



(RESEARCH ARTICLE)



## Options for correction of the Pectus carinatum

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### Abstract

The article reveals the problem of treatment of the pectus carinatum. The authors described in detail the historical facts, options for surgical treatment. The advantages and disadvantages of each method are noted, the directions of development of thoracic and plastic surgery of the keeled deformity of the chest in the near future are outlined. For the first time, a large proprietary material on the correction of this deformation with the help of a corset is presented. The original method of monitoring the treatment and supervision of the patient until full recovery is described.

**Keywords:** Pectus carinatum; Correction; Abramson operation; Corset

### 1. Introduction

Coelho Mde S, et al. (2007) consider that among the deformities of the thoracic wall, pectus carinatum (PC) has not received the same attention as has pectus excavatum [1]. Few pulmonologists, pediatricians, and thoracic surgeons are aware of the approaches to treating this condition. As a consequence, patients with pectus carinatum are not referred for treatment. This deformity, with an incidence of 1:1000 teenagers, is oligosymptomatic. However, for aesthetic and emotional reasons, it accounts for a large number of medical appointments. Such patients are introverted and do not engage in physical activities, since they are unwilling to expose their chest, which also discourages them from going to the beach or to swimming pools. The diagnosis is clinical and visual, and details are obtained through chest X-rays and computed tomography. The treatment is based on a well-known organogram that summarizes orthopedic and surgical procedures. Dynamic compression, combined with physical exercises, is indicated for teenagers with flexible thorax in inferior and lateral pectus carinatum, with limited indication for those with superior pectus carinatum. For individuals of any age with rigid thorax, surgery is indicated for aesthetic reasons. Among the techniques described, the modified sternum chondroplasty stands out due to the excellent aesthetic results achieved.

Robicsek F. (2010) noted that **pectus carinatum**, just like its sister deformity pectus excavatum, is a condition with an undefined developmental mechanism and debated surgical techniques [2]. Elongation of the costal cartilages and elongation and anterior displacement of the sternum characterize the different varieties of pectus carinatum. Repair of the anomaly involves positional correction as well as the shortening of the sternum and the maintenance of its corrected position by action of the rectus abdominis and pectoralis muscles.

The exact etiology of this deformity remains unclear. The main hypotheses are developmental disorders, proliferation of rib cartilage or genetic predisposition [3]. Moreover, PC can often accompany certain diseases, such as Marfan disease, homocystinuria, osteogenesis imperfecta, Noonan syndrome or mitral valve prolapse [2]. Patients with PC mainly suffer

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from cosmetic problems, which leads to a decrease in self-esteem and a lower quality of life than patients without this deformity [4]. Indications for surgical correction are both cosmetic and functional disorders [5].

Currently, PE and PC could be repaired with both surgical and conservative methods, which are available. The history of modern treatments for PC dates back to 1949 when Ravitch described his technique of removing the abnormal costal cartilage and sternal osteotomy [6]. This method has become the standard treatment of PC for the next over 50 years. The disadvantages of this method: extensiveness and the formation of an unaesthetic scar in the medial line of the sternum resulted in the search for less aggressive methods for treating this benign condition. A related point to consider is the recurrence rate after the Ravitch procedure, which could reach even 30% [7, 8]. In growing patients, the compressive external bracing is a high-profile, non-invasive PC treatment method that could succeed and help avoid the operation [9, 10]. In some departments, the results were so favorable that the brace therapy was introduced as a first-line treatment for PC, followed by surgery once the effect was not satisfying [11].

In 2005, Abramson described the minimally invasive surgical technique for correcting PC first in Spanish [12], and later in English [13]. In the next 15 years, the minimally-invasive techniques such as the Abramson procedure (or reversed Nuss procedure) have gained in popularity and are frequently performed as the alternative to the more extensive Ravitch procedure. It should be emphasized that the Ravitch method involves a significant interference with the thoracic skeleton [14], in contrast to the Abramson method, which is essentially based on the compression effect. According to Abramson, the most challenging part of the operation is the subpectoral bar placement, requiring a PVC tube with a trocar during dissection. Therefore, the authors of this procedure's modifications decided to use the two curved Doyen intestinal clamps to prepare a submuscular tunnel [15].

Varela P, et al. (2011) used thoracoscopic cartilage resection with partial preservation of the suprachondrium in unilateral PC [16]. They modified the technique by introducing a complete cartilage resection of all abnormal rib cartilages performed thoracoscopically. Three thoracoscopic ports were used. The cartilage was removed gradually using wire cutters, preserving the anterior part of the cartilage. The authors believe that this is an alternative to the treatment of unilateral PC.

Zhang *et al.* used a novel steel bar type in the anti-Nuss procedure [17]. The main modification was the bar's composition, consisting of three parts with different elasticities. According to the authors, such a structure significantly increases its plasticity and makes it easier to design the shape of the bar for the patient's deformity type. As the authors reported, removing the newly designed bar was less time-consuming and traumatic for the patient. From a practical point of view, another significant advantage of this new bar is the ability to modify the steel bar's shape further, even once it is placed in the body. Furthermore, the newly designed stabilizer and multiple wires enabled the authors to stabilize the bar firmly and reduce the number of complications related to its displacement.

Skrzypczak P et al. ((2022) a new steel bar was also used in the treatment of PC [18]. Given that the majority of patients are children and young people, it is tempting to assume that modifications of available methods: reduction of scarring, postoperative pain and the risk of other complications will arouse increasing interest among patients and doctors in the coming years [19]. Bell R, et al. (2012) concluded that minimally invasive thoracoscopic repair of symmetric PC using chondrotomies and suprasternal bar compression is a feasible alternative to open repair [20].

Many types of pectus carinatum have been identified, and the following three types are most common in the clinic according to the shape of the sternum and chest deformity [2, 21]:

- Type A (typical pectus carinatum): the sternum protrudes forward in a straight line and forms an angle with the xiphoid. In this type, the maximum prominence is at the stern-xiphoid junction, and it is always accompanied by depression of the lateral ribs.
- Type B: the sternum and xiphoid form an arc shape, the xyphoid remains in a straight continuation of the sternal axis, and the maximum prominence is at the highest point of the arc, not the stern-xiphoid junction.
- Type C: this is the asymmetrical type, with a unilateral prominence of the elongated costal cartilage and concomitant tilting of the sternum towards the opposite side at various angles.

Minimally invasive repair of pectus carinatum (MIRPC) has become increasingly popular in recent years, and many different methods with Nuss steel bars or other modified bars have been reported [22, 23]. However, the installation and removal of Nuss steel bars is sometimes difficult, time-consuming and traumatic. To further simplify the procedure, we designed a new steel bar to facilitate minimally invasive surgical correction of pectus carinatum and have treated more than 100 patients with good results and few complications.

For a long time, the Ravitch procedure or its modified versions were considered classic correction procedures for pectus carinatum. The procedure involves resection of the deformed costal cartilage, xiphoid division from the sternum, and transverse sternal osteotomy to displace the sternum anteriorly [24, 25]. Although the method has achieved good results, it has disadvantages, including a long operation duration, a long hospitalization period, a large amount of blood loss, and scarring of the anterior chest wall. In 1987, Dr. Donald Nuss designed a new steel bar for the correction of pectus excavatum, and after his publication in 1998, some used the bar to correct pectus carinatum as well [26, 27]. In the last 10 years, we also used the Nuss method to correct more than 200 cases of pectus carinatum [28]. Although good results were achieved, quite a few disadvantages were revealed during the operations. For example, the steel bar has to be plasticized before operation, there were difficulties in placing or removing the steel bar through the tissue in front of the sternum, and there were long operation times for both the implant procedure and removal procedure. Based on the disadvantages above, we designed a new steel bar that could be placed through a modified procedure. The minimally invasive technique has overcome the disadvantages of the Nuss procedure, resulting in satisfying aesthetic outcomes with few complications. The complications during hospitalization included pneumothorax and pleural effusion, but no drainage tubes needed to be placed. The complications after discharge included wound infection, nickel allergy, screw loosening, wire breakdown, bar fracture, and overcorrection leading to excavatum.

Hypercorrection can spontaneously regress if the rod is removed earlier, but early removal can also lead to a recurrence of PC. In a study by Yuksel et al., 10 patients with hypercorrection underwent beam removal 12-13 months after surgery, 9 patients regressed spontaneously without any intervention, but the PC recurred in 4 patients. Earlier removal of the rod may cause a recurrence of the PC [23].

Martinez-Ferro M, et al (2019) believe that awareness of pectus carinatum has increased among the medical community over the last several decades, as innovative options for nonsurgical treatments have become more widely known [29]. Management alternatives have shifted from open resective to minimally invasive strategies, and finally, to reshaping the chest using both surgical and non-surgical modalities.

The incidence of pectus carinatum is very difficult to estimate because the condition is often underdiagnosed. The development and spread of non-invasive treatment methods has raised interest in this malformation, and referral has increased exponentially in the last 20 years. Pectus carinatum is considered the second-most common cause of thoracic malformations. Its reported incidence ranges from a fifth of that of pectus in some centres, to an equal incidence in others. It is more prevalent in males, at a ratio of 3 or 4 to 1.

Katrancioğlu O, et al. (2023) investigated the prevalence of chest deformity in middle- and high-school students in Sivas province of Turkey, to identify the risk factors associated with the psychological and physical disorders caused by the deformity, and to facilitate early diagnosis and treatment guidance by increasing awareness of this problem [30]. Between October 2011 and May 2012, a total of 15,862 students (8,508 males, 7,354 females; mean age:  $15.9 \pm 1.3$  years; range, 12 to 19 years) from public schools were included. Chest wall deformity was detected in a total of 250 students (1.6%). The prevalence rates of pectus carinatum and pectus excavatum in the children were 0.7% and 0.6%, respectively. The overall prevalence of chest wall deformity was 1.6%. The authors concluded that chest wall deformity is more common in boys and pectus carinatum is the most common deformity type. Chest wall deformity is more common in the 15-16 age group and female sex is a risk factor for psychological discomfort.

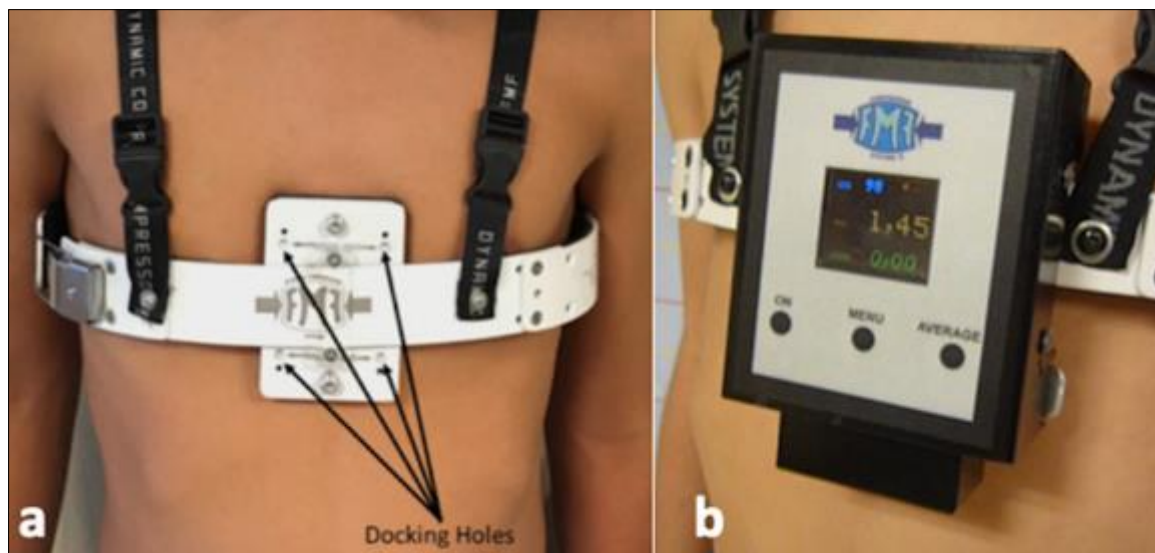
Diagnosis is made by physical examination; the deformity can be characterised without complementary studies such as X-ray or computed tomography, which can add no information and in addition require radiation. Systematic photography is used to assess the shape of the chest for the duration of the follow-up period. The elasticity of the sternum and cartilages should always be assessed; this can be achieved subjectively by manual compression or by means of pressure-measuring devices. Only in special cases should further studies be done, such as in associated skeletal deformities, or when associated syndromes such as von Recklinghausen, Poland or Marfan, or cardiac conditions, are suspected.

Although dynamic chest compression was described by Haje and Raymundo as early as 1979, this modality did not gain popularity among surgeons until the Nuss technique of chest remodelling (instead of resecting) completely changed the conception of treatment [31].

This change of paradigm inspired surgeons to explore the concept of reshaping the thorax from the outside, avoiding the need for an operation. In 2008, Martinez-Ferro *et al.* reported the creation of a pressure-controlled bracing system, and described its application in patients, introducing new concepts such as pressure of initial correction and pressure of treatment, as well as the use of pounds per square inch (psi) as a unit of measure for rigidity of the thoracic cage. In

summary, the treatment modalities of pectus carinatum may be either surgical or non-surgical, and surgical treatments are either resective or non-resective.

Bracing therapy has gained popularity as a non-operative alternative that has proven to be as good as operative strategies to correct pectus carinatum in patients with flexible thoracic cages and high compliance. This is a good choice as the first line of treatment in almost all cases, and the only solution necessary in many cases with non-complex deformities, flexible thoracic cages and a high level of compliance. This last aspect is the major cause of failure of treatment and abandonment, so a multidisciplinary approach is recommended, with the participation of rehabilitation physicians and physical therapists. There is still a lack of consensus regarding the minimum number of hours patients should wear the brace, and whether bracing may play a role in adult patients. In 2008, Martinez-Ferro *et al.* published an 8-year review on the use of a specially designed dynamic compression system (the FMF Dynamic Compression System) [29] (Fig. 1).



**Figure 1** Pressure-measuring devices allow protocolisation of follow-up and determination of cutoff values. (a) FMF Dynamic Compressor System in place. Docking holes permit measuring the pressure of treatment with a device. (b) Pressure-measuring device docked in place

In 2018, de Beer *et al.* published a systematic review of the measured dynamic compression system [32]. They found 14 studies published between 2008 and 2018, and selected 8 for further analysis. A total of 1 185 patients were included, of whom 44% were still under treatment, 29% had completed treatment successfully, 6% had dropped out and 21% were lost to follow-up. Strategies are needed to decrease rates of abandonment by increasing compliance, which will probably improve results.

Overall, the results obtained with bracing are considered better than those obtained with surgical procedures, making this the first treatment of choice for compliant patients with pectus carinatum.

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## 2. Material and methods

For the period 2019-2022, 3454 patients with PC were corrected in the Zdrava clinics, the TS clinic of Krasnodar and the Surgemed clinic (Uzbekistan, Urgench). Of these, 400 patients are citizens of Uzbekistan. Men – 2824 (81.7%), women – 630 (18.3%) patients. The age ranged from 12 to 20 years.

Abramson's surgery was performed in 4 (0.116%) patients. Of these, 1 patient 27-year-old with breast hypoplasia underwent Abramson surgery with breast augmentation with Mentor implants. In the remaining 3451 (99.91%) cases, a corrective corset was used.

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## 3. Results and discussion

The average period of wearing a corset is 18±6 months for 14-18 hours a day. Good and satisfactory results were obtained in 96% of cases. We give clinical examples:

### 3.1. Example 1

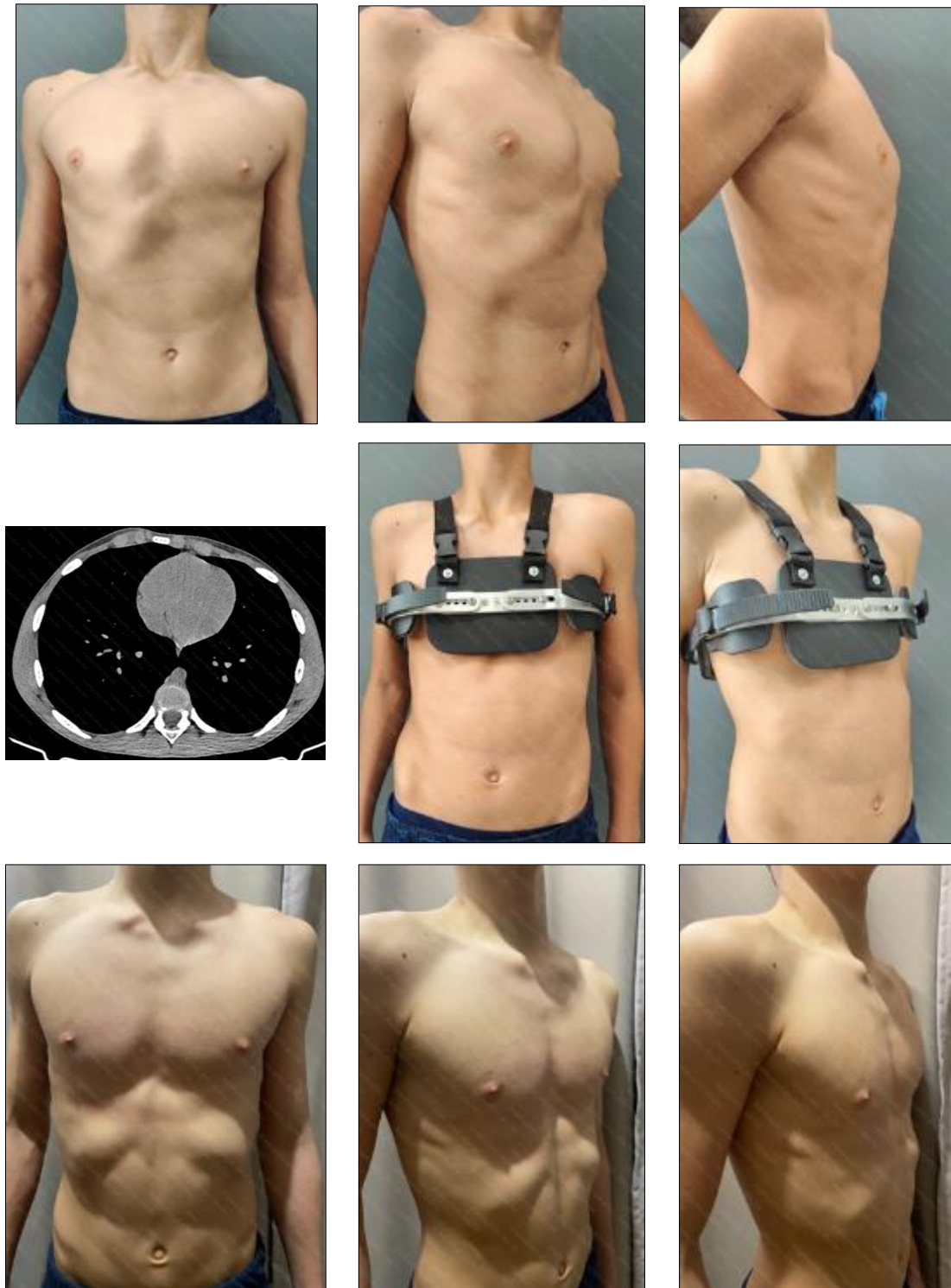
A 15-year-old boy. 1 year of wearing a corset to correct the pectus carinatum. Currently, the treatment of the keel is fully completed, but the young man continues to wear a posture corrector (Fig. 2).



**Figure 2**\_Results obtained with dynamic chest wall compression, before treatment, during compression and after 1 year of treatment

### 3.2. Example 2

A 13-year-old teenager from Sochi, with an asymmetric form of keeled chest deformity and an indestructible will to win. Treatment was started in August 2022 with the use of a corset for non-surgical correction of PC. According to the photos, after only 7 months (March 2023) of wearing a corset, the effectiveness of non-surgical correction of PC is obvious (Fig. 3).



**Figure 3** Dynamic compression of the chest wall. Before treatment, MSCT scan, during compression and after 7 months of treatment

The patient and his parents who are serious about using a corset for non-surgical correction of CDGC are doomed to success! It is difficult to overestimate the need to comply with the regime of wearing a corset to achieve results. The mode is the basis. Unsatisfactory results are obtained in the absence of discipline and responsibility.

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## 4. Conclusion

In general, the results obtained with the help of a bandage are considered better than the results obtained with surgical interventions, which makes this the first line of correction for obedient patients with chest deformity.

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## Compliance with ethical standards

### *Acknowledgments*

This work is dedicated to pediatricians, thoracic surgeons, pulmonologists and family doctors who not only can, but also must detect chest deformity in children in time and do everything possible to correct it.

### *Disclosure of conflict of interest*

There is no conflict of interest.

### *Statement of ethical approval*

The study was approved by the Ethics Committee of the Tashkent Medical Academy, opinion №245, Uzbekistan.

### *Statement of informed consent*

Informed consent was obtained from all individual participants included in the study by signing the Free and Informed Consent Form.

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