DOI: 10.15825/1995-1191-2020-4-75-82

J-SHAPED STERNOTOMY IN AORTIC VALVE REPAIR AND ASCENDING AORTA REPLACEMENT. SHORT-TERM RESULTS

G.A. Akopov, A.S. Ivanov, T.N. Govorova, D.V. Moskalev

Shumakov National Medical Research Center of Transplantology and Artificial Organs, Moscow, Russian Federation

Objective: to evaluate the short-term outcomes of surgical treatment of aortic valve and ascending aorta defects performed through mini-sternotomy using normothermic cardiopulmonary bypass and hyperkalemic cardioplegia via Calafiori technique from May 8, 2019 to May 14, 2020. **Materials and methods.** The study enrolled 80 patients with isolated aortic valve disease and combined pathology of the aortic root and ascending aorta. It lasted from May 8, 2019 to May 14, 2020. The patients were divided into two groups: Group 1 included 30 patients in whom the upper median J-shaped sternotomy was applied as an access, while Group 2 consisted of 50 patients in whom standard median sternotomy was used as an access. The patients consisted of 43 (53.7%) males and 37 (46.3%) females; the average age was 55.1 ± 11.6 years. All patients were examined before surgery. There were no statistically significant differences between the two groups. **Results.** Group 2 had a 30-day mortality of 2% (n = 1) due to the development of acute heart failure against the background of heart rhythm disturbances. One patient in this group had a late mortality due to acute cerebrovascular accident occurring a month after discharge, which corresponded to 2% (n = 1). There were no deaths in Group 1. In Group 1, there were two conversions (6.7%) to longitudinal median sternotomy. In the first case, it was not possible to restore heart rhythm through repeated defibrillator discharges from mini-sternotomy access due to the presence of an adhesive process in the pericardial cavity. In the second case, ligation of the right internal thoracic artery was required after sternal wire sutures. Artificial ventilation (AV) lasted for 170.9 ± 70.2 minutes in Group 1 and 358.2 ± 169.5 minutes in Group 2. Cardiac activity was independently restored in 23 patients (77%) in Group 1, and in 12 (24%) in Group 2 ($p < 0.001$). Intraoperative blood loss was 400 ± 150 mL and 850 ± 150 mL ($p < 0.05$) in Group 1 and Group 2, respectively. In the early postoperative period, it was 200 ± 150 mL in Group 1 and 350 ± 150 mL in Group 2. The length of stay at the intensive care unit and the duration of intensive therapy did not exceed 1 day in both groups. In the early postoperative period, 4 patients in Group 1 (13%) and 27 patients in Group 2 (54%) needed inotropic support ($p < 0.001$). The need for painkillers and non-steroidal anti-inflammatory drugs was within 3–4 days in Group 1 and 8–10 days in Group 2. In-hospital postoperative period varied from 10 to 16 days in both groups, depending on the severity of the initial condition, presence of concomitant diseases and the need to select an adequate anticoagulant dose. The patients were discharged in satisfactory condition under the supervision of a cardiologist at their homes. There were no inflammatory complications in the access area in both groups during their in-hospital stay. Among the complications in the mid-term postoperative period, two months after discharge, mediastinitis was observed in Group 2. The patient was re-hospitalized, after a course of antibiotic therapy which resolved the mediastinitis; sternal osteosynthesis was performed. **Conclusion.** Based on the study, it has been shown that this technique reduces the duration of mechanical ventilation, ensures early extubation, decreases blood loss, and, accordingly, ensures the use of replacement therapy, chest stability and a better cosmetic effect. It should be noted that there was no mortality and sternal complications in the patient group with a minimally invasive approach.

Keywords: minimally invasive surgery, aortic surgery, aortic valve, mini-sternotomy.

Despite the first successful minimally invasive aortic valve replacement surgery performed in Cleveland in 1996 by Cosgrove and Sabik [1], longitudinal median sternotomy remains the main standard approach among cardiac surgical access techniques. In May 1997, at the 1st World Congress on Minimally Invasive Cardiac Surgery in Paris, it was decided that the main goal of minimally invasive surgery is to reduce the number of predicted complications and accelerate patient recovery, provided that the effectiveness of surgical treatment and the duration of therapeutic effect are maintained. In Russia, the first aortic valve replacement through the upper mininotomy was performed in October 1997 by L.A. Bockeria [2].

Some of the main advantages of minimally invasive techniques after surgery over the conventional access include reduced traumatic nature of surgical intervention, superior cosmetic results, reduced pain in the postope-

Corresponding author: Tuiaara Govorova. Address: 1, Shchukinskaya str., Moscow, 123182, Russian Federation.
Phone: (985) 852-30-17. E-mail: tuyagov@inbox.ru

rative period, and possibility of early patient activation due to thoracic stability, which leads to shorter hospital stay [3].

Studies have shown that the minimally invasive technique provides reduced pain, lower number of sternal complications, respiratory disorders due to thoracic stability and preservation of the integrity of the diaphragmatic attachment to the chest wall, reduced blood loss and transfusions, and shorter hospital stay. There was also a decrease in the incidence of atrial fibrillation, myocardial infarction and strokes in the postoperative period [3–22]. In 2017, German colleagues reported on their experience, which showed that upper sternotomy during aortic arch surgery does not increase the risk of complications and mortality [3]. The Swiss Cardiac Surgery Guidelines, published in February 2020, reported that, when compared with the conventional access, minimally invasive aortic valve surgery reduces postoperative mortality and complications [23].

Most revealing is the data provided by T.A. Rayner et al. In January 2020, the results of a comparative meta-analysis based on online databases Medline, EMBASE, Cochrane Library and Web of Science, were published. The meta-analysis included 1101 patients with minimally invasive aortic surgery and 1405 patients with standard median sternotomy from thirteen published studies. The confidence level in all previously reported results remains very low. Mortality and incidence of stroke were similar between the 2 cohorts. Meta-analysis demonstrated increased length of cardiopulmonary bypass (CPB) time, more time in hospital and intensive care among patients undergoing standard median sternotomy compared with minimally invasive surgery of the aortic root and ascending aorta. This group also had higher risks of bleeding and renal impairment [24].

To reduce the risk of surgery, patients with concomitant coronary artery disease can be offered two-stage operations using endovascular surgery [8]. The success of minimally invasive surgery also depends on individual selection of patients. The patient's specific anatomical and pathophysiological characteristics, as well as the experience of the surgical team in provision of adequate access and working in minimally invasive conditions should be taken into account.

This technique has its disadvantages: the need (in some cases) for the use of peripheral cannulation for CPB, internal thoracic artery injury, as well as cases of conversion to complete longitudinal median sternotomy [5].

Objective: to evaluate the short-term outcomes of surgical treatment of aortic valve and ascending aorta defects performed through mini-sternotomy using normothermic cardiopulmonary bypass and hyperkalemic cardioplegia via Calafiori technique from May 8, 2019 to May 14, 2020.

MATERIALS AND METHODS

The study enrolled 80 patients with isolated aortic valve disease and combined pathology of the aortic root and ascending aorta. It lasted from May 8, 2019 to May 14, 2020. The patients were divided into two groups: group 1 included 30 patients in whom the upper median J-shaped sternotomy was applied as an access – aortic valve prosthetics (15), aortic valve and ascending aortic prosthetics with a valve-containing conduit according to the Bentall-De Bono technique (1) and the Kouchoukos modifications (4), valve-preserving operations according to the David I (3) and the Florida Sleeve (1) techniques, supracoronary ascending aortic replacements (4), ascending aorta prosthetics with annuloplasty of the aortic annulus fibrosus (2). Group 2 consisted of 50 patients in whom standard median sternotomy was used as an access: aortic valve replacement (17), aortic valve and ascending aorta valve replacement with valve-containing conduit according to the Bentall-De Bono technique (4) and the Kouchoukos modifications (1), valve-preserving operations according to the David I (18) and Florida Sleeve (5) techniques, aortic valve leaflet repair (5).

There were 43 (53.7%) males and 37 (46.3%) females that underwent surgery. Their mean age was 55.1 ± 11.6 years.

Before surgery, all patients underwent standard examinations, including collection of complaints, medical history, physical examination, laboratory and imaging investigations (electrocardiography, echocardiography (EchoCG)), chest X-ray in direct projection, direct X-ray contrast-enhanced spiral CT). Preoperative evaluation revealed no statistically significant differences between the two groups.

Chest X-ray in direct projection and chest X-ray contrast-enhanced spiral CT help to determine the level of the aortic root location and its projection onto the sternum and intercostal space, which is the determining factor for choosing the level of the intercostal space when conducting a median J-shaped mini-sternotomy for planning the access length and predicting visualization of the aortic root and ascending aorta (Fig. 1, 2).

The skin incision was made longitudinally for 7–9 cm, departing from the sternum handle by 2–3 cm. The median J-shaped mininotomy, depending on the projection of the aortic root onto the sternum, was performed along the 3rd and 4th intercostal spaces in 13 (43%) and 17 (57%) patients, respectively (Fig. 3, 4).

After opening the pericardium, standard direct aortic cannulation and venous cannulation of the right atrial appendage were performed using a two-level cannula. The left heart was drained through the right superior pulmonary vein (Fig. 5).

Surgical interventions were performed under cardiopulmonary bypass in conditions of moderate hypothermia or normothermia at 34.1–36.2 °C temperature with

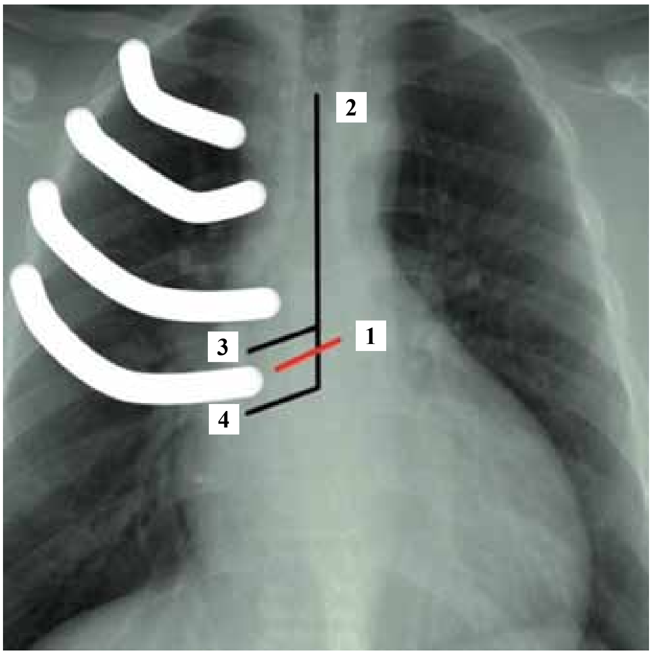

Fig. 1. Chest X-ray in a direct projection: (1) aortic root projection, (2) sternotomy line, (3) intersection of the sternum through the 3rd intercostal space, (4) intersection of the sternum through the 4th intercostal space. The white areas indicate the position of the ribs

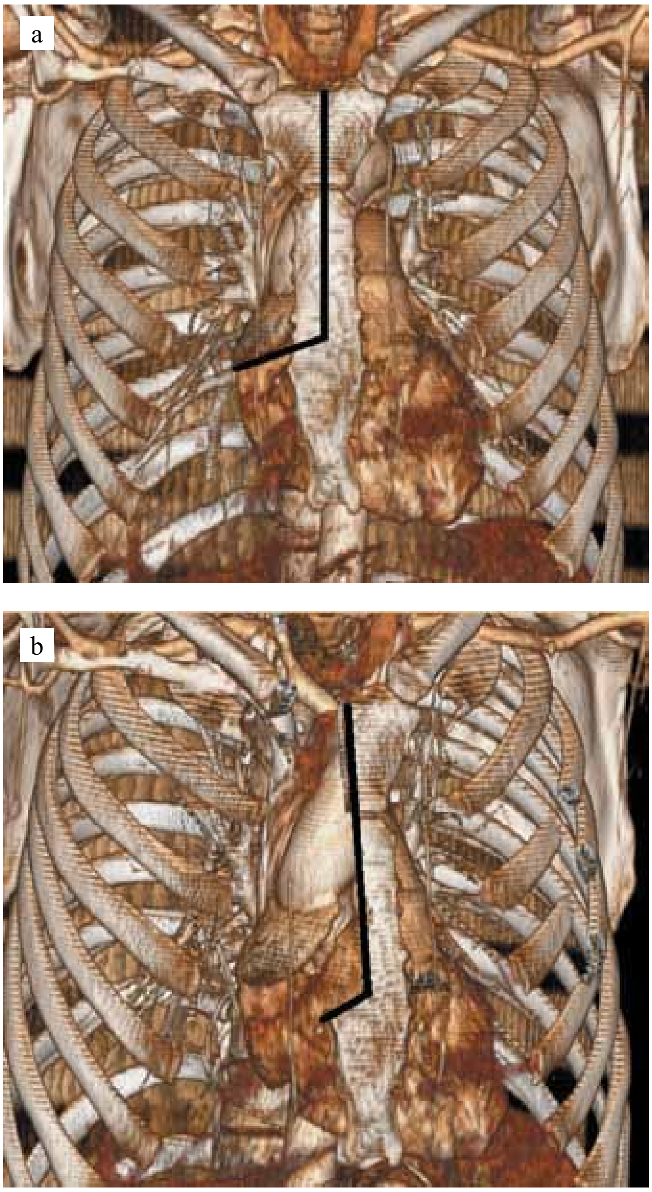

Fig. 2. X-ray contrast-enhanced spiral CT scan of the chest with a J-shaped access line. (a) the sternum is preserved, (b) a section of the sternum was removed along the cutting line, for the purpose of approximately visualizing the aortic root and ascending aorta

selective introduction of blood hyperkalemic cardioplegia via Calafiori technique. A standard set of instruments, a small wound retractor and a defibrillator with small internal paddles were used.

All patients underwent surgical interventions under transesophageal echocardiography to assess myocardial contractility, fill the cardiac cavities, assess the adequacy of air embolism prevention and surgical treatment outcome.

When using a minimally invasive technique, ultrasound control is necessary to assess the location of the venous cannula in order to prevent impaired blood outflow in the CPB device, as well as to evaluate the correction performed (prosthetics or heart valve repair). Also, at the end of CPB, ultrasound assessment of the deaeration process and heart function is necessary, since direct visual monitoring of cardiac activity is impossible. Fig. 6 shows the final view after skin suturing. Fig. 7 shows X-ray contrast-enhanced spiral computed tomography with reconstruction of the aortic root and ascending aorta (a – before surgery, b – after reconstruction of the aortic root and ascending aorta according to the David I technique).

The peculiarity of using the mini-access is to effect drainage into the pericardial cavity and suture the electrode to the right ventricle for temporary stimulation before removing the clamp from the aorta, with an unfilled heart.

Air embolism was prevented by active drainage of the left heart and intraoperative injection of carbon dioxide into the pericardial cavity at 2 L/min. To prevent aeroembolism, the ascending aorta was additionally punctured.

RESULTS

Thirty-day mortality in group 2 was 2% (n = 1) due to the development of acute heart failure amidst heart rhythm disturbances. Late mortality was also observed in group 2 in one patient due to stroke one month after discharge, corresponding to 2% (n = 1). There were no deaths in group 1.

In group 1, two patients underwent conversion to median longitudinal sternotomy – 6.7%. In the first case, it was not possible to restore rhythm with multiple defibrillator discharges from the ministerial access due to

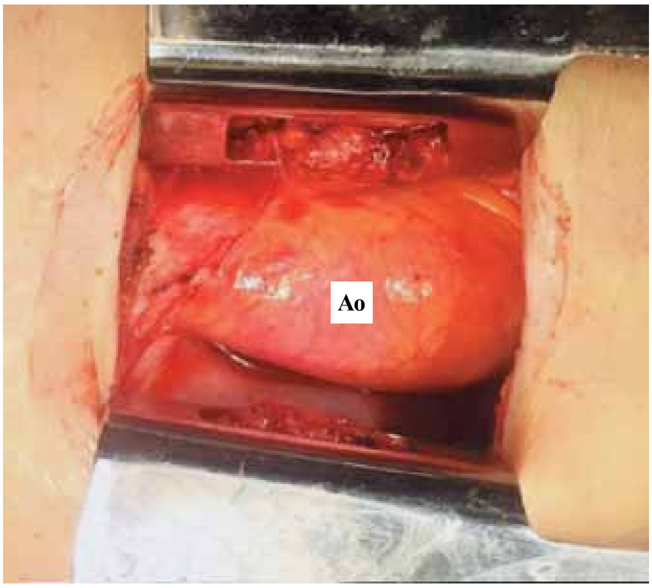

Fig. 3. Median J-shaped mini-sternotomy through the 3rd intercostal space. Optimal visualization of the aortic root and ascending aorta

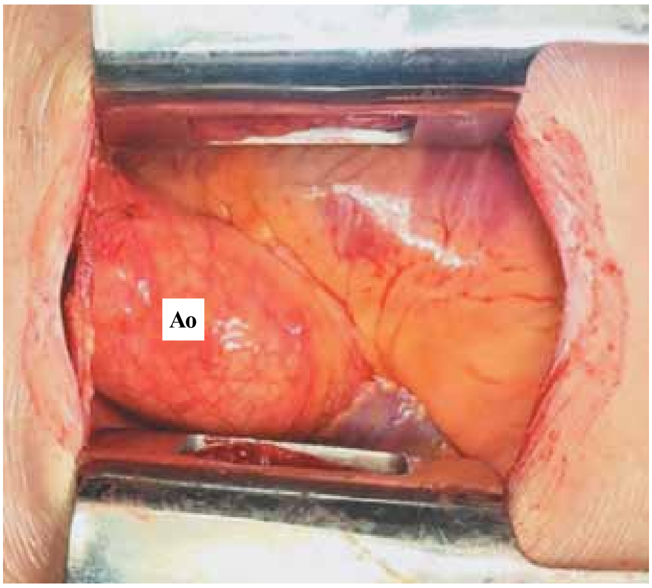

Fig. 4. Median J-shaped mini-sternotomy through the 4th intercostal space

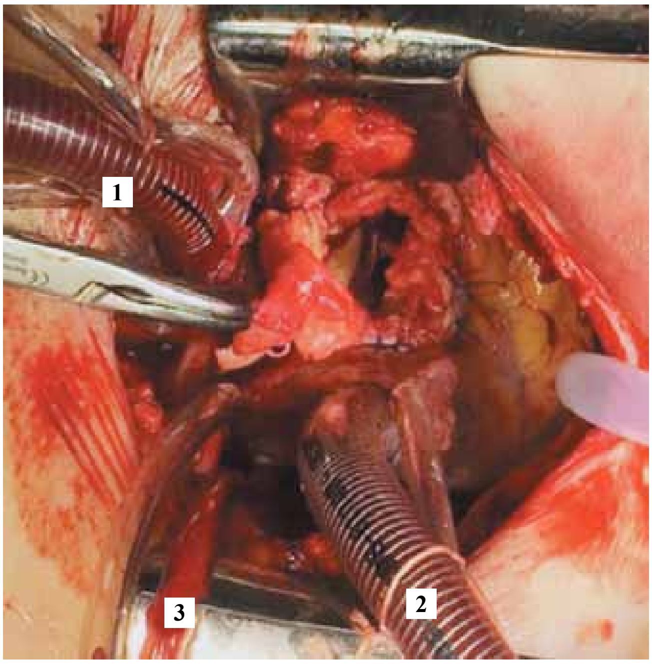

Fig. 5. (1) Central cannulation of the ascending aorta (2) and the right atrium (3) with the left cannula laid through the right superior pulmonary vein

Fig. 6. A 8.5-cm skin incision

adhesions in the pericardium. The second required ligation of the right internal thoracic artery after sternum stitching with wire sutures.

Artificial ventilation in group 1 and in group 2 lasted for 170.9 ± 70.2 minutes and 358.2 ± 169.5 minutes, respectively.

There was independent restoration of cardiac activity in 23 patients (77%) in group 1, and in 12 (24%) in group 2 ($p < 0.001$).

Intraoperative blood loss in group 1 and group 2 was 400 ± 150 mL and 850 ± 150 mL ($p < 0.05$), respectively. In the early postoperative period – 200 ± 150 mL and 350 ± 150 mL, respectively.

Length of intensive care among all patients in both groups did not exceed 1 day.

In the early postoperative period, 4 patients (13%) needed inotropic support in group 1, and 27 patients (54%) in group 2 ($p < 0.001$). The need for painkillers and non-steroidal anti-inflammatory drugs in group 1 and group 2 was within 3–4 days and 8–10 days, respectively.

In group 2, two patients (4%) required a second intervention due to sternal diastasis; sternal osteosynthesis was performed in the early postoperative period.

In-hospital postoperative period in both groups varied from 10 to 16 days, depending on severity of the initial

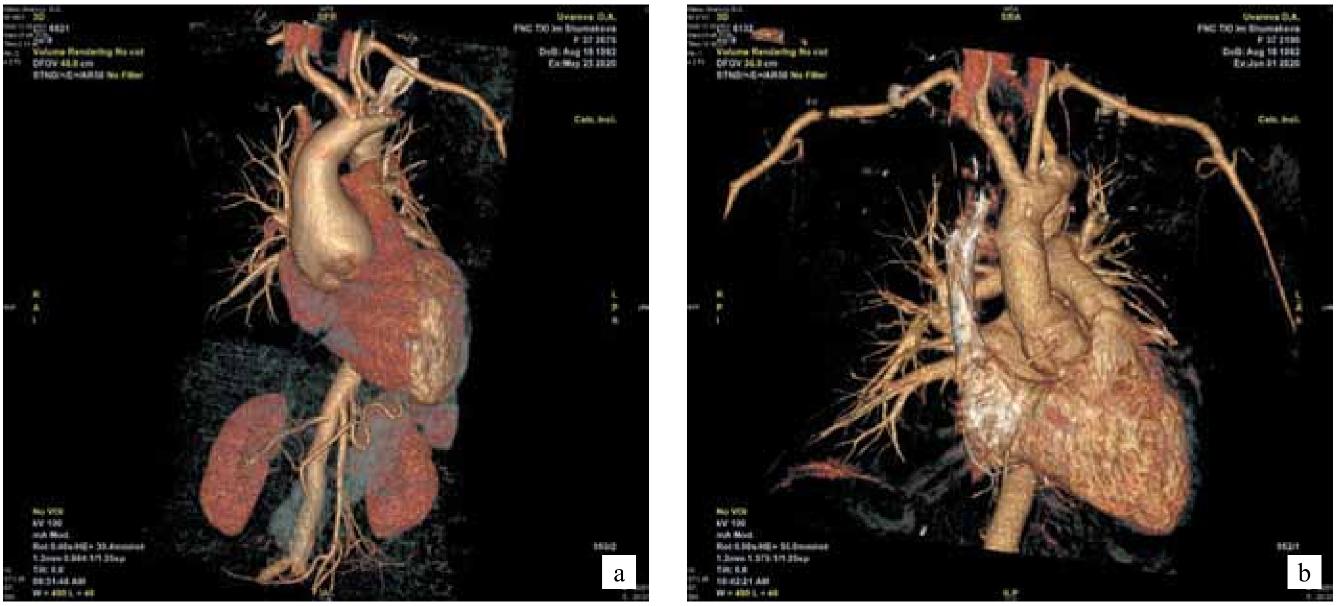

Fig. 7. X-ray contrast-enhanced spiral CT scan with reconstruction of the aortic root and ascending aorta: (a) before surgery, (b) after reconstruction of the aortic root and ascending aorta by the David I method

condition and presence of concomitant diseases and the need to select an adequate anticoagulant dose. The patients were discharged in satisfactory condition under the supervision of a cardiologist at their place of residence.

There were no inflammatory complications in the access area in both groups during the hospital period. Among the complications in the mid-term postoperative period, two months after discharge, mediastinitis was observed in group 2. The patient was re-hospitalized, after a course of antibiotic therapy with resolution of mediastinitis, sternal osteosynthesis was performed.

FINDINGS:

1. Median J-shaped mini-sternotomy is a safe and feasible approach to perform a full range of interventions on the aortic valve and ascending aorta, which provides adequate visualization to the aortic root and ascending aorta and partially to the right heart, while maintaining the integrity of the thoracic cage.
2. Mini-sternotomy, in contrast to the standard median sternotomy, showed reduced blood loss, earlier extubation, reduced need for inotropic support, absence of wound, infectious and other sternal complications, and absence of in-hospital mortality.
3. In planning the length of access and predicting adequate visualization of the aortic root and ascending aorta, chest X-ray contrast-enhanced spiral computed tomography should be performed.
4. Blood hyperkalemic cardioplegia by Calafiori technique is the preferred method of myocardial protection in surgical correction of aortic defect. Our experience shows that independent restoration of the rhythm was recorded in 77% of cases when this myocardial protection method was carried out.
5. Repeated interventions and pronounced adhesions can complicate heart rhythm restoration, increasing the likelihood of conversion to median sternotomy.

CONCLUSION

The technique reduces the duration of mechanical ventilation, ensures early extubation, reduced blood loss (and, accordingly, reduced use of replacement therapy), and provides thoracic stability and superior cosmetic results. Note that there was no mortality and sternal complications in the group of patients with a minimally invasive approach.

A better thoracic stability makes minimally invasive surgical access the first choice both in comorbid patients and in patients with high body mass index, and in high-risk patients in general.

A properly performed surgery shortens the operation time. This in turn reduces the cardiopulmonary bypass, myocardial ischemia, anesthesia and blood loss during operation.

We also agree with our colleagues about the need for a prospective randomized study in order to avoid possible erroneous conclusions from retrospective data.

The authors declare no conflict of interest.

REFERENCES

1. *Cosgrove DM 3rd, Sabik JF*. Minimally invasive approach for aortic valve operations. *Ann Thorac Surg*. 1996; 62: 596–597.
2. *Bokerija LA, Skopin II, Narsija BE, Sedov IN*. Minimal'no invazivnaja hirurgija priobretennyh poro-

kov serdca. *Grudnaja i serdechno-sosudistaja hirurgija*. 1999; 3: 4–7.
3. *Goebel N, Bonte D, Salehi-Gilani S, Nagib R, Ursulescu A, Franke UFW*. Minimally Invasive Access Aortic Arch Surgery. *Innovations (Phila)*. 2017 Sep/Oct; 12 (5): 351–355. doi: 10.1097/IM000000000000390.
4. *Fenton JR, Doty JR*. Minimally invasive aortic valve replacement surgery through lower half sternotomy. *J Thorac Dis*. 2013 Nov; 5 (Suppl 6): S658–S661. doi: 10.3978/j.iss072-1439.2013.09.22. PMCID: PMC3831833. PMID: 24251024.
5. *Klein P, Klop IDG, Kloppenburg GLT, van Putte BP*. Planning for minimally invasive aortic valve replacement: key steps for patient assessment. *Eur J Cardiothorac Surg.* 2018; 53: ii3–ii8. doi: 10.1093/ejcts/ezy086.
6. *Young CP, Sinha S, Vohra HA*. Outcomes of minimally invasive aortic valve replacement surgery. *Eur J Cardiothorac Surg*. 2018; 53: ii19–ii23. doi: 10.1093/ejcts/ezy186.
7. *Boix-Garibo R, Uzzaman MM, Bapat VN*. Review of Minimally Invasive Aortic Valve Surgery. *Interventional cardiology (London, England)*. 2015; 10 (3): 144–148. https://doi.org/10.15420/IC015.10.03.144.
8. *Paredes FA, Cánovas SJ, Gil O, García-Fuster R, Hornero F, Vázquez A et al*. Minimally Invasive Aortic Valve Surgery. A Safe and Useful Technique Beyond the Cosmetic Benefits. *Revista Española de Cardiología (English Edition)*. 2013; 66 (9): 695–699. doi: 10.1016/j.re013.02.013.
9. *Brown JM, O'Brien SM, Wu C et al*. Isolated aortic valve replacement in North America comprising 108,687 patients in 10 years: changes in risks, valve types, and outcomes in the Society of Thoracic Surgeons National Database. *J Thorac Cardiovasc Surg*. 2009; 137: 82–90.
10. *Gilmanov D, Bevilacqua S, Murzi M, Cerillo AG, Gasbarri T, Kallushi E et al*. Minimally invasive and conventional aortic valve replacement: a propensity score analysis. *Ann Thorac Surg*. 2013; 96 (3): 837–843.
11. *Yamada T, Ochiai R, Takeda J, Shin H, Yozu R*. Comparison of early postoperative quality of life in minimally invasive versus conventional valve surgery. *J Anaesth*. 2003; 17 (3): 171–176.
12. *Mihaljevic T, Cohn LH, Unic D, Aranki SF, Couper GS, Byrne JG*. One thousand minimally invasive valve operations: early and late results. *Ann Surg*. 2004; 240 (3): 529–534.
13. *Gilmanov D, Bevilacqua S, Murzi M, Cerillo AG, Gasbarri T, Kallushi E et al*. Minimally invasive and conventional aortic valve replacement: a propensity score analysis. *Ann Thorac Surg*. 2013; 96 (3): 837–843.
14. *Cheng DC, Martin J, Lal A, Diegeler A, Folliguet TA, Nifong LW et al*. Minimally invasive versus conventional open mitral valve surgery. A metaanalysis and systematic review. *Innovations (Phila)*. 2011; 6 (2): 84–103.
15. *Tabata M, Khalpey Z, Aranki SF et al*. Minimal access surgery of ascending and proximal arch of the aorta: a 9-year experience. *Ann Thorac Surg*. 2007; 84: 67–72.
16. *Brown ML, McKellar SH, Sundt TM et al*. Ministernotomy versus conventional sternotomy for aortic valve replacement: a systematic review and meta-analysis. *J Thorac Cardiovasc Surg*. 2009; 137: 670–679.e5.
17. *Gilmanov D, Solinas M, Farneti PA et al*. Minimally invasive aortic valve replacement: 12-year single center experience. *Ann Cardiothorac Surg*. 2015; 4: 160–169.
18. *Shehada SE, Öztürk Ö, Wottke M et al*. Propensity score analysis of outcomes following minimal access versus conventional aortic valve replacement. *Eur J Cardiothorac Surg*. 2016; 49 (2): 464–469; discussion 469–470.
19. *Charchyan ER, Breshenkov DG, Belov YuV*. Minimally invasive approach in thoracic aortic surgery: a single center experience. *Russ Jour of Card and Cardiovasc Surg. = Kard i serd-sosud khir*. 2019; 12 (6): 522–535. (In Russ.). https://doi.org/10.17116/kardio201912061522.
20. *Bakir I, Casselman FP, Wellens F, Jeanmart H, De Geest R, Degrieck I et al*. Minimally invasive versus standard approach aortic valve replacement: a study in 506 patients. *Ann Thorac Surg*. 2006; 81 (5): 1599–1604.
21. *Belov JuV, Stepanenko AB, Gens AP, Babaljan GV*. Protezirovanie aortal'nogo klapana iz mini-dostupa. *Vestnik hirurgii im. I.I. Grekova*. M., 1998; 157 (3): 47–49.
22. *Charchyan ER, Skvortsov AA, Panfilov VA, Belov YuV*. J-shaped mini-sternotomy for frozen elephant trunk procedure. *Kardiologija i serdechno-sosudistaja hirurgija*. 2017; 10 (1): 42–46. doi: 10.17116/kardio201710142-46.
23. *Glauber M, Miceli A*. Minimally Invasive Aortic Valve Surgery. *S. Raja (eds). Cardiac Surgery*. Springer, Cham. 2020 Feb; 12: 421–428. https://doi.org/10.1007/978-3-030-24174-2_46.
24. *Rayner TA, Harrison S, Rival P, Mahoney DE, Caputo M, Angelini GD et al*. Minimally invasive versus conventional surgery of the ascending aorta and root: a systematic review and meta-analysis. *European Journal of Cardio-Thoracic Surgery*. 2020 Jan; 57 (Issue 1): 8–17. https://doi.org/10.1093/ejcts/ezz177.

The article was submitted to the journal on 9.07.2020