 cm with MSCT;
4a – depth of deformation before treatment – 2.1 cm with MSCT, 4b – depth of deformation after 1 year – 0.6 cm with MSCT;
5a – depth of deformation before treatment – 3.5 cm with MSCT, 5b – depth of deformation after 1 year 7 months – 1.6 cm with MSCT;
6a – the depth of deformation before treatment is 2.4 cm with MSCT, 6b – the depth of deformation after 1 year 5 months is 1.0 cm with MSCT;
7a – the depth of deformation before treatment is 2.0 cm with MSCT, 7b – the depth of deformation after 1 year 8 months is 0.5 cm with MSCT.

Early good cosmetic results are seen in most cases in children with CDH (Fig. 3).

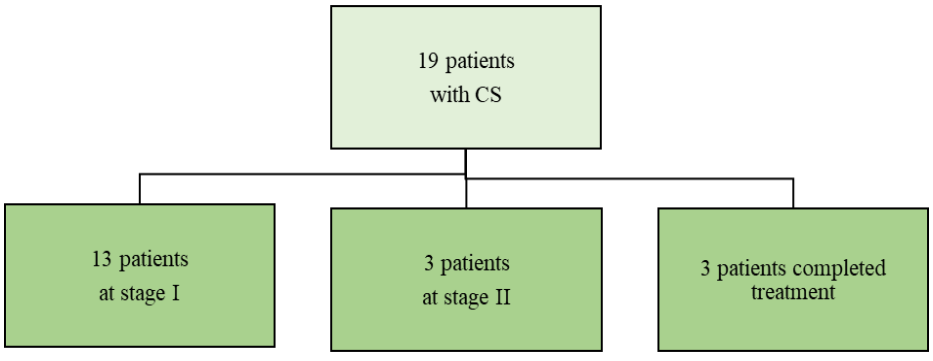


Fig. 3. Results of conservative treatment of CDGK



Fig. 4. Intermediate results of conservative treatment of CDH: 1a – before treatment, 1b – after 6 months; 2a – before treatment, 2b – after 8 months; 3a – before treatment, 3b – after 1 year 2 months

Thirteen patients are currently in Phase I of treatment, with the device wearing durations ranging from 4 to 12 months. The duration of device wear depends on the severity of the deformity and the compression force applied by the patients themselves. Some interim results of conservative treatment of CDH are presented in Figure 4.

Three patients with CDGK completed treatment with recovery (Fig. 5).

No complications were observed when wearing VK and DKS.



Fig. 5. Final results of conservative treatment of CDH: 1a – before treatment, 1b – intermediate result after 5 months, 1c – recovery after 1 year 3 months; 2a – before treatment, 2b – intermediate result after 3 months, 2c – recovery after 1 year 2 months; 3a – before treatment, 3b – recovery after 12 months.

Discussion. Currently, there is no uniform data on the indications for the use of VK. According to the literature, in some sources, VK is indicated for patients with a mild degree of PE and/or those who refuse surgical correction [14]. In other sources, VK is indicated for patients with a moderate to severe degree of PE who are too young for surgical correction [15]. According to I. Loufopoulos et al., suitable candidates are patients with a deformity depth of less than 1.5 cm and a flexible chest [1]. However, as a result of the study by Y. Eunjue et al., excellent results were also obtained in patients with a large deformity depth if they had a flexible chest [16]. Most researchers agree that VK treatment is more likely to benefit younger patients. In particular, the start of treatment before the age of 11 years is a predictor of an excellent outcome [1]. It should also be taken into account that the German engineer Eckart Clobe, who suffered from PVD, achieved positive results after starting treatment with VK at the age of 36 [4]. In addition, VK can be used intraoperatively to facilitate dissection of the retrosternal space and placement of a retrosternal plate during the Nuss procedure [4].

In contrast to the indications, there are clear contraindications. The VK is contraindicated in patients suffering from skeletal diseases, vasculopathy, coagulopathy, and cardiac diseases [15, 17]. Therefore, before starting VK treatment, patients must undergo chest CT, ECG, ECHO-CG, and a consultation with a cardiologist. The VK should not be used in patients with severe chest asymmetry, since the device must fit well to the chest and be leak-proof [6]. Any chest asymmetry prevents the VK from sealing and reduces the effectiveness of its treatment. Therefore, before starting VK treatment, a medical examination and careful selection of candidates is necessary.

In addition to the correct selection of patients for conservative treatment, the correct use of the VK is of paramount importance. There is no consensus regarding the duration of VK use; we recommend 5-6 hours/day for children and 10-12 hours/day for adolescents.

Similarly, there are differences in the overall duration of treatment required to achieve excellent results. According to F.M. Haecker, the duration of treatment in children and adolescents with mild to moderate symmetrical PE with a flexible chest wall is 12-15 months, whereas in adolescents and adults with moderate PE and a rigid chest wall it is 24-36 months [14] [17]. In the studies of D. Luo et al., the treatment period and the time of daily use of the VK in preschool-aged children were clearly shorter, possibly because the patients in their study were younger and the chest wall was still soft, and the depth of chest deformity was less pronounced than in older children [18]. Their results are consistent with the data of M. Lopez, who reported a higher correction rate in the pediatric group [19]. R.J. Obermeyer et al. also reported good results in children (<18 years) than in adults [20]. As the child ages, the rigidity of the chest increases and flexibility decreases, which affects the outcome of conservative treatment.

Conservative treatment of CDH using external corsets has excellent results, exceeding 70%, if treatment recommendations are followed [7].

According to the literature, daily wearing of a compression system is recommended for 23 hours (excluding sports, swimming, or showering) [21–22]. Other sources recommend 8–12 hours per day, with similar favorable treatment results [23–24]. Thus, there is no consensus on and a single protocol for wearing a compression system [25]. Our patients wore the compression system for up to 20–22 hours per day.

Another not entirely precisely predetermined parameter is the total duration of treatment, the values of which vary greatly in the literature [8]. Some studies indicate that the total duration of DKS treatment varies from 6–12 months [26], while other studies indicate 14–24 months [7, 24]. Studies by Martinez-Ferro et al. indicate that in their cases the duration of treatment was 7 months [27]. In our 3 cases, DKS treatment lasted from 12 to 15 months.

Although conservative correction of PVD and CPB is easier at a young age, there is a high risk of relapse during the growth spurt, requiring restarting therapy with VK or DKS, or extending therapy until the end of the growth spurt [7]. Typically, relapse is associated with ongoing pubertal growth and responds to restarting conservative therapy [24].

Patient compliance is considered a key factor in successful treatment [28]. The literature describes a high rate of treatment discontinuation, from 30 to 43% [29], [24]. In our case, 37% of patients discontinued treatment with VK, and 24% with KDS. The reasons for discontinuing therapy include pain, skin problems, shame, and discomfort [28], [30], [13].

Conclusion. It is important to remember that the key to successful conservative treatment of chest deformities is therapeutic discipline, motivation and support from parents.

The use of conservative methods of treating chest deformities can be considered as an alternative treatment method for patients with a “soft” chest who prefer non-invasive treatment.

A mandatory component of conservative treatment for chest deformities is regular exercise and sports, exercises to strengthen the muscles of the back, chest and abdomen, breathing exercises, and not just wearing the device.

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