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Elimination of factors contributing to the development of colo-esophageal anastomotic dehiscence following retrosternal colonic esophagoplasty performed for esophageal atresia correction

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Abstract

Aim. *Development of methodology that would allow surgeons to decrease the risk of colo-esophageal anastomotic dehiscence following esophagoplasty through prevention of colonic transplant compression in the retrosternal tunnel and surgery facilitation.*

Material and methods. *Ultrasound examination was carried out on 43 infants (22 boys and 21 girls) without sternal pathologies. The dorsal sternal angle and thickness of the upper and lower parts of the sternal manubrium were evaluated. The prominence and structure of muscular arrangement in various parts of the dorsal side of the sternal manubrium were examined in 15 infant patients. The results of treatment based on the method developed in accordance with the RF Invention Patent No. 2552095 were analyzed for infant patients (8 boys and 7 girls) suffering from esophageal atresia. Nine patients had the fenestration of the sternal manubrium performed across its entire length, and six infants had it*

performed in its upper segment only. X-ray control was used to detect colonic transplant compression. The significance of differences between the studied variables in the examined groups was assessed using the Mann-Whitney U test (M-W) for data measured on an ordinal scale.

Results. *The upper part of the sternal manubrium (above the attachment of the first rib) was found to exert the highest pressure on the transplant as it is statistically significantly thicker (M-W=4.44; p<0.01), being covered with a more prominent muscular layer (M-W=6.71; p<0.001) over a larger area (M-W=4.42; p<0.01) and considerably reclined. In infant age, the dorsal sternal angle is 164.9±0.8 degrees. Its value was consistently (M-W=2.66; p<0.01) higher in the girls' group with significant individual variations. Based on the collected data, an original technique was developed for individual approach to the resection of the manubrium sterni applied during retrosternal colonic esophagoplasty in 15 patients with esophageal atresia. No signs of colo-esophageal anastomotic dehiscence or transplant compression were revealed in any of those cases.*

Conclusion. *The suggested method allows surgeons to assess in every case the narrowness of retrosternal space and individually select the scope of sternal manubrium resection to eliminate the important factors contributing to the development of colo-esophageal anastomotic dehiscence after retrosternal esophagoplasty in cases of esophageal atresia thus facilitating the surgery and preventing transplant compression in the retrosternal tunnel.*

Keywords: esophageal atresia, retrosternal colonic esophagoplasty, anastomotic dehiscence, sternal manubrium resection

Conflict of interests Authors declare no conflict of interest

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USE – ultrasound examination

M–W – Mann-Whitney U test

Introduction

Esophageal atresia is one of the most common congenital malformations with an incidence of 1:2500 newborns [1]. This condition is referred to diseases requiring urgent surgical care [2] and is corrected by esophagoplasty with colonic grafting, including retrosternally [3].

A fairly common complication of the esophageal atresia surgical treatment is the colo-esophageal anastomotic dehiscence, which occurs in 10–20% of patients [4]. Anastomotic leaks are the most serious and detrimental complications of esophageal surgery [5]. Therefore, the identification and elimination of factors provoking its development is an urgent task.

According to many surgeons [6, 7], the most important factor in the occurrence of the colo-esophageal anastomotic dehiscence in any method of grafting, including the retrosternal graft, is its compression by surrounding tissues. Currently, there are more and more studies proving a statistically significant relationship between anastomotic dehiscence and the size of the superior thoracic aperture [6, 8, 9]. There are reports on the impact of some anatomical formations on the graft compression, and methods are proposed to eliminate this pressure. For example, the dissection of the sternothyroid muscles, the resection of the

sternoclavicular joint, medial parts of the clavicle and first rib have been described, indicating that they help to reduce the incidence of anastomotic dehiscence [10].

Due to the fact that the sternal manubrium is reclined from the vertical axis, it is due to the manubrium that the size of the superior thoracic aperture decreases. So, this circumstance was the reason to propose the manubrium excision techniques. The use of partial excision of the sternal manubrium, mainly in the region of the left sternoclavicular joint has been described [6, 11, 12]. However, we found no scientific reports substantiating the technique of the sternal manubrium resection based on a systematic study of the interposition of anatomical structures in this area. Also, despite the observed interest in the problem of the graft compression, at present there is still a few studies that allow a comprehensive analysis of the factors leading to compression of the bowel tube in the retrosternal tunnel. Meanwhile, the knowledge of these factors seems to us important for the development of a differentiated approach in children to prevent the graft compression and the colo-esophageal anastomotic dehiscence in retrosternal esophagoplasty with colonic graft.

Aim of the study was to develop a technique that would reduce the risk of the colo-esophageal anastomotic dehiscence after esophagoplasty by preventing the colonic graft compression in the retrosternal tunnel and facilitating the surgical procedure.

Material and methods

Ultrasound examination (USE) on a SAMSUNG MEDISON Accuvixx V20 scanner (Republic of Korea) was performed in 43 infants (22 boys and 21 girls) without sternum pathology. The dorsal angle of the sternum (as determined on the dorsal side of the sternum, between

manubrium and the body of the sternum) and the thickness of the sternum manubrium in its lower and upper parts were assessed. Using 15 preparations of the sternal manubrium resected in infants, when performing esophagoplasty, a histotopographic study of the muscles located in this anatomical region was performed. To study the obtained morphological samples, the microscopy was performed using a Levenhuk C510 NG digital camera (USA). The thickness of the muscles and the size of the area they occupy were determined in different parts of the dorsal side of the sternal manubrium.

According to the developed technique (the RF Patent for Invention No. 2552095), 15 infants (8 boys and 7 girls) with esophageal atresia were operated on. To perform retrosternal esophagoplasty with colon interposition, the graft was cut out from the left half of the colon and a cervical colo-esophageal anastomosis was formed. Nine patients had the fenestration of the sternal manubrium performed across its entire length, and six infants had it performed in its upper segment only. The presence of the artificial esophagus compression was established radiographically.

For statistical analysis of the studied variables, the arithmetic mean and standard error of the mean were used. When determining a statistically significant difference between quantitative variables in groups, the Mann–Whitney ordinal test (M–W) was used. The differences in the results of statistical calculations between the groups were considered significant at p-value lower than 0.05. Statistical processing of the obtained data was performed using the STATISTICA 7.0 software package (StatSoft Inc., USA).

The performance of the study presented in the paper was approved by the Local Independent Ethics Committee of the Federal State Budget-Financed Educational Institution of Higher Education "Rostov State

Medical University" of the Health Ministry of the Russian Federation (Protocol No. 12/14 dated June 26, 2014).

Results and discussion

When assessing, to which degree the superior thoracic aperture is narrowed by the sternal manubrium in infants, an ultrasound examination was performed to measure the dorsal angle of the sternum (Fig. 1).

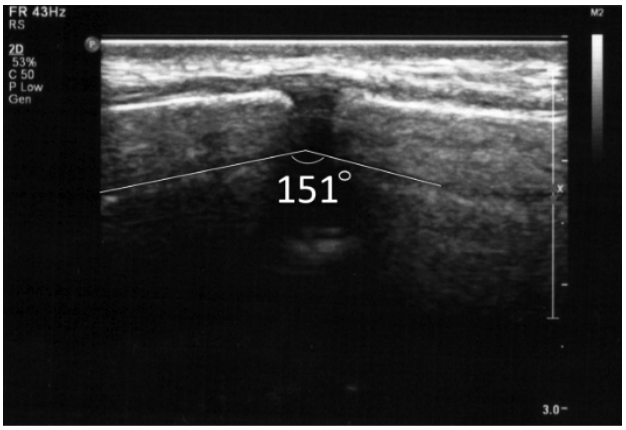

Fig. 1. Ultrasound examination of a child's sternum. On the dorsal side of the sternum, between its body and manubrium, an angle of 151° is determined

The dorsal angle of the sternum at early age was found to make 164.9°±0.8°. Moreover, in boys, this figure was 162.6°±1.3° and statistically significantly (M–W=2.66; $p<0.01$) differed from the parameter (166.8°±0.9°) measured in girls of this age. The data obtained showed that in infant boys, the sternal manubrium is more reclined backwards compared to girls and, therefore, can more often lead to the colonic graft compression. It is important to note that at ultrasound, considerable differences (reaching 24°) were recorded in sizes of the dorsal sternum angle between the examined infants. From our point of view, this dictates the need to set the value of the dorsal sternal angle in

each specific case in order to have a clear idea of the degree of the sternal manubrium displacement in the dorsal direction in a child.

The ultrasound examination we performed made it possible to establish that when the sternal manubrium is reclined posterior, the superior thoracic aperture diameter decreases, not only due to the manubrium inclination to the body of the sternum, but also due to an increase in the transverse size (thickness) of the manubrium in its upper section. Thus, in children of the studied age group, the size of the sternal manubrium upper section (at the level of the line connecting the medial edges of the clavicular notches) reaches 0.78±0.09 cm. This is statistically significantly (M–W=4.44; $p<0.01$) more than in the lower sections (above the sterno-manubrial synchondrosis) where the studied parameter made 0.63±0.09 cm. Moreover, it was not possible to establish a statistically significant difference in the studied parameters between the groups of boys and girls. Meanwhile, individual thickness, first of all, of the upper part of the sternal manubrium varied significantly, which should be taken into account when assessing the risk of colonic graft compression in the retrosternal tunnel in each specific case.

Given that the graft in the retrosternal tunnel is located on the dorsal (posterior) surface of the sternal manubrium, we considered it reasonable to study the anatomical characteristics of the sternal manubrium dorsal surface and the specific architecture of the muscles attached to it. The sternohyoid and sternothyroid muscles are attached to the posterior (graft-facing) surface of the sternal manubrium. Therefore, the level of location of these muscles on the dorsal surface of the sternal manubrium and the degree of their development are extremely important for assessing the risk of colonic graft compression. A histotopographic study revealed that the muscle layer covers the posterior surface of the sternal manubrium differently in its different parts. Significant differences were found in the

distribution and severity of the muscle layer on the dorsal side of the sternal manubrium in its areas above and below the first rib.

Thus, a histotopographic study revealed the clearly contoured outer and inner muscle layers, occupying 29.1±2.5% of the surface of the upper part of the sternal manubrium dorsal side. Each of the muscle layers includes two paired muscles. The outer layer contains the sternohyoid muscles, and the inner layer contains the sternothyroid muscles. Meantime, studying a fragment of the sternal manubrium dorsal side, which was located below the first rib, we could establish that 16.3±1.9% of its surface was covered with a single muscle layer containing the sternothyroid muscles. This difference was statistically significant (M-W=4.42; $p<0.01$). Highly statistically significant (M–W=6.71; $p<0.001$) was the predominance in the thickness of the muscle layer in the upper part of the sternal manubrium dorsal side (2.7±0.3 mm) over the thickness of the muscles (1.3±0.2 mm) lying on the dorsal surface of the sternal manubrium below the first rib.

The data obtained indicate that the colonic graft compression in the retrosternal tunnel, which is associated with the risk of the colo-esophageal anastomotic dehiscence, is caused primarily by the upper part of the sternal manubrium covered with a powerful muscle layer reclined from the body of the sternum backwards. The revealed new data on the factors contributing to graft compression served as the basis to develop a method [13] to reduce the risk colo-esophageal anastomosis dehiscence occurrence after retrosternal intestinal esophagoplasty.

Prevention of the anastomotic dehiscence should be aimed at with creating the conditions of no compression for the colonic graft passed in the retrosternal tunnel at surgical esophagoplasty. To reach this aim, we have proposed to remove the sternal manubrium section of a certain size depending on the numerical value of the sternum dorsal angle measured

at ultrasound examination in each patient before surgery. In a situation where the numerical value of the dorsal angle of the sternum is under 165°, the child should undergo the removal of the median fragment of the sternal manubrium along its entire length, leaving intact lateral sections located next to the paired clavicular and two upper costal notches (Fig. 2).

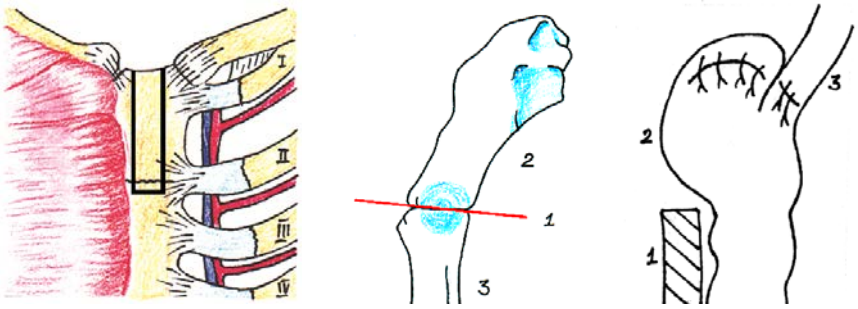

Fig. 2. Resection of the sternal manubrium performed along its entire length. A – front view. B – side view: 1 – resection level; 2 – sternal manubrium; 3 – the body of the sternum. C – view after surgery. The surgical field was expanded and the possibility of compression of the colonic graft was eliminated: 1 – body of the sternum; 2 – intestine; 3 – stump of the esophagus

When the dorsal angle of the sternum reaches or exceeds 165°, the median fragment of the sternum manubrium should be removed only to the lower border of the first costal notch. In this case, as in the first variant, it is necessary to leave intact lateral sections of the sternal manubrium near the sternoclavicular joints and synchondroses of the first rib with the sternum (Fig. 3).

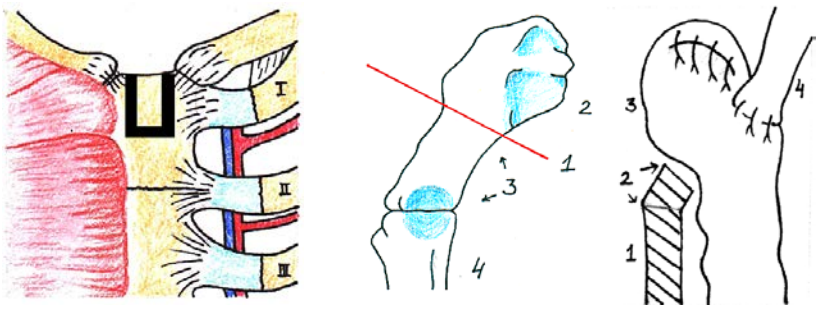

Fig. 3. Resection of the sternal manubrium performed with preservation of the lower section. A – front view. B – side view: 1 – resection level; 2 – sternal manubrium; 3 – undamaged lower fragment of the sternal manubrium; 4 – the body of the sternum. C – view after surgery. The surgical field was expanded and the possibility of compression of the colonic graft was eliminated: 1 – body of the sternum; 2 – undamaged lower fragment of the sternal manubrium; 3 – colonic transplant; 4 – stump of the esophagus

The use of this technique prevents the risk of graft compression, and saves a large area of the sternal manubrium. This makes a lesser extent of breaking the integrity of the pectoralis major muscles possible and leaves the fixation sites of the sternothyroid muscles intact. Saved and not severely traumatized muscles can be used to protect the anastomosis area by placing them in front of the created anastomosis. Fenestration of only the upper fragment of the sternal manubrium saves its lower part, which is largely filled with red bone marrow.

In all 15 patients with esophageal atresia who underwent retrosternal intestinal esophagoplasty with an individually determined level of the sternal manubrium resection, the postoperative period was without signs of colo-esophageal anastomotic dehiscence or of the colonic graft necrosis. The X-ray examination performed did not reveal graft compression in the retrosternal tunnel. The contrast agent bypasses the saved part of the esophagus without delay and completely fills the graft that runs smoothly in the forward direction behind the sternum.

Next, the contrast enters the stomach in portions (Fig. 4). No signs of compression or esophageal diverticula formation were seen.

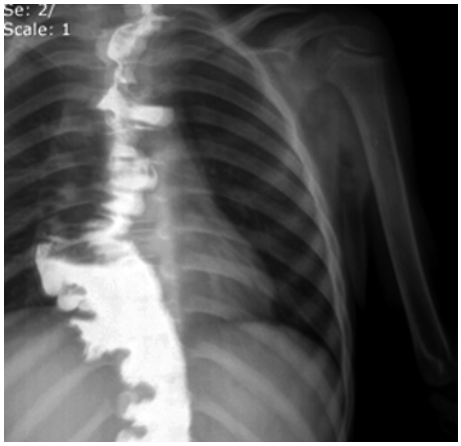

Fig. 4. Contrast esophagography in a patient after retrosternal intestinal esophagoplasty performed according to the developed method. Sufficient patency of contrast through the colonic graft

The data obtained show that the proposed technique prevents the compression of the colonic graft in the retrosternal tunnel, thereby eliminating an important prerequisite for the development of the colo-esophageal anastomotic dehiscence.

In addition, a limited size of the surgical field making manipulations in the wound more difficult represents a significant factor contributing to the anastomotic dehiscence development. The resection of the sternal manubrium provides an extended surgical access, which facilitates the performance of the surgical technique and has a positive effect on the surgery results.

The study has established a number of topographic and anatomical prerequisites associated with the development of colo-esophageal anastomosis dehiscence after retrosternal esophagoplasty with colonic

graft in infants with esophageal atresia. The opinion was confirmed that the compression of the colonic graft in the retrosternal tunnel, which is an important factor for the development of the colo-esophageal anastomosis dehiscence, is made by the sternal manubrium and the muscles located on its inner surface. It was revealed that the upper part of the sternal manubrium (above the level of the first rib attachment) exerts the most pronounced pressure on an artificial esophagus, being statistically significantly thicker and covered with a more prominent layer of muscles over a larger area. At the same time, this section of the sternal manubrium is the most reclined backwards, which is the main factor that ensures its pressure on the graft. The degree of this reclination (and, accordingly, of the graft compression) is characterized by the magnitude of the dorsal angle. The value of this variable statistically significantly prevails in girls and has significant individual variances. On the basis of the data obtained, a method of an individual approach to the sternal manubrium resection was developed and successfully applied in 15 patients, which guaranteed the avoidance of an undesired cause of the colo-esophageal anastomotic dehiscence such as the graft compression in the retrosternal tunnel and provided ease of manipulation in the surgical wound. Neither signs of colo-esophageal anastomotic dehiscence, nor artificial esophagus compression were seen in any of the cases.

Conclusion

The proposed method in each case enables a surgeon to assess the degree of narrowness of the retrosternal space and, owing to the individual choice of the sternum resection volume, to eliminate undesired factors involved in the development of colo-esophageal anastomotic dehiscence in retrosternal esophagoplasty in patients with esophageal

atresia, facilitating the performance of surgical technique and preventing the graft compression in the retrosternal tunnel.

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