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Choice of sternal closure technique in patients with poststernotomy mediastinitis

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Abstract

Aim. Comparison of the efficacy of different sternal closure techniques for patients with poststernotomy mediastinitis.

Methods. From 2011 until 2016, we observed 29 patients after cardiothoracic surgeries complicated by poststernotomy mediastinitis and sternal dehiscence. We divided the patients into three groups depending on the technique used for re-osteosynthesis. In group 1, re-osteosynthesis was performed with steel surgical wire; in group 2, titanium nickelide staples were used; and in group 3, a modernized U-shaped wire suture was used on the padding, developed by the authors and consisting of perforated metal sheet (titanium mesh). During the preoperative period, all patients received vacuum wound drainage. In some patients, vancomycin paste was used during re-osteosynthesis.

Results. The rate of sternal dehiscence recurrence in group 1 was 30%, 12.5% in group 2, and 9% in group 3 ($p_{1-2} = 0.08$, $p_{1-3} = 0.04$, $p_{2-3} = 0.2$). The average hospital stay for group 1 patients was 51 days, 27 days for group 2, and 24 days for group 3 ($p_{1-2} = 0.05$, $p_{1-3} = 0.07$, $p_{2-3} = 0.4$). In unharmed sternum bone tissue, titanium nickelide staple use decreases the risk of recurrent sternal dehiscence by 17.5% compared with the widely used osteosynthesis method with the steel wire.

Conclusion. The osteosynthesis method suggested by the authors demonstrated its reliability in 91% of cases; use of vancomycin paste during re-osteosynthesis prevented recurrent wound infections, over both short- and long-term periods, in 100% of cases.

Keywords: mediastinal surgery, poststernotomy mediastinitis, sternal dehiscence, sternal osteosynthesis.

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Post-sternotomy mediastinitis is a life-threatening condition, especially in patients who have undergone open heart surgery. The incidence of this complication is up to 6% [1], but mortality related to post-sternotomy mediastinitis reaches 20%, even with the current level of care [2]. With open wound management, it increases to 50% [3]. The costs of treating patients in this group may exceed the costs of primary cardiac surgery [4], and the lack of proper surgical care contributes to the recurrent and protracted nature of this disease, causing considerable distress to patients [5].

According to foreign authors and according to our observations, post-sternotomy mediastinitis is often accompanied by instability of the sternum. The cause may be asymmetric sternotomy, severe osteoporosis, or inadequate primary osteosynthesis of the sternum. In some cases, instability of sternotomy access provokes the development of mediastinitis, or developed mediastinitis leads to melting of bone tissue and eruption of sternum ligature with the development of instable sternotomy access [6, 7]. In both cases, instability is always accompanied by infectious contamination of the sternum, which has an extremely unfavorable effect on disease prognosis.

The modern strategy of early active surgical treatment of post-sternotomy mediastinitis provides for the maximum sanitation of the wound region, which in cases of sternal diastasis requires the opening of sternotomy access with the removal of all elements of primary osteosynthesis to drain the substernal space [3, 5]. Consequently, the surgeon is faced with the question of choosing the optimal method of reosteosynthesis.

There are many devices and methods of sternal osteosynthesis. However, under conditions of destructive and inflammatory changes in bone tissue and transverse fractures of the sternum in patients with post-sternotomy mediastinitis, some of them are of limited use, and the efficiency of the others requires detailed analysis to determine case-by-case indications and contraindications.

In these patients, osteosynthesis is an actual and unresolved problem, and a large number of osteosynthesis methods, after primary surgeries,

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Fig. 1. Titanium nickelide braces of various sizes.

are far from effective under conditions of destruction and fragmentation of the sternum.

We developed and introduced into clinical practice the modernized U-shaped wire suture on gaskets made of perforated metal plates (titanium mesh) [8]. This work aimed to compare the efficiency of various methods of sternal osteosynthesis in patients with post-sternotomy mediastinitis. Between 2011 and 2016, we followed 43 patients in the cardiac surgery departments of the Interregional Clinical Diagnostic Center in Kazan. The patients were treated for acquired heart defects and coronary heart disease complicated by post-sternotomy mediastinitis, which amounted to 2.1% of the total number of patients who underwent surgical procedures during this period. The study group included 29 patients (67.4%) with concomitant instability of sternotomy access.

The characteristics of patients are presented in Table 1.

Until 2012, in most cases, the sternum osteosynthesis after the primary surgery was performed by simple cerclage sutures using the steel surgical wire ETHICON No. 7. Since 2012, the titanium nickelide braces with shape memory were used with wire sutures as a routine method of osteosynthesis (ZAO KIMPF, Moscow, Figure 1).

Since 2013, in cases with pronounced osteoporosis of the sternum and non-median sternotomy, the U-shaped suture on the gaskets made of perforated metal plates proposed by the team of authors was used [8]. All these methods of osteosynthesis were also used for reosteosynthesis in patients with post-sternotomy mediastinitis and instability of the sternum.

Patients were managed according to the following algorithm. As soon as possible after the wound complication was verified, surgical intervention was performed for revision, sanitation, and drainage of the wound. Surgical treatment of the wound was performed in all cases under operating unit conditions and with the use of general anesthesia.

Table 1. Characteristics of patients

Indicators	Patients (n = 29)
Age, years	62.2±4.1
Gender (male/female)	16/13
Diabetes mellitus	7 (24.1%)
Body mass index ≥35 kg/m^2	5 (17.2%)
Chronic obstructive pulmonary disease	9 (31%)
Time from primary surgery to verification of wound complication, days	24.3±9.2
Coronary bypass surgeries	11 (37.9%)
Valve replacement surgeries	16 (55.2%)
Concurrent surgeries	2 (6.9%)
Type of mediastinite (according to R.M. El Oakley and J.E. Wright):	
– Type I	1 (3.4%)
– Type II	9 (31%)
– Type III	17 (58.6%)
– Type IV	2 (7%)
Infectious agents:	
– *St. Epidermidis*	13 (44.8%)
– *St. Aureus*	8 (27.6%)
– Methicillin-resistant Staphylococcus aureus	5 (17.2%)
– Other pathogens	3 (10.3%)
Consistency of the sternal bone tissue in the intercostal spaces: – consistent – partial or total destruction	 13 (44.8%) 16 (55.2%)

When signs of instability of sternotomy access were revealed, the sternal fixing elements were completely removed without attempting to reach the weakened or partially cut wire ligatures. The edges of the sternotomy wound were separated, the wound (including the substernal space and the spongy substance of the sternum) was sanitized with antiseptic solutions, and the nonviable tissues were removed.

In all cases, the wound revision was completed by installing a vacuum drainage system Vivano Tec HARTMANN (Germany). The rarefaction in the wound was created in a constant mode at a level of 90–120 mm Hg. The system was changed every 2–4 days. Vacuum drainage was completed with at least two of the following criteria:

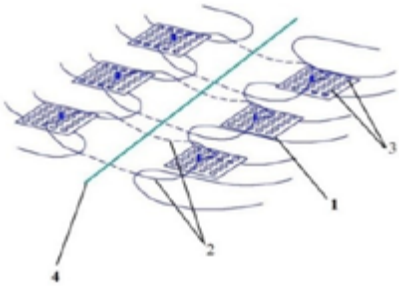

Fig. 2. The principle of the suture formation. 1. Perforated metal plate. 2. Wire ligatures. 3. Perforation plate holes. 4. Sternotomy line.

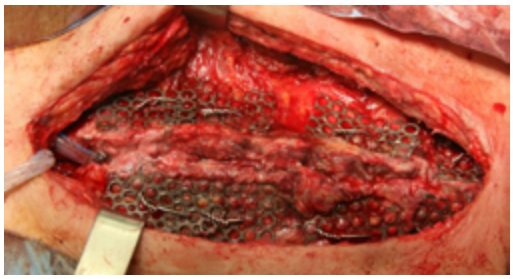

Fig. 3. Final appearance of sutures on the sternum.

(1) macroscopic signs of wound cleansing and development of granulation tissue;

(2) arresting of fever;

(3) negative results of inoculation from the wound or colony-forming units (CFU) $\leq 10^3$;

(4) decrease in the level of C-reactive protein of blood plasma by two times or more, compared with the initial value.

After cleansing the wound, we performed reosteosynthesis of the sternum and repair of the local tissues on the postoperative wound. Depending on the osteosynthesis method used, the patients were divided into three groups.

– Group 1 ($n = 10$, operated in 2011–2013) consisted of patients with different degrees of sternal destruction and osteoporosis. Reosteosynthesis in this group was performed using separate Z-shaped or cerclage sutures with the steel surgical wire ETHICON No. 7.

– Group 2 ($n = 8$, operated in 2012–2016) consisted of patients with fully preserved bone tissue of the body of the sternum in the intercostal spaces, pronounced adhesive processes in the substernal space and close attachment of the heart structures (right ventricle, mammary coronary bypass, and aortocoronary bypasses) to the rear surface of the sternum. In this group, reosteosynthesis was performed with the use of titanium nickelide braces with shape memory, manufactured by ZAO KIMPF (Moscow).

– Group 3 ($n = 11$, operated in 2013–2016) consisted of patients with severe osteoporosis, significant foci of destruction and resections of bone tissue, as well as complete transverse fractures of the body of the sternum and nonmedian sternotomy. In this group, reosteosynthesis was performed using a modernized U-shaped wire suture on gaskets made of perforated metal plates, in this case from a titanium mesh (Figs. 2 and 3).

Until 2013 (due to the absence of alternative methods), in all cases reosteosynthesis was performed with wire ligatures. With transverse fractures of the sternum, Z-shaped sutures were applied with the involvement of a fracture in the suture. With pronounced shortage and destruction of the sternal body, the wire sutures were applied through the cartilaginous parts of the ribs. In all cases, it was necessary to isolate the substernal space and sternum from adhesions, which in cases of close attachment of the heart structures or bypasses, significantly increased the risk of intervention.

With the introduction of titanium nickelide braces with shape memory and a modernized U-shaped suture on the titanium mesh gaskets, a different approach was taken to choose the method of reosteosynthesis. The main criteria for the application of a various methods were the following:

(1) the degree of osteoporosis and destruction of the sternum body;

(2) the presence of sufficient bone tissue of the sternum in the intercostal spaces; and

(3) the presence of close attachment of the heart structures to the sternum (by-passing surgeries, nonsutured pericardium after the primary surgery).

The use of titanium nickelide braces did not require the allocation of the substernal space. After preparation, with an electrocoagulator of areas on the body of the sternum in the projections of intercostal spaces with the use of a gauge, we selected brace numbers from 0 to 8. The braces were implanted into the areas of the intercostal spaces 1, 2, 3, 4, and 5.

In all cases of reosteosynthesis with the U-shaped sutures, the substernal space was extracted from the adhesions before the projection of the parasternal lines on both sides. Also, the greater pectoral muscle was partially separated from the body of the sternum on both sides to create a site for placing the gaskets over the sternum and to mobilize the musculocutaneous flap for the subsequent repair of the postoperative wound.

Table 2. The incidence of complications associated with osteosynthesis of the sternum and relapse of infection

Complications/indicators	Group 1	Group 2	Group 3	P
Restitution of sternum instability	3 (30%)	1 (12.5%)	1 (9%)	p_{1-2}=0.08 p_{1-3}=0.04 p_{2-3}=0.2
Recurrence of mediastinitis	1 (10%)	1 (12.5%)	0	p_{1-2}=0.01 p_{1-3}=0.9 p_{2-3}=0.4
Duration of hospitalization, days	51±14.8	27±7.3	24±8.1	p_{1-2}=0.05 p_{1-3}=0.07 p_{2-3}=0.4
Chronic fistulas of the sternum	4 (40%)	1 (12.5%)	2 (18.2%)	p_{1-2}=0.06 p_{1-3}=0.3 p_{2-3}=0.7

When forming the U-shaped sutures, the wire ligatures (steel surgical wire ETHICON No. 7) were passed through the body of the sternum and through the rib cartilage in cases of bone tissue deficiencies. The number of sutures was selected individually for each specific case. The gaskets were used as titanium mesh used for the repair of defects of the cranial bones. The wires were then wound over the gaskets, alternately from the right and left sides, until the edges of the sternotomy access were completely approximated (see Figs. 2 and 3).

Soft tissue repair was performed in patients of all groups studied, as a final stage of the intervention. This was due to the use of vacuum drainage of the wound, since this method involves the formation of significant defects in the skin and subcutaneous tissue.

The greater pectoral muscle was separated, on both sides, from the sternum along the whole line of its attachment to the periosteum, to the parasternal or midclavicular lines. Thus, a single mobile complex (skin, subcutaneous tissue, greater pectoral muscle) was formed on each side, enabling us to approximate the edges of the wound. Soft tissues were approximated over the sternum by means of coarse nodal sutures across all layers. Drainages on active aspiration regions were installed in the wound, and removed 5–7 days after the surgery.

Since 2015, we rubbed a compounded paste into the spongy substance of the sternum in all patients during reosteosynthesis. This paste was prepared in the operating room by mixing 3 g of vancomycin lyophilizate with 3–4 ml of isotonic sodium chloride solution.

For statistical analysis, we used MS Excel packages, Statistica 6.0., GraphPadPrism version 5.00. The results of the study were assessed using Student's *t*-test. Statistical differences were considered significant at $p < 0.05$. The described method of sternal osteosynthesis, developed by the authors, is approved and authorized by the local ethics committee of the Kazan State Medical University. The incidence of complications associated with sternal osteosynthesis and relapse of infection is presented in Table. 2.

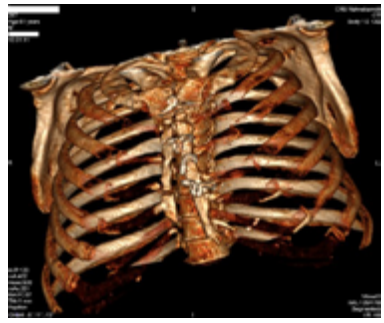

Fig. 4. Patient K, 51 years old. The primary surgery was aortic valve replacement. In view of the post-sternotomy mediastinitis that developed with instability of sternotomy access, vacuum draining of the wound was performed, followed by soft tissue repair and sternal reosteosynthesis with titanium nickelide braces. Computed tomography of the chest with 3D reconstruction on day 4 revealed dislocation of braces 3 and 4 with the development of diastasis of the body of the sternum.

The frequency of restitution of sternum instability was the highest in group 1. The causes of instability in group 2 were the eruption of the wires and destruction of the sternal body. In group 2, there was a dislocation of the titanium nickelide braces (Figure 4), while in group 3, in one patient, sternal instability occurred due to the total rupture of the wire ligatures. This patient suffered from chronic obstructive

pulmonary disease with pronounced cough.

All cases of restitution of sternal instability occurred in the early postoperative period (up to 14 days) and were accompanied by recurrence of sternal mediastinitis, which required repeated interventions for sanitation, drainage, and reosteosynthesis of the sternum.

There were also cases of recurrent wound infection in patients without signs of unstable sternum (one patient in group 1 and one patient in group 2). In both cases, according to computed tomography, no signs of infection of bone tissue and the retrosternal space were identified; infection contamination was limited to the subcutaneous tissue. These cases also required repeated interventions with sanitation and drainage of the postoperative wound.

In the long term, seven patients were observed with chronic sternal fistula; the largest number was noted in group 1 (40%). One case was seen in group 2 (12.5%), and two cases were noted in group 3 (18.2%). Within a period of 4–6 months, all sternum fixing elements were removed, in all patients, along with excision of fistulous passages and sanitation of foci of the spongy substance of the sternum.

It should be noted that in all the cases, when reosteosynthesis was supplemented with inunction of the paste with vancomycin into the spongy substance of the sternum, no recurrences of wound infection and formation of the chronic fistulas were revealed.

The average duration of hospitalization in group 1 was 51 days; in group 2, it was 27 days; and in group 3, it was 24 days. In our opinion, the increase in the hospitalization period of group 1 patients was associated with return of sternal instability, which required a repeated course of treatment in these patients.

The present data indicate that the existing algorithm for managing patients with post-sternotomy mediastinitis, including early revision of the wound, removal of all sternal fixing elements with minimal diastasis of sternotomy access, application of vacuum drainage of the wound, and selection of the method of reosteosynthesis based on the state of the sternal tissue (titanium nickelide braces or the proposed U-shaped suture), with inunction of paste with vancomycin into the spongy substance, is efficacious.

The method of osteosynthesis of the sternum using a U-shaped wire suture on the titanium mesh gaskets was the most reliable in our observations. According to the authors, the proposed method significantly reduces the risk of wire ligatures erupting by distribution of the wire pressure, not on the spongy substance of the sternum, but on the metal plates, thereby increasing the area of pressure. The method enables performance of reliable sternotomy access with fragmentation of the sternum, asymmetric sternotomy, and pronounced destructive processes in the sternum, even under the conditions of developed sternal mediastinitis. Using this method, osteosynthesis does not require special surgical skills. The method is simple and safe in execution.

CONCLUSIONS

1. Provided that the bone tissue of the sternum is preserved in the intercostal spaces, the use of titanium nickelide braces with shape memory is the most optimal method, reducing the risk of restitution of sternal instability by 17.5% compared with the conventional method of osteosynthesis with steel wire.

2. The proposed method of osteosynthesis, using a U-shaped wire suture on gaskets made of perforated metal plates, was reliable in 91% of patients with sternal fragmentation, asymmetric sternotomy, and pronounced destruction of bone tissue.

3. The use of paste with vancomycin during reosteosynthesis helped avoid recurrence of wound infection over both the immediate and long-term postsurgical periods in 100% of cases.

REFERENCES

1. El'bala F.B. Surgical treatment of mediastinitis after the open heart surgeries. *Meditsinskiy zhurnal*. 2006; (1): 103–104. (In Russ.)

2. Schimmer C., Sommer S.P., Bensch M. et al. Management of poststernotomy mediastinitis: experience and results of different therapy modalities. *Thorac. Cardiovasc. Surg.* 2008; 56: 200–204. DOI: 10.1055/s-2008-1038386.

3. Scott C.H., John H.C., Glyn E.J. et al. Thoracic reconstruction with the omentum: indications, complications and results. *Ann. Plastic Surg.* 2001; 46 (3): 242–249.

4. Graf K., Ott E., Vonberg R.-P. et al. Economic aspects of deep sternal wound infections. *Eur. J. Cardiothorac. Surg.* 2010; 37 (4): 893–896. DOI: 10.1016/j.ejcts.2009.10.005.

5. Vishnevskiy A.A., Pechetov A.A., Golovteev A.A. et al. Sternal re-osteosynthesis with the use of shape-memory fixators after median sternotomy in chronic medistinitis. *Infektsii v khirurgii*. 2009; (2): 5–9. (In Russ.)

6. Gorbunov V.A., Dzhordzhikiya R.K., Vagizov I.I. et al. Mediastinitis after cardiac procedures via median sternotomy: comparative analysis of outcomes. *Kazanskiy meditsinskiy zhurnal*. 2013; (6): 826–831. (In Russ.)

7. Robicsek F. Complication of midline stemotomy. *Thoracic Surg.* 2002; 51: 1351–1392.

8. Gorbunov V.A., Dzhordzhikiya R.K., Omelyanenko A.S. A method of sternal osteosynthesis after median sternotomy and perforated metal sheet for sternal osteosynthesis after median sternotomy. Patent №2607180 RF. Bull. №1 issued in 2017. (In Russ.)