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Review

Surgical treatment of children with asymmetric pectus excavatum: Literature review

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BACKGROUND: The surgical treatment of children with pectus excavatum is regarded as an urgent problem still demanding solution despite the multitudes of surgical correction methods available nowadays. The currently available well-known techniques cannot be considered perfect because they are not proper enough for solving all the tasks, not to mention the problem of asymmetric forms of pectus excavatum treatment.

AIM: To analyze publications containing information on the methods of surgical treatment used for children with pectus excavatum.

MATERIALS AND METHODS: The study presents the results of literature review on the methods of surgical correction of pectus excavatum. Information was retrieved in PubMed, Google Scholar, and eLibrary scientific databases using keywords. Consequently, 63 foreign and domestic scientific sources over the period from 1609 to 2022 were identified. Among them, 29 publications refer to the latest decade.

RESULTS: Given the variety of methods used for chest deformity correction, thoracoplasty by D. Nuss has become the "gold standard" for the treatment of pectus excavatum. However, according to the search results, it is impossible to name one universal method of surgical intervention that could solve all the urgent problems at present. Modern surgery methods used for pectus excavatum correction can be considered only as modifications of treatment methods having been used before.

CONCLUSIONS: The shortcomings of modern thoracoplasty determine the necessity to keep searching for new techniques and improve those available at present. Besides, the standard suitable for both surgeons and patients should be elaborated.

Keywords: asymmetric, pectus excavatum; thoracoplasty; children.

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Научный обзор

Хирургическое лечение детей с асимметричной воронкообразной деформацией грудной клетки (обзор литературы)

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Обоснование. Хирургическое лечение детей с воронкообразной деформацией грудной клетки является актуальной и до конца не решенной проблемой, несмотря на существование множества способов хирургической коррекции. Известные на данный момент методики не лишены недостатков и не позволяют решать все существующие задачи, особенно в отношении асимметричных форм воронкообразных деформаций грудной клетки.

Цель — проанализировать публикации, содержащие информацию о методиках хирургического лечения детей с воронкообразной деформацией грудной клетки.

Материалы и методы. В статье представлены результаты поиска литературы, посвященной методам хирургической коррекции воронкообразной деформации грудной клетки. Поиск данных проводили в базах научной литературы PubMed, Google Scholar, eLibrary по ключевым словам. Были выбраны 63 иностранных и отечественных источника за период с 1609 по 2022 г., из которых 29 за последние 10 лет.

Результаты. Среди множества методик коррекции деформации грудной клетки торакопластика по D. Nuss стала «золотым стандартом» лечения воронкообразных деформаций грудной клетки. Однако на данный момент не существует универсального варианта оперативного вмешательства, позволяющего достигать всех целей лечения. Используемые в современной хирургии способы коррекции воронкообразной деформации грудной клетки представляют собой преимущественно этапные модификации более ранних методов лечения.

Заключение. Недостатки современных торакопластик определяют необходимость поиска новых методик и совершенствования старых, а также формирования стандарта, удовлетворяющего хирургов и пациентов.

Ключевые слова: асимметричная, воронкообразная деформация грудной клетки; торакопластика; дети.

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ЭКО•ВЕКТОР

BACKGROUND

Pectus excavatum (PE) (cobbler's chest) is manifested by the retraction of the sternum and deformity of the costal cartilages. For the first time, this curvature of the chest was described in 1594 by Bauhinius [1]. This anomaly may be present at birth or develop during puberty. About a third of cases are recorded in infancy, and the rest are detected in childhood before puberty [2–4]. During the adolescence spurt, PE becomes more pronounced in one-third of cases, while in two-thirds of patients, no further progression of chest curvature is noted [5, 6].

PE accounts for >90% of the total number of chest deformities, and the remaining 8% of cases are keel chest (sparrowy chest, pigeon chest, and *pectus carinatum*), i.e., from 3:1 to 13:1, respectively [7–10]. The incidence of PE in the population ranges from 0.06% to 2.3% [11, 12], and the prevalence of the pathology ranges from 0.2% to 1.3%. In children, PE occurs in 1 per 400–1000 healthy people. PE in boys is 3–5 times more often than that in girls [13–17]. Approximately 60% of the patients have a symmetrical chest, and the remaining 40% have an asymmetrical chest [18]. According to some data, genetic factors play a leading role in the occurrence of pathology. The evidence is the presence of concomitant malformations in patients and existence of similar changes in relatives [19]. The hereditary nature of the pathology is confirmed in 37%–40% of cases. Other authors did not reveal a direct genetic relationship [20–22]. Its pathogenesis is not fully understood [23].

The work aimed to analyze publications containing information on methods of surgical treatment of children with PE.

MATERIALS AND METHODS

The study presents the results of a literature search on the methods of PE surgical correction. Data search was performed in the scientific literature databases PubMed, Google Scholar, and eLibrary using the keywords "asymmetric, pectus excavatum" and "thoracoplasty63 international and Russian sources were identified from 1609 to 2022, including 29 sources over the last 10 years. The inclusion criteria were information and methodological materials with the availability of full-text sources, randomized controlled and uncontrolled studies, and systematic reviews. Duplicate works comprising similar information were excluded, and if similar ones were detected, the chronologically later version was chosen.

RESULTS AND DISCUSSION

Surgical techniques for PE correction, introduced in large numbers of cases in the early XX century, were initiated by Meyer in 1911 [24]. Subsequently, various authors implemented new and improved old methods of surgical treatment, namely, Klapp in 1912, Zahradnicek in 1925, Sauerbruch in 1931, Oshsner and DeBakey in 1939, Brodkin in 1948, and Ravitch in 1949 [25–30].

Ravitch proposed a surgical method, including subchondral resection of the costal cartilages in the deformity zone and sternal osteotomy. Despite the introduction of new surgical methods for the correction of chest deformity, the above method was the standard for surgical treatment of PE worldwide [31].

Bairov's surgery, based on excision and bringing down the xiphoid process, transverse sternotomy, and subchondral resection of the costal cartilages at the deformity apex, followed by traction of the mobilized sternum, was found to be ineffective because of deformity recurrence during the child's growth and development [32].

The list of currently irrelevant methods of surgical correction, owing to their high injury rate and low efficiency, includes surgical techniques based on the rotation of the sternum by 180° in the anteroposterior direction, which were developed by Judet and Jung [33].

To date, according to Nuss, thoracoplasty is the most common and effective, taking into account modifications, and has become the "gold standard" [34, 35]. It is based on a change in the shape of elastic costal cartilages during retrosternal placement of a titanium plate, which allows nearly complete and instantaneous correction of the anterior chest wall [36].

In recent years, the Nuss technique has undergone many changes and modifications [37–39]. Thoracoplasty is performed from two lateral approaches. An arcuately curved plate, modeled taking into account the shape of the chest deformity, is passed through a pre-formed retrosternal canal and rotated by 180°, followed by fixation of the end sections to the ribs. The lack of visual control during plate insertion increases the risk of complications such as damage to the heart, pericardium, lungs, large vessels, diaphragm, and internal organs, and cardiac arrhythmia, which is confirmed by literature data [40–42]. However, the probability of complications in minimally invasive thoracoplasty is also dependent on the operator [43, 44]. The use of video-assisted thoracoscopy reduced the probability of the above problems, especially in severe deformities [45, 46].

In 2007, Harrison proposed an alternative treatment for PE based on the strength of the magnetic field. Two magnets, surgically placed retrosternally and antesternally in the orthosis, allow the displacement of the anterior chest wall anteriorly and the correction of the deformity due to the generated magnetic field traction. This method is currently at the stage of human clinical trials [47, 48].

As a rule, no cardiorespiratory syndrome in grade I PE has been identified; therefore, only aesthetic problems come

to the fore, and in cases where there are no indications for thoracoplasty, surgical cosmetic correction can be applied [49, 50]. The retraction of the anterior chest wall is eliminated by filling it with a silicone implant, which is placed antesternally and subfascially, often using an umbilical approach to obtain the most aesthetic result [51, 52].

Over time, the shortcomings of the original Nuss technique and its modifications became apparent, such as chest deformity recurrence, possible curvature overcorrection, residual deformity of the anterior chest wall, and plate migration. Moreover, if by now the problem of deformity recurrence has been largely resolved by increasing the timing of implant fixation and the risks of migration have been reduced due to the evolution of fixation methods and design, then two other issues have not been fully resolved.

Despite the efficiency of the treatment of PE using the Nuss method, with a low incidence of complications and minimally invasiveness, the correction of asymmetric PE leads to residual asymmetry, often manifested as rigid deformities. Such an aesthetic problem causes dissatisfaction by surgeons and patients with the results of the surgical treatment and requires additional correction [53]. If a satisfactory correction of gross asymmetric PE is not achieved, a surgical approach has been proposed, including an intraoperative transition from an isolated minimally invasive intervention to a combination with elements of radical thoracoplasty [18].

The application of the Nuss technique in some cases leads to a secondary deformity of the anterior chest wall [54]. According to the author's data, i.e., results of a 10-year work, 8% of poor results are registered [32]. For several researchers, the frequency of poor results using the Nuss method reaches 21% [55].

Since the introduction of the Nuss procedure, many modifications to chest correction, taking into account the morphology of the pathological process, have been proposed to improve results and increase safety, including those by Dr. H. Park for asymmetric PE. The key principle of this method is the asymmetric shape of the plate, which is opposite to the contours of the chest deformity [56, 57]. A retrospective data analysis reported certain success of this technique in the treatment of asymmetric PE; however, all the tasks set could not be solved, which determined the need for further research [56, 57]. In the above study, a new technique was proposed, in which special attention was paid to the places of entry and exit of the sheath, from the upper asymmetrical to the lower contralateral side, which determines the surgery simplicity and final aesthetic result. This simple but practical method allows for simultaneous pressure on the protruding chest and elevation of the depressed contralateral side, whereas the plate was formed after the insertion of the sheath for increased accuracy [58].

The "sandwich technique" of surgical correction of deformity should also be noted, which was also developed by H. Park, which implies the insertion of at least two plates, one retrosternally and the other antesternally (by Abromson), to ensure mutual compression of the plates with their subsequent fixation to each other [59]. Despite the advantages of the above technique, antesternal insertion of the plate through the thickness of soft tissues increases the risk of various complications, not to mention the insufficient pressure of this plate on the anterior chest wall owing to the lack of support points in rigid deformity. With asymmetric deformity and genetic syndrome, the risk of plate migration increases by 4 and 3 times, respectively, which determines the need to search for more thorough and stable fixation [60]. To prevent most complications, including pathology recurrence and formation of residual or secondary deformity, more acceptable methods with minimal invasiveness are necessary for the correction of PE [61–63].

CONCLUSION

Severe PE is treated by surgical reconstruction of the retrosternal space. Minimally invasive methods are the most common, which are promising in terms of modernization and application. Despite significant progress and ongoing research on the topic, this direction is currently important and relevant, especially in relation to rigid asymmetric PE. No universal technique that satisfies surgeons and patients and is devoid of shortcomings that affect the final treatment result has been established.

ADDITIONAL INFORMATION

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Author contributions. *B.H. Dolgiev* collected the literature data and wrote the article. *D.V. Ryzhikov* conceived the scientific work and edited the text of the article. *S.V. Vissarionov* contributed to the study design and edited the text of the article.

All authors made a significant contribution to the research and article preparation and read and approved the final version before its publication.

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