DOI 10.26724/2079-8334-2023-1-83-179-183
UDC 616.712–001:616.712.1–001.5: 617.54

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COMPARATIVE ANALYSIS OF THE EFFECTIVENESS OF DIFFERENT TYPES OF SURGICAL STABILIZATION OF THE CHEST WALL IN CASE OF MULTIPLE RIB FRACTURES

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The choice of the method of surgical stabilization of the chest wall in case of multiple rib fractures is controversial in the case of various types of injuries and the presence of intrapleural complications. Clinical trials were based on a group of 637 patients with complicated rib fractures. Thoracoscopic external fixation of rib fractures was performed in 388 patients, rib plates fixation – 194, intramedullary osteosynthesis – 34, pneumatic stabilization of the chest wall – in 21 patients. We observed a significant reduction in the length of stay of patients in the intensive care unit in patients who underwent thoracoscopic external fixation of rib fractures. The use of rib plates is a reliable method of treating multiple rib fractures without additional damage to the lungs and pleura. Thoracoscopic external fixation of costal fragments has significant advantages over other methods in the presence of intrapleural pathology and traumatic lung injury.

Key words: rib fractures, surgical treatment of rib fractures, thoracoscopic external fixation of rib fractures.

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ПОРІВНЯЛЬНИЙ АНАЛІЗ ЕФЕКТИВНОСТІ РІЗНИХ ВИДІВ ХІРУРГІЧНОЇ СТАБІЛІЗАЦІЇ КАРКАСУ ГРУДНОЇ СТІНКИ ПРИ МНОЖИННИХ ПЕРЕЛОМАХ РЕБЕР

Вибір методу хірургічної стабілізації грудної стінки при множинних переломах ребер є суперечливим при різних видах травм та наявності внутрішньо плевральних ускладнень. Численні систематичні огляди повідомляють про важливий вплив методів хірургічної фіксації переломів ребер для надійної стабілізації грудної клітки. Клінічні випробування проводилися на групі з 637 пацієнтів з ускладненими переломами ребер. Торакоскопічна зовнішня фіксація переломів ребер виконана у 388 пацієнтів, фіксація реберними пластинами – 194, інтрамедулярний остеосинтез – 34, пневмостабілізація грудної стінки – 21 хворому. Застосування реберних пластин є надійним методом лікування множинних переломів ребер без додаткового пошкодження легень і плеври. Торакоскопічна зовнішня фіксація реберних уламків має суттєві переваги перед іншими методами за наявності внутрішньоплевральної патології та травматичного ушкодження легень.

Ключові слова: переломи ребер, хірургічне лікування переломів ребер, торакоскопічна зовнішня фіксація переломів ребер.

The study is a fragment of the research project: "Improvement of surgical tactics for diseases of the neuroendocrine system's organs in order to improve treatment results and the quality of patients' life", state registration No. 0122U001740.

Multiple rib fractures are common injuries in both the young and elderly. Rib fractures account for 10 % of all trauma admissions and are seen in up to 39 % of patients after thoracic trauma [4]. The number of ribs fractured correlates with the severity of the injury and together with age, they are the most important determinants of morbidity and mortality [7, 9]. Four or more fractured ribs are associated with higher mortality rates and seven or more have a mortality rate of 29 % [1]. The presence of a flail chest alone has a reported mortality rate of 33 %, since the paradoxical chest movement further inhibits effective ventilation [2, 6]. Fracture of the ribs due to injury can be accompanied by numerous complications. Stabilization of the chest wall is an important issue in the treatment of patients with chest injuries [3, 11]. The most pronounced violations of respiratory function occur in multiple fractures of the ribs with displacement of fragments and loss of stability of the chest wall with formation of floating segments [5]. There are many methods of stabilizing the chest wall: intramedullary osteosynthesis (IMOS), fixation with rib plates (RP), thoracoscopic external fixation of rib fractures (TEFRF), pneumatic stabilization with lung ventilation (PS). However, some of these methods have significant drawbacks: inadequate repositioning and unstable retention of broken fragments.

The purpose of the study was to determine the effectiveness of each of the known surgical methods of fixation of rib fragments in various types of rib fractures.

Materials and methods. During 2015–2022, we analyzed 1,038 patients with closed chest injuries. Among them, rib fractures were diagnosed in 978 (94.2 %) patients, hemothorax – 438 (42.2 %), hemopneumothorax – 423 (40.7 %), traumatic pneumothorax – 108 (10.4 %), diaphragm rupture – 27 (2.6 %), rupture of the trachea – 9 (0.87 %). Among patients with rib fractures, uncomplicated fractures were found in 341 (34.9 %) patients, complicated – 637 (65.1 %). Our clinical trials were based on a group of 637 patients with complicated rib fractures. Inclusion criteria were fracture 3 or more ribs and flail chest. Among these patients, displacement of rib fragments was 254 (39.9 %), multiple rib fractures 238 (37.4 %), and floating rib fractures – 145 (22.8 %). The average age of patients was 38 years (from 18 to 77 years),

412 (64.7 %) men and 225 (35.3 %) women. Thoracoscopic external fixation of rib fractures (TEFRF) was performed in 388 (60.9 %) patients, fixation with the use of rib plates (RP) – 194 (30.5 %), intramedullary osteosynthesis (IMOS) of the ribs – 34 (5.3 %), pneumatic stabilization (PS) of the chest wall – in 21 (3.3 %) patients. TEFRF was performed according to the methodology developed in our clinic. Very important that 89 % of patients with multiple rib fractures were diagnosed with hemo- and hemopneumothorax, all of these patients required VATS to eliminate hemothorax and diagnose other injuries of the pleural cavity and lungs. After introducing thoracoscopic optics into the pleural cavity, the inner surface of the chest wall was examined and broken ribs were diagnosed, revealing mobile areas that penetrate into the pleural cavity or floating areas by using external finger pressure. On the upper edge of a broken rib, the fixing thread was wrapped around a rib under the control of a thoracoscope and deduced on the bottom edge outside was carried out. By pulling on the fixing threads, all broken sections of the rib were compared and fixed to the outer clamp, which was used as a perforated transparent solid sheet or metal rail. A perforated plate or metal rod should rest on undamaged areas of the chest wall. The operation was completed by drainage of the pleural cavity.

The variational-statistical method of analysis of the obtained results using a personal computer IBM 586 and an application program for working with spreadsheets Microsoft Excel was used to objectively judge the reliability of the study results. At all stages of the study, author's computer programs based on Microsoft Excel were developed, where the materials were grouped by study contingent (calculation of relative and mean values, their errors and standard deviation). The nature of the distributions for each of the variation series was evaluated by the Shapiro-Wilk method. The probability of the difference in the comparison groups, given the large number of observations and the proximity to the normal distribution, was based on the calculation of the Student's t-factor and determining the accuracy of the error prediction (p), the results were considered reliable at $p<0.05$.

Results of the study and their discussion. The outcome measures were intensive care unit (ICU) length of stay, pneumonia, and need for tracheostomy, Frequency of other complications, length of hospital stay, duration of surgery, the need for additional surgery, duration of artificial lung ventilation, cosmetic defect. The effectiveness of the methods was determined by the quality of comparison and healing of rib fragments, the need for repeated operations, and the absence of complications. The long-term outcome measures included a return to work at 6 and 12 months. We estimated the length of stay in the ICU, in the hospital, as well as the duration of artificial lung ventilation and the duration of the operation depending on the type of chest wall stabilization (Table 1).

Table 1

Comparative assessment of the length of stay of patients in the intensive care unit, and the duration of the operation using different methods of stabilization of the chest wall

	TEFRF	RP	IMOS	PS
ICU length of stay, days	1.3±0.2	2.1±0.3	2.5±0.3	4.4±0.5
duration of artificial lung ventilation, days	0.8±0.04	0.7±0.04	1.1±0.2	3.8±0.2
duration of the operation, min	26±1.9	48±5.2	58±6.7	-
length of stay in the hospital, days	9±0.8	5±0.8	8±1.1	14±1.1

Thus, with the use of TEFRF, we observed a significant reduction in the length of stay of patients in the ICU, as well as a small time required for artificial ventilation. The duration of surgery in RP and IMOS was much longer. The length of hospital stay was lowest in patients with RP, as these patients often had uncomplicated injuries without lung damage. When we used external fixation, there was a decrease in the duration of the operation aimed at fixing the costal fragments, because we have already penetrated the pleural cavity with thoracoscopic optics to eliminate hemothorax and it did not require additional operations and anesthesia. A slightly different situation was when comparing the following factors (fig. 1)

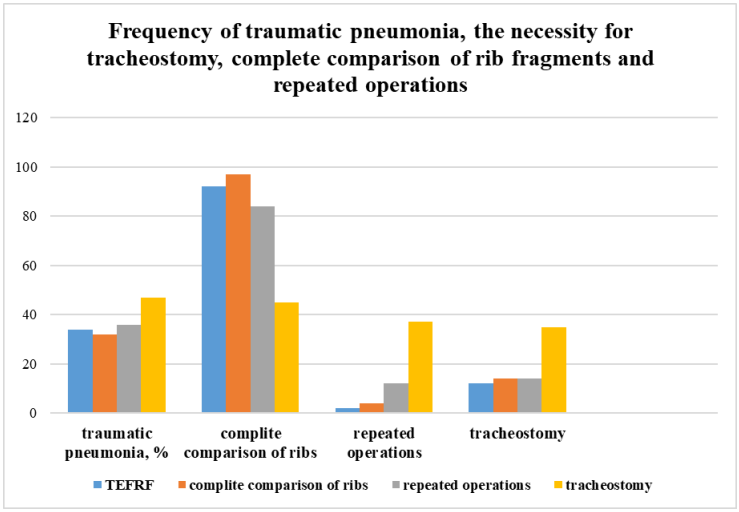

Fig. 1. Frequency of traumatic pneumonia, the necessity for tracheostomy, complete comparison of rib fragments and repeated operations using different methods of surgical stabilization of the chest wall

The complete comparison of coastal fragments was the best in the RP, however, in the TEFRF it was 92 %, which did not differ significantly. The worst comparison of rib fragments was at PS and was only 45 %. In addition, the need for repeated operations to fix the coastal fragments were observed in TEFRF only in 2 % of cases and 4 % for RP. frequency of traumatic pneumonia was almost the same for all methods except PS. The need for tracheostomy did not differ significantly from other methods of repositioning bone fragments of the ribs, only in PS, it was significantly increased.

Each of the methods of stabilization of the chest wall noted complications that occurred during surgery or in the postoperative period, as shown in Table 2. The presence of complications during and after operations is an important criterion for the effectiveness of treatment.

Table 2

Intra and postoperative complications using different methods of fixing rib fragments

	TEFRF	RP	IMOS	PS
Intraoperative bleeding, %	1.2±0.2	2.9±0.2	4.5±0.5	-
Hemothorax, %	0	2.2±0.1	2.7±0.3	20.1±2.7
Coagulated hemothorax, %	0	6.5±0.7	7.3±0.6	26.4±3.2
Iatrogenic pneumothorax, %	-	2.5±0.2	7.1±0.8	-
Hematoma of soft tissues of the chest wall, %	1.2±0.1	3.9±0.4	3.4±0.4	-
Postoperative wound suppuration, %	3.1±0.4	2.8±0.3	2.3±0.3	-
Re-dislocation of fragments, %	2.1±0.2	3.9±0.5	11.7±1.9	34.3±4.1

Thus, with TEFRF, we observed significantly fewer complications during and after surgery. It is noteworthy that there are no complications such as hemothorax, collapsed hemothorax and iatrogenic pneumothorax, because during the operation we used VATS which provided to prevent these complications. TEFRF reduced the number of intraoperative bleedings and hematomas of the soft tissues of the chest wall, as all surgical procedures were performed under visual control and did not require extensive wound opening and muscle dissection. We attribute a slightly higher percentage of postoperative wound suppuration to the open method of fixation ligatures, but we have significantly reduced the number in recent years by improving wound disinfection.

According to the results of our research, there is no doubt about the feasibility of surgical stabilization of the chest wall in case of multiple rib fractures which allows reducing mechanical ventilation time and ICU stay, lower incidence of lung infection, respiratory failure and thoracic deformity, reduced cases of tracheotomy, significantly relieved pain.

The conservative treatment methods for floating chest include wide tape fixation, cotton pad compression dressing, elastic chest strap, etc. Although the above-mentioned methods can relieve pain and assist coughing, they reduce the ventilation function of the chest on the injured side, which may lead to atelectasis and respiratory insufficiency, significantly increasing the incidence of complications [10, 12]. Moreover, the fractured ends are not anatomically fixed. The curative effects of chest wall traction fixation and internal fixation of ventilators are not reliable [13].

When conducting research to identify the reliability of fixation of various methods, it was found that used systems of IMOS on the first cycles of loading showed certain levels of irreversible deformations. The largest irreversible deformations were obtained by immersion IMOS spokes and plates. In the case of submerged IMOS of ribs with spokes and plates, a pronounced tendency to migration of IMOS elements with the destruction of the load-bearing structures of the ribs and the appearance of backlash under static loads and unsatisfactory characteristics regarding the restoration of the rigidity. Extra-focal extrapleural TEFRF on the basis of plate-rods allows to achieve of stiffness values closest to the physiological level – up to 93 % of natural stiffness [1].

Intubated patients with a flail chest, respiratory failure, and prolonged ventilation, or non-intubated patients with a flail with deteriorating pulmonary function, are now considered for operative fixation [14]. The aim is to stabilize the chest to restore pulmonary mechanics and reduce pain. Other indications include rib fractures refractory to conventional pain management, rib fracture non-union, and during a thoracoscopy performed primarily for other injuries. Flail chest is a special problem in the treatment of rib fractures [9, 11]. The pathophysiological effects of flail chest involve several factors including the size of a flail segment, change in intra-thoracic pressure during spontaneous breathing and multiple injuries to the intra-thoracic organs. Therapy is related to the seriousness of respiratory disorder associated with flail chest, the degree of chest wall deformity and other complications of conservative treatment (dependence

on mechanical ventilation with no possibility of weaning). Surgical stabilization of the chest wall is the most reliable method of treatment which allows us to avoid or interrupt the adverse effect of rib displacement and chest instability [2, 9, 10].

If the fracture causes remarkable physiological hazards, fixation should be the top priority and the side injury caused by the operation should be evaluated in order to reduce or eliminate the damages. It is important to find a balance between the fixation effect and injury caused by surgery [3, 8].

Surgical treatment of complicated multiple rib fractures has undoubted advantages over conservative treatment. Five prospective randomized controlled trials and one prospective case-control study showed that compared with non-surgical treatment, patients who received surgical stabilization of rib fractures (SSRF) had significantly shorter mechanical ventilation time and intensive care unit (ICU) stay, lower incidence of lung infection, respiratory failure and thoracic deformity, reduced cases of tracheotomy, significantly relieved pain and improved respiratory function [2, 5, 9].

Pneumatic stabilization of the chest wall with rib fractures was used only in exceptional situations in the presence of severe comorbidities, as this method was not effective enough and was accompanied by frequent complications. Thus, the need for long-term ventilation of the lungs, the incidence of pneumonia was 47 %, residual collapsed hemothorax – 26.4 %, the need for tracheostomy – 35 %, the need for repeated operations – 37 %, and complete comparison of rib fragments was only 45 % of patients.

There is no clinical evidence that can prove intramedullary fixation is superior or inferior to cortical fixation. However, in biomechanics, the intramedullary rod only provides a fixed point, and the distal rib has no fixed point, which cannot prevent the separation of the fracture line theoretically. The intramedullary rib splint is commonly used for minimally invasive fixation of simple, non-comminuted fractures. It can replace reduction and fixation of ribs using Kirschner wire. This intramedullary fixation method is good for posterior rib fractures, but cannot be used for paravertebral fractures [4, 6]. Absorbable rib nails are made of polylactic acid polymer and have been successfully used in traumatic surgery. However, rib nails are of limited use in patients with anterior rib fractures or comminuted fractures, rib stenosis and small bone marrow cavity [7, 10].

Intramedullary osteosynthesis has a number of negative effects. Thus, in our studies with IMOS, we observed long-term ICU length of stay and duration of artificial lung ventilation, often traumatic pneumonia and the need for tracheostomy. Also, negative indicators were intraoperative bleeding (4.5 %), the presence of postoperative hemothorax (2.7 %), frequent iatrogenic pneumothorax (7.1 %) and re-dislocation of costal fragments (11.7 %) that required additional surgery.

Among the surgical methods of stabilization of the chest wall, the main methods are the use of rib plates and thoracoscopic external fixation of costal fragments. The use of RP is widely used in surgical practice and we consider this method reliable for fixing any rib fragments. However, in the presence of traumatic pneumothorax or hemothorax, we have to use VATS to eliminate these pathological conditions and the use of RP is accompanied by an increase in the duration of surgery, additional incisions with muscle separation and additional tissue trauma. To avoid this, in our patients in whom we used VATS, we more widely use TEFRF as the main method of fixing rib fragments.

Thoracoscopic reduction and external fixation for rib fractures has the following advantages: small surgical incision, improved visualization of rib fractures, especially subscapular and posterior fractures, reduced damage to chest wall muscle and nerves, minimized damage to the lungs and heart, avoiding discomfort caused by plate displacement, palpable plate and scapula contact, removal of residual hemothorax, placement of chest drainage tubes and local analgesic catheters, thoracic exploration and repair of intrathoracic injuries, less postoperative pain, and shortened time back to work [2, 11].

The advantages of TEFRF compared to the use of RP are: a decrease in the number of intraoperative bleeding (1.2 %), soft tissue hematomas of the chest wall (1.2 %), and the absence of intrapleural postoperative complications (hemothorax and collapsed hemothorax), reduced duration operations, reducing the cost of operations. The complete comparison of the costal fragments was slightly less in TEFRF, but not significant. Conventional rib fractures require a large incision to achieve satisfactory exposure. Therefore, we believe that both methods are quite good in the treatment of patients with multiple rib fractures, but the indications for each of them are divided. Thus, indications for TEFRF we consider: the presence of additional damage of the pleural cavity and lungs (hemothorax, hemopneumothorax, etc.) and at the same time it is possible to fix broken ribs and eliminate other pathological conditions without additional surgery. The use of RP is absolutely indicated as a reliable way to fix the costal fragments in patients without additional damage to the lungs and pleura.

Conclusions

1. Method of pneumatic stabilization of the chest wall in case of multiple and floating fractures of the ribs should be used only in the presence of severe concomitant pathology.

2. The use of rib plates is a reliable method of treating multiple rib fractures without additional damage to the lungs and pleura.

3. Thoracoscopic external fixation of costal fragments has significant advantages over other methods in cases of the presence of intrapleural pathology and traumatic lung injury, is accompanied by minor complications and allows to fix costal fragments effectively with the best results in the future.

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Стаття надійшла 14.02.2022 р.