УДК 617.54-001-053.2-08
DOI: 10.17816/PTORS6273-78

# EXTERNAL STABILIZATION OF THE THORAX IN COMPLEX TREATMENT OF CHILDREN WITH SEVERE CHEST INJURIES: DESCRIPTION OF CLINICAL CASES

© ***M.N. Satyvaldayev[1], M.A. Akselrov[2]***

[1] Regional Clinical Hospital No 2 of the Tyumen Region, Tyumen, Russia;
[2] Tyumen State Medical University of the Ministry of Health of the Russian Federation, Tyumen, Russia

Received: 22.08.2017 Accepted: 07.05.2018

**Aim.** To describe a proposed method of treating children with a traumatic disorder of the thorax.
**Material and methods.** Under the conditions of work in the Tyumen "Center of Medicine of Catastrophes", doctors of all specialties of the Tyumen region interact with thoracic surgeons. Special attention is given to children with polytrauma. In the Tyumen region for the period 2016–2017, two travels to treat children with multiple floating fractures of the ribs on one side were made. The patients were treated by using an original method of external chest stabilization. We present the advantages of the method in the descriptions of the clinical cases.
**Results.** The chest structure was stabilized by using a V-shaped model of the Cramer tire to increase the area of contact with the chest. The tire was fixed with Kapron thread No 5 by using a large cutting needle, which was wound under the ribs after marking the floating section of the chest. The ribs were stitched for stable areas along the edges and for an unstable fragment of the thorax. Later, the V-shaped model of the Cramer tire was applied and fixed by threads to the chest. This method is simple and acceptable in any hospital and allows early spontaneous breathing with no purulent-septic complications.
**Conclusions.** This method of restoring the skeletal function of the thorax with the help of external fixation of the V-shaped model of the Cramer tire allows reliable minimally invasive stabilization of the chest wall. External stabilization of the thorax allows early transfer of the victims to independent breathing and shortens the duration of treatment in the intensive care unit. The availability and simplicity of the design makes it possible to perform this procedure everywhere. Video thoracoscopic support is needed only if there is a suspicion of a clotted hemothorax.

**Keywords:** floating rib fractures; stabilization of the thorax; polytrauma in children.

# ВНЕШНЯЯ СТАБИЛИЗАЦИЯ ГРУДНОГО КАРКАСА У ДЕТЕЙ ПРИ КОМПЛЕКСНОМ ЛЕЧЕНИИ ТЯЖЕЛОЙ ТРАВМЫ ГРУДНОЙ КЛЕТКИ: ОПИСАНИЕ КЛИНИЧЕСКИХ СЛУЧАЕВ

© ***М.Н. Сатывалдаев[1], М.А. Аксельров[2]***

[1] ГБУЗ Тюменской области «Областная клиническая больница № 1», Тюмень;
[2] ФГБУ ВО «Тюменский государственный медицинский университет» Минздрава России, Тюмень

Статья поступила в редакцию: 22.08.2017 Статья принята к печати: 07.05.2018

**Актуальность.** Травма грудной клетки является лидирующей причиной фатальных осложнений. Частота травмы груди по-прежнему остается высокой. Экскурсия флотирующего фрагмента грудной стенки приводит к шунтированию крови в малом круге кровообращения, вызывая синдром «шокового легкого». Существует множество методов фиксации флотирующих участков грудного каркаса, которые технически сложны и привязаны к тем или иным материалам. Поиск возможности стабилизировать грудино-реберный комплекс без затрат на изготовление индивидуальных приспособлений лег в основание данной работы.
**Цель исследования** — описать предложенный способ лечения детей с травматическим нарушением каркасной функции грудной клетки.
**Материал и методы.** К торакальному хирургу Тюменского центра медицины катастроф обращаются врачи всех специальностей Тюменской области. Особое место занимают дети с политравмой. В Тюменской области за 2016–2017 гг. выполнено два выезда к детям с множественными флотирующими переломами ребер с одной стороны. Пациентам был применен оригинальный способ внешней стабилизации грудной клетки. Преимущества способа представлены при описании клинических случаев.

■ For citation: Satyvaldayev MN, Akselrov MA. External stabilization of the thorax in complex treatment of children with severe chest injuries: Description of clinical cases. *Pediatric Traumatology, Orthopaedics and Reconstructive Surgery*. 2018;6(2):73-78. doi: 10.17816/PTORS6273-78

**Результаты и обсуждение.** Пациентам выполнена стабилизация грудного каркаса моделированной шиной Крамера V-образной формы для увеличения площади контакта с грудной клеткой. Шину фиксировали капроновой нитью № 5 с крупной режущей иглой, которую заводили под ребра после разметки флотирующего участка грудной клетки. Ребра прошивали за стабильные участки по краям и за нестабильный фрагмент грудного каркаса. В последующем прикладывали V-образную моделированную шину Крамера и фиксировали нитями к грудной клетке. Данный метод прост, может быть применен в любом стационаре и позволяет добиться раннего спонтанного дыхания с отсутствием гнойно-септических осложнений.

**Выводы.** Метод восстановления каркасной функции грудной клетки с помощью внешней фиксации V-образной моделированной шины Крамера дает возможность надежно, малоинвазивно стабилизировать грудную стенку. Внешняя стабилизация грудного каркаса позволяет в ранние сроки переводить пострадавших на самостоятельное дыхание, сокращает длительность лечения в палате интенсивной терапии. Благодаря доступности и простоте конструкции данную процедуру можно осуществлять повсеместно. Видеоторакоскопическая поддержка необходима лишь при подозрении на свернувшийся гемоторакс.

**Ключевые слова:** флотирующие переломы ребер; стабилизация грудной клетки; политравма у детей.

## Background

Chest injuries are one of the most severe forms of trauma and are the primary cause of complications and deaths [1, 2]. The prevalence of chest injuries in peacetime traumas remains high and ranks third among all types of traumas. It accounts for 12.5% of all injury cases, and 55.4% of all injury-related deaths, as per autopsies. With multiple unilateral fractures of the ribs, the vital capacity of the lungs on the side of the lesion is reduced by 30%, and the costal valve reduces by 50% [3]. Floating rib fractures occur in 10%–20% of patients with closed chest injury and are associated with a fatality rate of 10%–35% [4].

One of the pathogenetic mechanisms in severe chest injury is the pathological excursion of the floating fragment of the chest wall that results in lung compression, alveolar collapse, and shunting of the blood in a small circle of blood circulation that leads to shock lung syndrome, with severe limitation of the chest respiratory excursion due to pain syndrome. Closed chest injury with floating rib fractures is present in 80%–90% of the cases owing to intrapleural complications, such as pneumothorax and hemothorax, caused by trauma to the intercostal vessels or injury of the lungs by rib fragments [5, 6].

In 1951, B.M. Carter et al. reported the use of artificial lung ventilation in severe injury for creating adequate drainage of the tracheobronchial tree by tracheostomy and provide internal support for the lungs by intermittent ventilation [7]. The method of internal pneumatic stabilization has now become widespread and has become the main method for the treatment of patients with floating rib fractures [8].

Anti-shock therapy, drug treatment, infusion therapy, analgesia, and antibacterial therapy are well known and approved, as comprehensively established in the recommendations of the national guidelines for “Intensive therapy” [9]. With respect to the surgical approach, this problem is cross-sectoral, involving traumatology, surgery, thoracic surgery, and pediatric surgery. Today, there is lack of consensus regarding the timing and scope of any medical manipulation at this time.

There are reports by the Russian public organization, the Russian Society of Surgeons, about chest injury, where problems associated with the stabilization of the chest are highlighted [10]. Chest stabilization methods are classified as internal and external. While using the internal, pneumatic stabilization method [11], the authors who aimed to identify the optimal method of ventilation succeeded in reducing the hospitalization duration and decreasing the purulent and septic complications [12, 13]. Isolated external stabilization of the chest appears to cause severe chest injury; therefore, it is an additional method that provides a stable chest frame during intensive therapy. The trocar is entered through the floating segment of the chest for traction to the plastic panel; alternatively, the injured ribs are fixed to a special splint [14–16].

The external method of fixation of the chest frame should restore the shape of the chest and be less traumatic. Currently, several methods for the fixation of the floating segments of the chest frame exist; the main disadvantages of these methods are the complexity of implementation and necessity of certain materials for their use [17]. The search for an opportunity to stabilize the sterno-costal without

additional costs for the manufacture of individual devices with maximum comfort for the patient formed the basis of this work.

This **study aimed** to describe the proposed method for treating children with traumatic disorders of the thoracic frame function.

## Material and methods

Doctors from all specialties in the Tyumen region apply to the thoracic surgeon of the Tyumen disaster medicine center, to consult patients remote from the thoracic center whose treatment is associated with staying in the district medical institutions. Among all the consultations, children with polytrauma require a multidisciplinary approach and special focus. The transfer of this category of patients with a recent trauma to the thoracic center is not always possible due to the severity of the condition, and their treatment is conducted on site on arrival of the specialized team. Thus, during 2016–2017, in the Tyumen region, two visits were made to children with severe chest injury, with multiple floating rib fractures on one side. The cause of the injury was a car accident. Both patients were treated with an original method of external chest stabilization. Based on this method, the useful model patent No 174276 "Device for external stabilization of the thoracic frame with floating rib fractures" was registered [18].

Given the small number of observations, the advantages of the used method are presented in the description of clinical cases. Parental consent was obtained for the surgical treatment. The method of surgical aid was approved by the ethical committee at the Tyumen State Medical University. The Department of Scientific Research under the Tyumen State Medical University approved the publication of the medical data and photographs. Parents and patients themselves provided consent for the publication of the data about the disease and the placement of the photographs in the media.

## Results and discussion

*Case 1.* A 17-year-old patient with multiple floating fractures of the ribs 4 and 9 on the left with hemopneumothorax on the left side of the injury site underwent thoracostomy on the left side with evacuation of 300 mL lysed blood. Tracheostomy was performed on day 5 after the trauma; however, it was not possible to wean the patient off the respirator. This patient consulted the thoracic surgeon on the 8$^{th}$ day after the trauma, following a telephonic consultation with the thoracic surgeon. Objectively, upon examination, the surgeon observed paradoxical respiration with floating. The initial radiographic image on the site of the consultation was as follows: the lungs were straightened, the mediastinum was structural, there were multiple fenestrated fractures of the ribs on the left, and the left pleural cavity was drained. On the 9$^{th}$ day after the injury, the patient underwent a surgery to stabilize the chest frame; the V-shaped Cramer splint was used as the stabilizing material to increase the contact area with the chest and mold it in the shape of the chest frame. The splint was fixed with a nylon thread no. 5 using a large cutting needle that was inserted under the ribs. The procedure was performed in the intensive care unit on a bed, under intravenous anesthesia. After marking the floating area of the thorax and processing the surgical field, the sutures were overlapped behind the ribs with formation of three conditional lines. The ribs were sutured with stable areas along the edges and the unstable fragment of the chest frame. Thereafter, a V-shaped modeled Cramer splint was applied and fixed to the chest with sutures (Figure 1).

The post-operative discharge is estimated based on the pleural drainage and presence of hemorrhage. Control radiography of the thoracic organs showed no complications. Two days postoperatively, the patient was weaned from the respirator. During the treatment course, the patient's condition returned to normal; this enabled the removal of the V-shaped modeled Cramer splint on postoperative day 9. The patient was discharged on postoperative day 14 when the chest frame was stabilized, with a satisfactory clinical and radiologic picture.

*Case 2.* Case 2 was that of a 12-year-old patient with multiple floating fractures of ribs 3 to 10 on the right side and hemopneumothorax on the right. At the injury site, laparotomy was performed with suture of the liver rupture and draining of the right pleural cavity (100 mL of lysed blood was evacuated). This pediatric patient visited the thoracic surgeon on the 4$^{th}$ day after injury; the consultation was performed on phone, during which, the visit to the thoracic surgeon was fixed. Objectively, upon examination, the surgeon observed paradoxical respiration with floating. The initial radiographic im-

**Fig. 1.** Appearance of the patient after the surgery

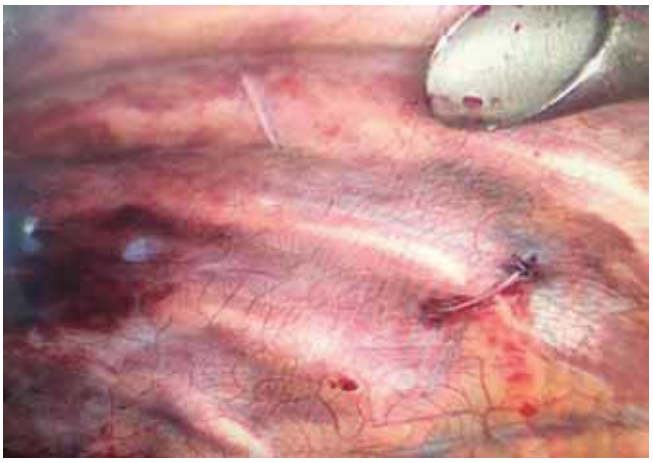

**Fig. 2.** Appearance with video-assisted thoracoscopy; the ligatures are visible on the skin

age of the site under consultation showed the following: the lung had expanded on the left; on the right, there was homogeneous total shadowing of the right hemothorax with displacement of the mediastinum to the right; there were multiple fenestrated fractures of the ribs on the right; and the right pleural cavity was drained. Sanation fibrobronchoscopy was technically impossible because the endotracheal tubes no. 4 and 5 could not be inserted into the endoscope. Rigid bronchoscopy was also technically impossible. On day 5, the patient underwent the surgery for stabilization of the chest frame. Considering the radiographic image of the chest organs and the presence of an endoscopic stand for endovideosurgical surgeries, diagnostic video-assisted thoracoscopy was performed with laparaports, and carboxythorax was applied at a pressure of 10 mm Hg.

In thoracoscopy, a blood clot with a volume of up to 150 mL was evacuated from the pleural cavity. Further, the right lung was traumatically changed; that is, there was pulmonary contusion. The material for stabilization of the chest frame was the Cramer splint that was V-shaped to increase the contact area with the chest and to mold it in the shape of the chest frame. For fixation, a caprone thread no. 5 with a large cutting needle was used to insert it under the ribs. The procedure was performed in the operating room during video-assisted thoracoscopy under endotracheal anesthesia. After marking the floating area of the chest and processing the surgical field, percutaneous sutures were taken under the ribs with the needle passing along the upper edge of the rib and under the rib in the downward direction; thereafter, the needle was removed through the skin under video-assisted thoracoscopic control (Figure 2).

Thus, we obtained three conventional rib-suturing lines on the stable areas along the edges and on an unstable fragment of the chest frame. Thereafter, a V-shaped modeled Cramer splint was applied and fixed with threads to the chest. Further,

**Fig. 3.** Placement of the fixing threads to the undamaged rib parts and to an unstable fragment of the chest frame

**Fig. 4.** Appearance of the chest wall after surgery completion

the pleural cavity was drained with two drains along the pleural cavity. The surgery was completed by the application of a tracheostoma (Figures 3, 4).

Control radiography of the chest organs revealed positive dynamics in the form of increased pneumatization of the right lung (Figure 5).

On day 7, the patient was weaned from the respirator; after 14 days, the V-shaped Cramer splint was removed. The patient was discharged on day 20 after stabilization of the chest frame with a satisfactory clinical and radiologic picture.

Thus, it is necessary to compare the results in a group of similar injury cases to evaluate the results of treatment; however, there are few cases with such injuries in our area. The data of 52 patients with floating fractures of the ribs treated in the M.I. Kalinin Samara regional clinical hospital during 2011 to 2014 can be considered an example [17]. All these patients received complex treatment of severe chest injury and acute respiratory failure; internal pneumatic stabilization was performed with artificial ventilation of the lungs and surgical stabilization of the chest wall frame. Surgical treatment was performed for all patients within 6–72 hours from the moment of eduction from a traumatic shock. With respect to the methods of external stabilization, skeletal traction with the ribs was performed in 14 patients, skeletal traction with fixing of the transpleural ligatures with thoracotomy or video-assisted thoracoscopy in 6 patients, and labor-intensive application of the device for extrafocal fixation of multiple and floating fractures of the ribs and sternum in 7 patients, where the fixation points were the intact collarbone and the pelvic bones that enabled the arrest of respiratory failure within 7–12 days; 25 patients underwent extra-cortical osteosynthesis of 2–5 damaged ribs with the extensible approach, while the duration for the artificial ventilation of the lungs was 2.5 days. Comparing these previous results with our data, we can state that our original method of stabilizing the chest frame is less labor-intensive with regard to installation, does not require special equipment, does not require an extensible approach directly to the ribs, can be performed in the intensive care ward, and involves an average duration of 4.5 days for artificial ventilation.

These clinical observations will draw the attention of surgeons, thoracic surgeons, pediatric surgeons, and traumatologists to the possibility of external fixation of the sternocostal complex in children with severe chest injury and multiple floating rib fractures. A V-shaped modeled Cramer splint (available in all district hospitals) was used as a stabilizer that was fixed to the ribs along three imaginary lines, two of which pass along the stable regions along the edges; the third passes from the middle of the unstable fragment of the thoracic framework. The surgery can be performed both with and without video-assisted thoracoscopic control.

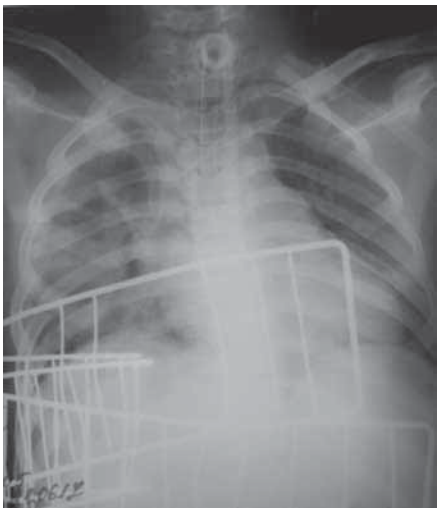

**Fig. 5.** A plain radiograph of the thoracic organs 6 days after the surgery

## Conclusions

1. The developed method of restoring the frame function of the thorax using an external fixation of the V-shaped modeled Cramer splint enables minimally invasive, reliable stabilization of the chest wall.
2. External stabilization of the chest frame enables early independent breathing in the patients and shortens the duration of treatment in the intensive care unit.
3. The accessibility and simplicity of the design enables the performance of this procedure at any location, including within the framework of specialized assistance "off-premise".
4. Video-assisted thoracoscopic support is necessary only in cases with a suspicion of a clotted hemothorax and ensures control over the fixation of the ligatures to the ribs.

## Funding and conflict of interest

The authors declare no conflicts of interest. The study received no external funding.

## References


1. Цеймах Е.А., Бомбизо В.А., Гонтарев И.Н. Мини-инвазивные технологии в комплексном лечении больных политравмой с доминирующими повреждениями груди. – Барнаул, 2013. [Tseymakh EA, Bombizo VA, Gontarev IN. Minimally invasive technologies in complex treatment of patients with polytrauma with dominant lesions of the breast. Barnaul; 2013. (In Russ.)]
2. Athanassiadi K, Gerazounis M, Theakos N. Management of 150 flail chest injuries: analysis of risk factors affecting outcome. *Eur J Cardiothorac Surg*. 2004;26(2):373-376. doi: 10.1016/j.ejcts.2004.04.011.
3. Вагнер Е.А. Хирургия повреждений груди. – М.: Медицина, 1981. [Vagner EA. Surgery of breast injuries. Moscow: Meditsina; 1981. (In Russ.)]
4. Davignon K, Kwo J, Bigatello LM. Pathophysiology and management of the flail chest. *Minerva Anestesiol*. 2004;70(4):193-199.
5. Хирургические болезни. Руководство / Под ред. В.Д. Федорова, С.И. Емельянова. – М.: МИА, 2005. [Surgical diseases. Ed by V.D. Fedorov, S.I. Emel'yanov. Guidelines. Moscow: MIA; 2005. (In Russ.)]
6. Liman S. Chest injury due to blunt trauma. *European Journal of Cardio-Thoracic Surgery*. 2003;23(3):374-378. doi: 10.1016/s1010-7940(02)00813-8.
7. Carter BN, Giuseffi J. Tracheotomy a useful procedure in thoracic surgery with particular reference to its employment in crushing injuries of the thorax. *J Thorac Surg*. 1951;21(5):495-505.
8. Nishiumi N, Fujimori S, Katoh N, et al. Treatment with internal pneumatic stabilization for anterior flail chest. *Tokai J Exp Clin Med*. 2007;32(4):126-130.
9. Интенсивная терапия: национальное руководство / Под ред. Б.Р. Гельфанда, А.И. Салтанова. – М.: ГЭОТАР-Медиа, 2009. [Intensive care: national guidelines. Ed by B.R. Gel'fand, A.I. Saltanov. Moscow: GEOTAR-Media; 2009. (In Russ.)]
10. Российское общество хирургов. Национальные клинические рекомендации по травмам грудной клетки [интернет]. 2014 [доступ от 12.02.2018]. Доступно по: http://общество-хирургов.рф/stranica-pravlenija/klinicheskie-rekomendaci/torakalnaja-hirurgija/travmy-grudnoi-kletki.html. [Russian Society of Surgeons. National clinical guidelines for chest injuries [Internet]. 2014 [cited 2018 Feb 12]. Available from: http://общество-хирургов.рф/stranica-pravlenija/klinicheskie-rekomendaci/torakalnaja-hirurgija/travmy-grudnoi-kletki.html. (In Russ.)]
11. Ambiavagar M, Robinson JS, Morrison IM, Jones ES. Intermittent positive pressure ventilation in the treatment of severe crushing injuries of the chest. *Thorax*. 1966;21(4):359-366. doi: 10.1136/thx.21.4.359.
12. Trinkle JK, Richardson JD, Franz JL, et al. Management of Flail Chest Without Mechanical Ventilation. *Ann Thorac Surg*. 1975;19(4):355-363. doi: 10.1016/s0003-4975(10)64034-9.
13. Kiraly L, Schreiber M. Management of the crushed chest. *Crit Care Med*. 2010;38(9 Suppl):S469-477. doi: 10.1097/CCM.0b013e3181ec6731.
14. Греджев А.Ф., Паниотов А.П. Панельная фиксация при множественных переломах ребер // Клиническая хирургия. – 1977. – № 8. – С. 69–73. [Gredzhev AF, Paniotov AP. Panel fixation for multiple fractures of ribs. *Klinicheskaia khirurgiia*. 1977;(8):69-73. (In Russ.)]
15. Голобородько Н.К., Булага В.В. Общие принципы работы специализированного центра политравмы и шока // Вестник хирургии им. И.И. Грекова. – 1989. – Т. 142. – № 6. – С. 139–141. [Goloborod'ko NK, Bulaga VV. General principles of the specialized center of polytrauma and shock. *Vestn Khir Im I I Grek*. 1989;142(6):139-141. (In Russ.)]
16. Котов И.И., Тилелюева Е.С. Методика наружной стабилизации грудной стенки при флотирующих переломах ребер // Вестник Национального медико-хирургического Центра им. Н.И. Пирогова. – 2014. – Т. 9. – № 1. – С. 43–47. [Kotov II, Tilelyuyeva ES. Methods of external stabilization of the thoracic wall in flotation fractures of the ribs. *Vestnik Natsional'nogo mediko-khirurgicheskogo Tsentra im. N.I. Pirogova*. 2014;9(1):43-47. (In Russ.)]
17. Бенян А.С. Применение этапного подхода к стабилизации грудной клетки при множественных и флотирующих переломах ребер // Медицинская наука и образование Урала. – 2014. – Т. 15. – № 4. – С. 60–63. [Benyan AS. The application of staged approach to stabilization of chest at patients with multiple rib fractures and flail chest. *Meditsinskaia nauka i obrazovanie Urala*. 2014;15(4):60-63. (In Russ.)]
18. Патент РФ на изобретение № 174276/09.01.17. Сатывалдаев М.Н., Аксельров М.А. Устройство для внешней стабилизации грудного каркаса при флотирующих переломах ребер. [Patent RUS № 174276/09.01.17. Satyvaldayev MN, Akselrov MA. Device for external stabilization of the thoracic framework with flotation fractures of the ribs. (In Russ.)]


*Information about the authors*


**Mustakhim N. Satyvaldayev** — MD, Head of the Surgical Thoracic Department No 1 of the Regional Clinical Hospital No 1 of Tuymen Region, Tyumen, Russia. E-mail: m.sativaldaev@gmail.com.

**Mikhail A. Akselrov —** MD, PhD, Professor, Head of the Department of Pediatric Surgery, Traumatology and Anesthesiology of the Tyumen State Medical University of the Ministry of Health of the Russian Federation, Head of the Children's Surgery Department No 1 of the Regional Clinical Hospital No 2 of the Tyumen Region, Tyumen, Russia. E-mail: akselerov@mail.ru. ORCID: https://orcid.org/0000-0001-6814-8894.

**Мустахим Нагимович Сатывалдаев** — заведующий хирургическим торакальным отделением № 1 ГБУЗ Тюменской области «Областная клиническая больница № 1», Тюмень. E-mail: m.sativaldaev@gmail.com.

**Михаил Александрович Аксельров** — д-р мед. наук, профессор, заведующий кафедрой детской хирургии, травматологии и анестезиологии ФБГОУ ВО «Тюменский государственный медицинский университет» Министерства здравоохранения РФ, заведующий детским хирургическим отделением № 1 ГБУЗ Тюменской области «Областная клиническая больница № 2», Тюмень. E-mail: akselerov@mail.ru. ORCID: https://orcid.org/0000-0001-6814-8894