ORIGINAL ARTICLE

Comparison between conventional open-heart valve surgery and minimally invasive valve replacement surgery regarding the length of hospital stay and usage of blood derivates: insights from a single-centre, single-surgeon study conducted in Bosnia and Herzegovina

Nermir Granov[1], Amel Hadžimehmedagić[1], Armin Šljivo[1], Tarik Selimović[1], Damir Kurtagić[1], Edin Kabil[1], Muhamed Djedović[1], Arian Abdulkhaliq[3]

[1] Clinical Centre University of Sarajevo, Sarajevo, Bosnia and Herzegovina; [2] Faculty of Medicine of Iuliu Haţieganu University of Medicine and Pharmacy Cluj-Napoca, Cluj-Napoca, Romania

ABSTRACT

Aim To analyse the correlation between different surgical methodologies employed in valve diseases treatment and their subsequent impact on the duration of hospitalization.

Methods This retrospective study conducted at the Clinical Centre of the University of Sarajevo analysed medical records of 163 valve disease patients treated between January 2019 and November 2022. The patients were divided into two groups: 77 had open-heart valve surgery and 86 underwent minimally invasive cardiac surgery (MICS).

Results The mean duration of the surgical procedures was 3.9±1.3 hours, with conventional open-heart surgery requiring an average of 3.6±1.1 hours and minimally invasive cardiac surgery (MICS) procedure 4.2±1.5 hours. No substantial disparities were found in the total length of hospitalization between the two groups, as both conventional (8.2±4.5 days) and MICS (8.7±7.0 days) demonstrated similar duration. Similarly, the total duration of intensive care unit (ICU) stay displayed similarity, with conventional surgery patients staying an average of 3.9±2.8 days and MICS patients of 4.2±4.1 days. The pattern of blood transfusion and fresh-frozen plasma usage revealed higher rates in the conventional valve surgery group comparing to the MICS group.

Conclusion Minimally invasive valve surgery, despite slightly longer operative times, resulted in lower blood transfusion requirements and comparable hospitalization and ICU stay.

Key words: blood, Bosnia and Herzegovina, cardiovascular surgical procedures, heart valves, minimally invasive surgical procedures

Corresponding author:
Armin Šljivo
Clinical Centre University of Sarajevo
Bolnička 25, 71 000 Sarajevo,
Bosnia and Herzegovina
Phone: +387 62 256 507;
E-mail: sljivo95@windowslive.com
Nermir Granov ORCID ID https://orcid.org/0000-0002-6228-6230

Original submission:
11 September 2023;
Revised submission:
06 November 2023;
Accepted:
22 November 2023
doi: 10.17392/1670-23

Med Glas (Zenica) 2024; 21(1):91-97

INTRODUCTION

Cardiac surgery has been the last area of clinical surgery to adopt and embrace minimally invasive surgical techniques, probably due to the concerns over intracardiac air and the fine line between life and death in every cardiac procedure (1). Median sternotomy is a standard approach for the repair or replacement of cardiac valves. During recent years, several reports have been published detailing less invasive techniques for cardiothoracic surgical procedures designed to limit surgical trauma while decreasing costs, the new era of cardiac valve repair and replacement was inaugurated and minimally invasive techniques have gained popularity in all cardiac valvular procedures (2).

Minimally invasive procedures have emerged as the preferred approach in many medical centres, although they continue to be a subject of ongoing debate (3). The concept of minimal invasiveness in valve surgery revolves around the notion of achieving precise outcomes while minimizing access to the chest cavity (3,4). In recent years, there has been a growing advocacy for ministernotomy as an alternative technique for various cardiovascular surgical procedures, which aims to reduce the surgical trauma traditionally associated with the conventional full sternotomy (4). Previous studies have unequivocally established the safety of aortic valve replacement via ministernotomy, revealing that it does not elevate the risk of mortality or major complications (5). Moreover, another study has elucidated the manifold benefits of ministernotomy, which encompass not only noteworthy cosmetic enhancements but also positive effects on blood loss, postoperative pain, and potentially even sternal stability (6). Furthermore, the investigations by the authors underscore its potential to enhance respiratory function during the recovery period (4). Minimally invasive or minimal-access surgery has firmly established itself in numerous medical centres, underscoring the importance of ensuring that patients are consistently informed about these advanced techniques. When this information is delivered objectively and patient selection is carried out accurately, these alternative approaches have a potential to improve postoperative recovery for the majority of patients. It is evident that a diverse range of alternative methods exists for specific pathologies (7-9).

The avoidance of a complete median sternotomy effectively mitigates wound complications in this area. Sternal dehiscence, often accompanied by infection and subsequent mediastinitis, is a dangerous complication causing high morbidity and mortality (10). One of the crucial advantages of minimally invasive heart valve surgery lies in its ability to circumvent the need for a complete median sternotomy leading to a more favourable cosmetic outcome (11). However, it is worth noting that this advantage often entails extended operation times and increased duration on extracorporeal circulation. Among the established approaches, there is the use of an incomplete upper sternotomy for aortic valve surgery, a right-sided lateral thoracotomy for mitral and tricuspid valve surgery, and an inferior sternotomy for some congenital heart defects. In order to ensure that patients have access to the full spectrum of therapeutic options, it is essential for every cardiac surgery centre to be proficient in these minimally invasive procedures. (4)

The aim of this study was to analyse a correlation between surgical methods in the treatment of valve diseases, with a particular focus on their impact on hospitalization duration marking the pioneering effort of its kind in Bosnia and Herzegovina (B&H). This ground-breaking research holds immense importance for both the medical community and the broader population of B&H. By shedding light on the correlation between surgical methods and hospitalization duration, it offers valuable insights that can significantly improve the healthcare outcomes and experiences of patients in the region. Moreover, as the first of its kind in B&H, it serves as a critical stepping stone for future research and advancements in the field, ultimately contributing to the enhancement of healthcare practices and patient care within the country.

PATIENTS AND METHODS

Patients and study design

This retrospective cross-sectional study was conducted between January 2019 and November 2022 at the Clinic of Cardiovascular Surgery of the Clinical Centre of the University of Sarajevo in Bosnia and Herzegovina. Medical records of 163 patients were reviewed: the first group comprised 77 patients treated with open heart surgery

and the second group comprised 86 patients treated with minimally invasive surgery. The exclusion criterion was minimally invasive valve repair or replacement that had an intraoperative conversion to the conventional approach.

The study was approved and validated in advance by the Ethical Committee of the Clinical Centre of the University of Sarajevo. All amendments to the Helsinki Declaration were adhered to in the study settings.

Methods

Prior to the surgical procedure each patient underwent preoperative evaluation, including medical history assessment (cardiac status, medication allergies, symptoms of coronary artery disease, past medical conditions and comorbidities) and clinical examination (electrocardiograms (ECG), echocardiography and coronary angiography), as well as patients risk scoring using the 2013 Society of Thoracic Surgery Risk Score (STS-score) (12) and the 2018 updated Society of Thoracic Surgery Short-Term Risk (STS Short-Term Risk) (13).

The 2013 Society of Thoracic Surgery Risk Score (STS score) (12) and the 2018 updated Society of Thoracic Surgery Short-Term Risk (STS Short-Term Risk) (13) are instrumental in quantifying the 30-day risk of mortality and morbidity in heart surgery, factoring in variables such as age, gender, race, weight, height, body mass index (BMI), haematocrit levels, white blood cell count, platelet count, previous comorbidities and therapies, family medical history, the severity of specific blood vessel stenosis, medication profiles, as well as tobacco and alcohol usage.

Postoperative evaluation (after the surgical procedure) included the duration of hospitalization, procedural timelines, length of mechanical ventilation, administration details of inotropic agents and pharmacological support, wound healing and drainage metrics, neurological and renal function evaluations, instances of cardiopulmonary resuscitation (CPR), overall patient survival outcomes, as well as immediate preoperative findings.

Surgical procedure. Open-heart valve replacement (conventional valve surgery) is a surgical procedure that utilizes a median sternotomy incision to access the heart and may involve the use of mechanical or biological valves, with the surgeon having the option to employ either on-pump or off-pump techniques during the operation. Minimally invasive cardiac surgery (MICS) is a type of heart surgery involving the use of small incisions between 2 and 4 inches (5 to 10 centimetres) in length, such as anterolateral mini-thoracotomy, rather than a median sternotomy, with the surgeon using specialized instruments to access the heart and perform the valve repair or replacement procedure. The choice of incision location depends on factors such as the specific valve to be addressed and the patient's anatomy. Specialized instruments play a pivotal role in MICS (14). These instruments are designed to accommodate the limited access afforded by small incisions. They are typically elongated and slender, often equipped with articulating tips to allow precise manipulation. Some may incorporate video cameras (thoracoscopy) to provide real-time visualization of the surgical field, aiding the surgeon in precise valve manipulation (14). Closure of the small incisions was performed with sutures, staples, or adhesive skin closures, marking the culmination of the surgical procedure. The patients are then transitioned to postoperative care, including monitoring in a cardiac care unit.

Statistical analysis

Normally distributed data were presented as frequencies, percentage and by mean ±standard deviation, while non-normally distributed data were presented as median (25^{th}, 75^{th} percentile). Descriptive statistics data were presented across a 3-year timeline among the groups. For parametric data, the independent sample t- test was used, and for nonparametric data, the Mann Whitney U test was used. The statistical significance level was set at $p<0.05$.

RESULTS

Our study included in total 175 patients who were admitted to the Clinic for Cardiovascular surgery at the Clinical Centre of University of Sarajevo for either aortic or mitral valve replacement. After excluding 12 patients who did not meet the inclusion criteria due to intraoperative conversion from minimally invasive valve repair or replacement to conventional surgery, the final sample consisted of 163 patients.

Males were predominated, 93 (57.0%), with a mean BMI 29.2±3.4, with median STS Risk

Score of 1.5 (0.7 and 4.1 25th and 75th percentile, respectively), and median short STS score of 11.5 (6.9 and, 29.0, 25th and 75th percentile, respectively). Mean age was 62.7±8.0 years ranging from 42 to 85 years. Considering comorbidities, hypertension was found among 135 (82.8%), diabetes mellitus in 51 (31.3%), hyperlipidaemia in 123 (75.4%), chronic renal disease in 11 (6.7%), chronic obstructive pulmonary disease in 28 (17.2%), and peripheral vascular disease in 74 (45.4%) patients. There was no statistical significance (p>0.05) in the occurrence of certain entities between groups of conventional valve surgery and MICS valve surgery (Table 1).

Table 1. Diagnostic procedures conducted in the preoperative period among conventional valve surgery and minimally invasive cardiac surgery (MICS) valve surgery groups

Variable	Conventional valve surgery (N=77)	MICS valve surgery (N=86)	p
Gender (No,%)			>0.05
Female	33 (42.9)	37 (43.1%)	
Male	44 (57.1)	49 (56.9%)	
Age (years) (mean ±SD)	63.0±7.1	62.5 ± 8.3	>0.05
BMI (kg/m2)	30.3±3.5	28.2 ±3.4	>0.05
STS score (25th, 75th percentile) (%)	1.6 (0.7, 4.2)	1.5 (0.8, 3.7)	>0.05
STS short term risk (25th, 75th percentile) (%)	12.5 (7.5, 29.8)	10.4 (6.7, 21.2)	>0.05
Comorbidity (No, %)			N/A
Diabetes mellitus	24 (31.1)	27 (31.4)	
HTA	65 (84.4)	70 (81.3)	
HLP	60 (77.9)	63 (73.2)	
CKD	5 (6.4)	6 (6.9)	
COPD	13 (16.8)	15 (17.4)	
PVD	32 (41.5)	42 (48.8)	
ECG changes* (No, %)			N/A
Sinus rhythm	70 (90.9%)	73 (85.0)	
Atrial fibrillation	4 (5.1%)	2 (2.3)	
AV block second or third degree	3 (4.0%)	0	
RBBB	8 (10.3)	4 (4.6)	
LBBB	11 (14.2)	7 (8.1)	
ECHO (mean ±SD)			
EF (%)	41.5±10.3	41.2±13.2	>0.05
TAPSE (mm)	17.0±23.6	16.5±12.0	>0.05
LVIDd (mm)	51.2±8.9	51.3±10.2	>0.05
LVIDs (mm)	36.9±8.5	37.5±11.5	>0.05
AR diameter (mm)	29.2±10.1	23.2±11.3	>0.05
MV diameter (mm)	35.1±12.4	33.4±9.7	>0.05
TV diameter (mm)	35.2±2.5	34.1±2.1	>0.05
PAP (mmHg)	14.9±21.0	13.4±21.8	>0.05

*Some patients had multiple ECG changes
STS score, 2013 Society of Thoracic Surgery Risk Score; BMI, body mass index; HTA, hypertension; HLP, hyperlipidaemia; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; PVD, peripheral vascular disease; ECG, electrocardiograph; ECHO, echocardiography; RBBB, right bundle branch block; LBBB, left bundle branch block; EF, ejection fracture; TAPSE, tricuspid annular plane systolic excursion; LVIDd, left ventricular internal diameter at end-diastole; LVIDs, left ventricular internal diameter at end-systole; AR, aortic root; MV, mitral valve;

The overall mean procedure duration was 3.9±1.3 hours, 3.6±1.1 h in conventional surgery and 4.2±1.5 h in MICS (p=0.008). The patients undergoing conventional valve surgery generally required mechanical ventilation for 22.4±18.3 h, whereas those undergoing MICS valve surgery required it for 17.7±12.4 h. No significant difference was observed in the total hospitalization length between the conventional versus MICS, 8.2±4.5 and 8.7±7.0, days, respectively. Similarly, the total intensive care unit duration was comparable between the conventional and MICS, 3.9±2.8 and 4.2±4.1 days, respectively.

Considering perioperative complications related to blood, conventional valve surgery group used considerably more blood derivatives: red blood cells (conventional 343 vs MICS 204), plasma (conventional 319 vs MICS 218), and comparable platelets (conventional 100 vs MICS 107) than the MICS valve surgery group. The patients receiving MICS also experienced fewer CPR incidents (MICS 5.8% vs conventional 10.3%) (Table 2).

Table 2. Postoperative evaluation of conventional valve surgery and minimally invasive cardiac surgery (MICS) valve surgery groups

Variable	Conventional valve surgery (N=77)	MICS valve surgery (N=86)	p
Procedure duration (hours) (mean ±SD)	3.6±1.1	4.2±1.5	0.008
Mechanical ventilation duration (hours) (mean ±SD)	22.4±18.3	17.7±12.4	>0.05
ICU duration (days) (mean ±SD)	3.9±2.8	4.2±4.1	>0.05
Hospitalization duration (days) (mean ±SD)	8.2±4.5	8.7±7.0	>0.05
Usage of blood derivates (No)			N/A
Red blood cells transfusion	343	204	
Fresh-frozen plasma usage	319	218	
Platelet transfusion	100	107	
CPR (No, %)			N/A
Asystole/Pea (yes)	5 (6.4)	3 (3.4)	
VF/VT (yes)	3 (3.8)	2 (2.3)	

ICU, intensive care unit; CPR, cardiopulmonary resuscitation; VF/VT, ventricular fibrillation /ventricular tachycardia;

DISCUSSION

This study represents the inaugural research endeavour in Bosnia and Herzegovina that systematically compares distinct approaches to valve surgery, namely open surgery versus minimally invasive surgery. This research not only elucidates the merits and outcomes of these surgical modalities but also sheds light on their prospective implications. Furthermore, it offers valuable insi-

ghts into the existing landscape of valve surgery procedures within the country, considering that coronary artery disease and other cardiac conditions stand as the predominant contributors to both mortality and morbidity rates. The majority of the sample consisted of males who were overweight, with a range of comorbidities such as hypertension, diabetes mellitus, hyperlipidaemia, chronic renal disease, chronic obstructive pulmonary disease, and peripheral vascular disease.

Even though the research has shown that minimally invasive cardiac surgery–required more time to conduct, it required less mechanical ventilation time and used less blood derivates including red blood cells, plasma and similar platelets than conventional valve surgery leading to faster recovery. Similar studies such as the one by Cohn et al. have shown that their experience with this approach led to patients' recovering faster, reduced hospital stays, and lowered cost. Patients with severe chest wall deformities might not be suitable for minimally invasive surgery as their conditions, such as severe pectus excavatum or carinatum, could impede exposure (1). What is noteworthy is that the effectiveness of the operation through a small incision rivals that of full sternotomy. The incidence of sternal wound infection was minimal (1).

Cardiac valve replacement requiring open-heart surgery remains among the procedures with the highest morbidity and mortality rates, surpassed only by aortic aneurysm repairs and surgeries for congenital heart defects (15-17). Minimizing invasiveness is a desirable goal. Various strategies to make valve repair or replacement less invasive have been pursued (18). Despite the promising outcomes reported with minimally invasive techniques, the duration of extracorporeal circulation is invariably longer than conventional procedures, as our study also corroborated (8). Wolfe et al. presented in great detail the surgical technique and the four pillars of a successful minimally invasive mitral valve surgery (MIMVS): adequate cannulation and perfusion, good view of mitral valve, thorough cardiac protection and procedure match to specific pathology and etiology of mitral valve defect (9).

Minimally invasive surgery is progressively adopted worldwide as an alternative to the conventional sternotomy for treating mitral valve pathologies (19). It is a safe method and is associated with low 30-day mortality and stroke rate (19,20). Alternatively, ministernotomy has been promoted over recent years as an alternative technique for different cardiovascular surgical procedures, aiming to minimize the trauma associated with conventional full sternotomy (21). Fewer perioperative complications, a decreased likelihood of surgical wound infections, and a shortened recovery period have been the main advantages of MIMVS and these results were obtained in our study as well (22,23).

The availability of increasingly accurate methods for pre- and intraprocedural imaging, the ability of precise tracking of intravascular catheters and, last but not least, the development of "smart metal" devices that can change configuration after introduction into the body, will make it possible to repair the valves using procedures of a minimally invasive character. The benefit to patients will be decreased pain and suffering, shorter disability and faster return to normal life (24).

In our study edge-to-edge repair method was not evaluated, but it is important to notice that less invasive trans-catheter techniques could be considered as the natural future evolution of structural heart disease and mitral reoperations (25). The safety and efficacy of edge-to-edge repair procedures have not been compared to open reoperations in a randomized trial (26). However, published case series and comparisons to historical cohort's comparisons suggest that they are an effective and feasible alternative (25). Continued monitoring of relevant medical literature will offer more insight into minimally invasive and transcatheter procedures and provide valuable clinical outcome data (24,27).

The current literature shows that MICS and conventional mitral valve surgery have a comparable perioperative outcome. Minimally invasive mitral valve surgery appears more favourable concerning ICU stay, hospitalization duration as well as the need for blood transfusion (28).

This study is limited by its retrospective nature and the small number of patients enrolled. Specifically, due to the limited number of patients, a statistical analysis was not performed. Further studies are necessary to clarify benefits of this approach compared with conventional full sternotomy.

In conclusion, this research is the first of its kind in B&H. Minimally invasive valve surgery, when compared to the conventional approach, took more time to conduct, required fewer blood transfusions, and had similar hospitalization and ICU duration. Our experience with minimally invasive valve surgery demonstrates that this method can be performed safely and effectively without an increase in the duration of mechanical ventilation, ICU stay and hospitalization. Considering that this is the first study on this topic in our country, it serves as a promising start for more extensive research on this important topic. By emphasizing the importance of this research within the context of B&H healthcare challenges, such as high prevalence of coronary artery disease and cardiac conditions, it underscores the direct applicability of its findings to address pressing health issues in the region. Also, this research sets the stage for more extensive studies on the topic, serving as a promising starting point for ongoing investigations into the benefits and outcomes of minimally invasive valve surgery in the local context.

FUNDING

No specific funding was received for this study.

TRANSPARENCY DECLARATION

Competing interests: None to declare.

REFERENCES

1. Cohn LH. Minimally invasive valve surgery. J Card Surg 2001; 16:260-5.
2. Glauber M, Karimov JH, Farneti PA, Cerillo AG, Santarelli F, Ferrarini M, Del Sarto P, Murzi M, Solinas M. Minimally invasive mitral valve surgery via right minithoracotomy. Multimed Man Cardiothorac Surg 2009; 2009 (122):mmcts.2008.003350.
3. Di Tommaso E, Bruno VD. Commentary: The rise of minimalism in cardiac surgery. JTCVS Tech 2021; 7:67-8.
4. Gulbins H, Pritisanac A, Hannekum A. Minimally invasive heart valve surgery: already established in clinical routine?. Expert Rev Cardiovasc Ther 2004; 2:837-43.
5. Filip G, Bryndza MA, Konstanty-Kalandyk J, Piatek J, Wegrzyn P, Ceranowicz P, Brzazinski M, Lakkireddy D, Kapelak B, Bartus K. Ministernotomy or sternotomy in isolated aortic valve replacement? Early results. Kardiochir Torakochirurgia Pol 2018; 15:213–8.
6. Bonacchi M, Prifti R, Giunti G, Frati G, Sani G. Does ministernotomy improve postoperative outcome in aortic valve operation? A prospective randomized study. Ann Thorac Surg 2002; 73:460-5.
7. Kohorst K, Pretorius M. Future Technology. Semin Cardiothorac Vasc Anesth 2019; 23:123-33.
8. Harky A, Botezatu B, Kakar S, Ren M, Shirke MM, Pullan M. Mitral valve diseases: Pathophysiology and interventions. Prog Cardiovasc Dis 2021; 67:98-104.
9. Wolfe JA, Malaisrie SC, Farivar RS, Khan JH, Hargrove WC, Moront MG, Ryan WH, Ailawadi G, Agnihotri AK, Hummel BW, Fayers TM, Grossi EA, Guy TS, Lehr EJ, Mehall JR, Murphy DA, Rodriguez E, Salemi A, Segurola RJ Jr, Shemin RJ, Smith JM, Smith RL, Weldner PW, Lewis CT, Barnhart GR, Goldman SM. Minimally Invasive Mitral Valve Surgery II: Surgical Technique and Postoperative Management. Innovations (Phila) 2016; 11:251-9.
10. Singh K, Anderson E, Harper JG. Overview and management of sternal wound infection. Semin Plast Surg 2011; 25:25-33.
11. Abu-Omar Y, Fazmin IT, Ali JM, Pelletier M. Minimally invasive mitral valve surgery. J Thorac Dis 2021; 13:1960-70.
12. Kirmani BH, Mazhar K, Fabri BM, Pullan DM. Comparison of the EuroSCORE II and Society of Thoracic Surgeons 2008 risk tools. Eur J Cardiothorac Surg 2013; 44:999–1005.
13. Shahian DM, Jacobs JP, Badhwar V, Kurlansky PA, Furnary AP, Cleveland JC, Lobdell KV, Vassileva C, Wyler von Ballmoos MC, Thourani VH, Rankin JS, Edgerton JR, D'Agostino RS, Desai ND, Feng L, He X, O'Brien SM. The Society of Thoracic Surgeons 2018 adult cardiac surgery risk models: Part 1—background, design considerations, and Model Development. Ann Thorac Surg 2018; 105:1411–8.
14. Glauber M, Ferrarini M, Miceli A. Minimally invasive aortic valve surgery: state of the art and future directions. Ann Cardiothorac Surg 2015; 4: 26-32.
15. Movahed MR, Etemad S, Hashemzadeh M, Hashemzadeh M. Persistent reduction in the age adjusted mortality rate from aortivc valve surgery in the United States with elimination of gender gap in recent years. Am J Cardiovasc Dis 2020; 10:522-27.
16. Schlösser FJV, Vaartjes I, van der Heijden GJMG, Moll FL, Verhagen HJM, Muhs BE, borst GJ, Groenestege TT, Kardaun JWPF, Bruin A. Mortality after elective abdominal aortic aneurysm repair. Ann Surg 2010; 251:158-64.
17. Berger JT, Holubkov R, Reeder R, Wessel DL, Meert K, Berg RA, Bell MJ, Tamburro R, Dean JM, Pollack MM. Morbidity and mortality prediction in pediatric heart surgery: physiological profiles and surgical complexity. J Thorac Cardiovasc Surg 2017; 154:620-8.e6
18. Pope NH, Ailawadi G. Minimally Invasive Valve Surgery. J Cardiovasc Transl Res 2014; 7:387-94.
19. Ko K, de Kroon TL, Post MC, Kelder JC, Schut KF, Saouti N, van Putte BP. Minimally invasive mitral valve surgery: a systematic safety analysis. Open Heart 2020; 7:e001393.

20. Ullah W, Sattar Y, Mukhtar M, Abdullah HM, Figueredo VM, Haas DC, Fischman DL, Chadi Alraies M. Outcomes of open mitral valve replacement versus transcatheter mitral valve repair; insight from the National Inpatient Sample Database. Int J Cardiol Heart Vasc 2020; 28:100540.
21. Iba Y, Yamada A, Kurimoto Y, Hatta E, Maruyama R, Miura S. Perioperative outcomes of minimally invasive aortic arch reconstruction with branched grafts through a partial upper sternotomy. Ann Vasc Surg 2020; 65:217-23.
22. Fishbein GA, Fishbein MC. Mitral Valve Pathology. Curr Cardiol Rep 2019; 21:61.
23. Grant SW, Hickey GL, Modi P, Hunter S, Akowuah E, Zacharias J. Propensity-matched analysis of minimally invasive approach versus sternotomy for mitral valve surgery. Heart 2019; 105:783-9.
24. Bergsland J, Mujanovic E, Elle OJ, Mirtaheri P, Fosse E. Minimally invasive repair of the mitral valve: technological and clinical developments. Minim Invasive Ther Allied Technol 2011; 20:72-7.
25. Sorajja P, Ukaigwe AC. Edge-to-edge repair: past challenge, current case selection and future advances. Ann Cardiothorac Surg 2021; 10:43-9.
26. Shechter A, Lee M, Kaewkes D, Koren O, Skaf S, Chakravarty T, Koseki K, Patel V, Makkar RR, Siegel RJ. Repeat mitral transcatheter edge-to-edge repair for recurrent significant mitral regurgitation. J Am Heart Assoc 2023; 12: e028654.
27. Botta L, Cannata A, Bruschi G, Fratto P, Taglieri C, Russo CF, Martinelli L. Minimally invasive approach for redo mitral valve surgery. J Thorac Dis 2013; 5:S686-93.
28. Sündermann SH, Czerny M, Falk V. Open vs. Minimally invasive mitral valve surgery: surgical technique, indications and results. Cardiovasc Eng Technol 2015; 6:160-6.