

Minimally invasive thoracoscopic vs. sternotomy approach in mitral valve surgery

Jana Čobejová, Tomáš Toporcer, Peter Šafár, Štefánia Mižáková, Lukáš Vajda, Štefan Lukačín, Adrián Kolesár

Department of Heart Surgery, East Slovak Institute of Cardiovascular Diseases and Medical Faculty, Pavol Jozef Šafárik University, Košice, Slovakia

ARTICLE INFO

Article history:

Submitted: 27. 2. 2026

Accepted: 14. 3. 2026

Available online: 5. 10. 2026

Klíčové slová:

Minimálně invazivní chirurgie

Mitrální chlopěň

Mitrální regurgitace

Sternotomie

SÚHRN

Úvod: V posledných desaťročiach sa popri štandardnom prístupe k mitrálnnej chlopni pomocou úplnej strednej sternotómie stáva minimálne invazívna srdcová chirurgia (MIMVS) čoraz populárnejším chirurgickým prístupom. Cieľom tejto štúdie bolo retrospektívne porovnať výsledky operácií mitrálnnej chlopne prístupom z video-asistovanej torakoskopie (VATS) a štandardnej sternotómie (ST).

Metódy: Retrospektívna analýza bola vykonaná na pacientoch, ktorí podstúpili operáciu mitrálnnej chlopne. Pacienti boli rozdelení do skupiny operovanej prístupom ST a skupiny operovanej prístupom VATS. Skúmané boli predoperačné, chirurgické a pooperačné parametre, vrátane prežívania a závažných kardiovaskulárnych príhod (MACE), ktoré zahŕňali mozgovú príhodu, infarkt myokardu, závažnú arytmiu a smrť. Pooperačné echokardiografické parametre boli hodnotené na podskupinách pacientov podstupujúcich jednotlivými prístupmi výhradne záchovnú operáciu mitrálnnej chlopne.

Výsledky: V skupine bolo 123 pacientov, z ktorých 69 bolo operovaných prístupom ST a 54 prístupom VATS. Predoperačne bolo hlavným rozdielom EuroScore, pričom skupina ST bola rizikovejšia (0,94 vs. 0,73 $p < 0,0001$). V skupine VATS prevažovala záchovná operácia (94 % vs. 55 %, $p < 0,0001$). Pacienti po VATS mali dlhší čas kardiopulmonálneho bypassu (CPB) a aortálnej svorky (146 vs. 91,8 min; $p < 0,0001$; 110 vs. 75,5 min; $p < 0,0001$). Echokardiograficky neboli v podskupine mitrálnnych záchovných výkonov štatisticky významné rozdiely v pooperačných tlakových gradientoch na mitrálnnej chlopni ani v parametroch remodelácie ľavej komory. Miera prežívania a MACE boli v skupinách podobné. V pooperačnom období bol v ST skupine zistený vyšší výskyt evakuácie perikardiálnej efúzie (12 vs. 0 %, $p < 0,01$) a podania krvnej plazmy (1,17 vs. 0,46, $p < 0,001$). Sledovanie pooperačných komplikácií ako revízia, infekcia rany, punkcia fluidothoraxu, drenáž pneumothoraxu, implantácia kardiostimulátora, vznik predsieňovej fibrilácie, dĺžka hospitalizácie, neurologické komplikácie, nutnosť eliminačnej terapie nezaznamenalo medzi skupinami štatisticky významné rozdiely.

Záver: Údaje naznačujú, že VATS ponúka porovnateľné chirurgické výsledky ako ST pri operáciách mitrálnnej chlopne s dodatočnými kozmetickými výhodami.

© 2026, ČKS.

ABSTRACT

Introduction: In recent decades, minimally invasive cardiac surgery (MIMVS) has become an increasingly popular surgical approach alongside the standard approach to the mitral valve using complete median sternotomy. The aim of this study was to retrospectively compare the results of mitral valve surgery using video-assisted thoracoscopy (VATS) and standard sternotomy (ST).

Methods: A retrospective analysis was performed on patients ($n = 123$) who underwent mitral valve surgery. They were divided into ST ($n = 69$) and VATS ($n = 54$) groups. Various preoperative, surgical, and postoperative parameters were examined, including survival and major adverse cardiac events (MACE), which included stroke, myocardial infarction, severe arrhythmia and death.

Results: Preoperatively, the main difference was in EuroScore, with the ST group being at higher risk (0.94 vs. 0.73, $p < 0.0001$). In the VATS group, conservative surgery prevailed (94 vs. 55%, $p < 0.0001$), while in the ST group, valve replacements prevailed (45 vs. 6%, $p < 0.0001$). Patients after VATS had longer cardiopulmonary bypass (CPB) and aortic clamp times (146 vs. 91.8 min; $p < 0.0001$; 110 vs. 75.5 min; $p < 0.0001$). Echocardiographically, there were no statistically significant differences in postoperative pressure gradients across the mitral valve or in left ventricular remodeling in the mitral valve repair (MVP) subgroup. Survival rates and

Keywords:

Minimally invasive surgery

Mitral regurgitation

Mitral valve

Sternotomy

Address: MUDr. Jana Čobejová, Department of Heart Surgery, East Slovak Institute of Cardiovascular Diseases and Medical Faculty, Pavol Jozef Šafárik University, Ondavská 8, 04001 Košice, Slovakia, e-mail: cobejovaj@gmail.com

DOI: 10.33678/cor.2026.027

MACE were similar. In the postoperative period, the ST group had a higher incidence of pericardial effusion evacuation (12 vs. 0%, $p < 0.01$) and blood plasma administration (1.17 vs. 0.46, $p < 0.001$). Monitoring of postoperative complications such as revision, wound infection, fluidothorax puncture, pneumothorax drainage, TKS implantation, atrial fibrillation, length of hospitalisation, neurological complications, and the need for CVVHD did not reveal any statistically significant differences.

Conclusion: The data suggest that VATS offers comparable surgical results to ST in mitral valve surgery with additional cosmetic advantages.

Introduction

Mitral valve diseases are one of the most common cardiac pathologies and include two primary disorders: mitral stenosis and mitral regurgitation. Mitral regurgitation is the second most common valvular defect after aortic stenosis requiring intervention.^{1,2} The epidemiological profile has changed significantly over the last decade, with degenerative pathology coming to the fore in developed countries ahead of rheumatic pathology, which was dominant in the past.³ European ESC/EACTS guidelines state that mitral valve repair (especially when indicated early) has a positive effect on preserving/restoring the elasticity of the left ventricle and on ejection fraction compared to late indication or inappropriate replacement.⁴

The standard surgical approach in cardiac surgery is generally median sternotomy, which allows easy access to the heart, flexibility in myocardial protection, multiple approaches to the mitral valve, and high-quality cardiac ventilation. However, the invasiveness of sternotomy is associated with a delayed return to preoperative physical function and an increase in postoperative complications.⁵ In recent decades, there has been a significant progress in the development of minimally invasive procedures in cardiac surgery thanks to advances in surgical instruments, telemanipulation, and perfusion technology. VATS, performed through a 4 to 7 cm lateral thoracotomy, is a less invasive alternative with comparable quality and safety to standard sternotomy (Fig. 1).⁶

The aim of this study was to compare the standard sternotomy and minimally invasive approaches to the mitral valve in terms of intraoperative parameters, postoperative complications and short-term postoperative out-

comes, and to evaluate the results of mitral valve repair using the ST vs. VATS approach.

Material and methods

This study presents a retrospective analysis of data from patients who underwent primary mitral valve surgery at the Department of Heart Surgery of VÚSCH a.s. Košice between January 2016 and December 2025. The inclusion criteria were isolated mitral valve surgery. Exclusion criteria included combined surgery, reoperation, and acute surgery. The following preoperative data were recorded for all patients: age, sex, type of valve disease (stenosis, regurgitation, infective endocarditis), body surface area (BSA), body mass index (BMI), risk of death during hospitalization (EuroScore II), left ventricular ejection fraction (LVEF), effective regurgitant orifice area (EROA), end-systolic and end-diastolic volumes (ESV, EDV), left ventricular size in systole and diastole (LKs, LKd), and regurgitant volume (RV).

The following perioperative and postoperative data were also recorded: type of surgical approach (complete sternotomy or video-assisted thoracoscopy), type of mitral valve procedure selected (replacement or repair), length of cardiopulmonary bypass, duration of cardioplegic arrest, early revision due to bleeding, evacuation of pericardial effusion, development of wound infection, development of emphysema, need for drainage or puncture of the pleural space, renal failure requiring CVVHD, development of neurological deficit, postoperative atrioventricular block (AVB), need for pacemaker implantation (PPM), persistent and paroxysmal postoperative atrial fibrillation, pressure gradient and residual regurgitation on the valve, length of stay in the intensive care unit (ICU), length of hospitalization, survival, and occurrence of major adverse cardiovascular events (MACE). Patient survival was recorded on the basis of a contract with the health insurance provider using the ÚDZS portal. Within the MACE, the postoperative incidence of stroke, myocardial infarction and death was monitored during the study period and was determined electronically based on e-health data.

Subsequently, patients undergoing valve replacement were excluded from the group for further analysis in order to objectively compare the effectiveness of mitral valve preservation surgery using ST vs. VATS. In the subgroups created, a comparison of postoperative echocardiographic parameters was performed between patients who underwent surgery using the ST and VATS approach.

Quantitative data are expressed in the statistical analysis as mean $\pm$ standard deviation. Qualitative data are

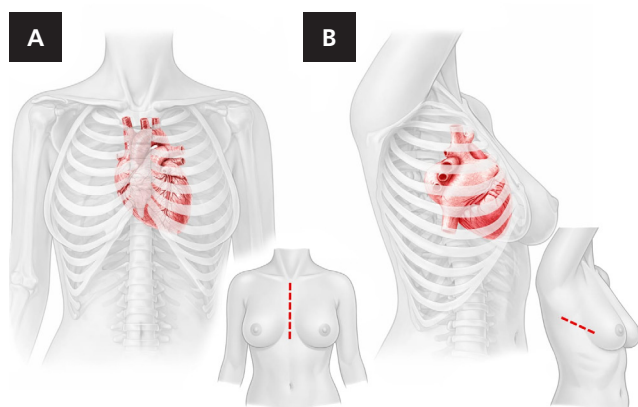


Fig. 1 – Topographic relationship between surgical access and the anatomical position of the heart (A – median sternotomy; B – left thoracotomy).

expressed as a percentage of positive cases. A two-sample t-test was used to compare the ST and VATS patient groups (for quantitative parameters), and the chi-square and Fisher's exact tests were used to compare qualitative parameters. Survival outcomes and MACE incidence in the two patient groups (ST and VATS) were compared using Kaplan–Meier survival curves and the log-rank test. Statistical analysis was performed using SPSS version 20. Parameters with a p -value <0.05 were considered statistically significant in each evaluation.

Results

A total of 123 patients were included in the analysis and divided into two groups based on the surgical approach chosen: patients with ST ($n = 69$) and VATS ($n = 54$). The average age of the patients was 55 years. The cohort included 40/123 (32.5%) women.

The average left ventricular ejection fraction (LVEF) for the entire group was $60\% \pm 7.9\%$, the mean effective regurgitant orifice area (EROA) was 0.57 ± 0.2 , regurgitant volume (RV) was 84 ± 33.7 ml, left ventricular size in systole (LVs) 38.8 ± 6.9 mm, left ventricular size in diastole (LVd) 56.2 ± 7.4 mm, end-diastolic volume (EDV) 151.3 ± 51 ml, end-systolic volume (ESV) 63 ± 27 ml. The average body surface area (BSA) was 1.9 ± 0.3 , the average body mass index (BMI) was 26.8 ± 4.7 kg/, and the in-hospital mortality parameter (EuroScore II) was 0.85 ± 0.35 . The indication for surgery was mitral regurgitation in 85.4% of cases, stenosis in 3.3%, a combination of both in 3.3% and infectious endocarditis in 8% of cases. The primary minimally invasive thoracoscopic approach was chosen in 54/123 (43.9%) patients, with no cases requiring conversion to sternotomy.

The average duration of cardiopulmonary bypass (CPB) for the entire group was 116 ± 43.7 minutes and the duration of aortic clamping was 90.8 ± 27.5 minutes. The valve was replaced in 27.6% of patients. The length of stay in the intensive care unit was 5.1 ± 3.5 days and the total length of hospitalization was 12 ± 6.7 days. After surgery, 4% of patients were diagnosed with new atrioventricular block requiring pacemaker implantation, early revision due to bleeding was necessary in 3.3% of patients, and late revision due to pericardial effusion was necessary in 6.5% of patients. Paroxysmal atrial fibrillation was detected in 34.2% of patients, with a transition to persistent atrial fibrillation in 20.3%. Surgical wound infection was reported in 5.7% of patients. The need for elimination therapy (CVVHD) was reported in 6.5% and neurological complications in 4.9% of patients.

Comparison of the ST and VATS groups revealed a difference in preoperative parameters in terms of surgical risk (EuroScore). Patients who underwent surgery via ST were at higher risk, with a statistical significance of $p < 0.001$. The difference in patient age, BMI, and BSA was not statistically significant (Table 1).

Surgery due to valvular stenosis was more prevalent in the ST group, but with no statistical significance (4% vs. 0%, $p = 0.255$), same as for infectious endocarditis (12% vs. 2%, $p = 0.08$). Surgery due to valvular insufficiency was statistically significantly more common in the VATS group

(98% vs. 77%, $p = 0.001$). In the ST group, valve replacement prevailed over repair surgery (45 vs. 55%), while in VATS, repair surgery prevailed (94 vs. 6%).

A comparison of perioperative parameters showed statistically significant longer CPB time and aortic clamp time in the VATS group, by 54 resp. 34 minutes ($p < 0.0001$ for both). A statistically significant difference in the amount of blood plasma administered (1.2 vs. 0.5, $p = 0.001$) and pericardial effusion evacuation (12 vs. 0%, $p < 0.01$) was demonstrated to the ST group. When comparing the need for revision, wound infection, fluidthorax puncture, drainage for pneumothorax, PPM

Table 1 – Comparison of pre-operative parameters

Parameter	ST (n = 69)	VATS (n = 54)	p-value
EuroScore	0.94	0.73	<0.0001
Age	56.61	52.94	0.186
BMI	27.35 kg/m ²	26.15 kg/m ²	0.20
BSA	1.91 m ²	1.97 m ²	0.05
Stenosis	4%	0%	0.255
Regurgitation	77%	98%	0.001
Stenosis + regurgitation	7.2%	0%	0.07
Infective endocarditis	12%	2%	0.08

Table 2 – Surgery, hospitalization and follow-up parameters – comparison

Parameter	ST (n = 69)	VATS (n = 54)	p-value
CPB	91.85 min	146.3 min	<0.0001
Aortic clamp	75.54 min	110 min	<0.0001
Atrial fibrillation	37.7%	29.6%	0.444
Permanent fibrillation	21.7%	18.5%	0.822
AVB	8.7%	1.9%	0.134
PPM	7.2%	0%	0.067
Wound infection	4.3%	7.4%	0.525
Hospitalization	12 days	11.9 days	0.461
ICU hospitalization	5.2 days	5.0 days	0.946
Neurological complication	3%	7%	0.403
Pneumothorax (right)	10.1%	22.2%	0.081
Pneumothorax (left)	5.8%	0%	0.13
Pericardial evacuation	11.6%	0%	0.01
Emphysema	4.3%	14.8%	0.058
Pleural puncture	5.8%	9.3 %	0.504
Erythrocytes	2.01	1.41	0.094
Plasma	1.17	0.46	0.001
Trombocytes	0.04	0.09	0.46
Protrombin	0.12	0.15	0.46
Revision	3%	4%	1.0
CVVHD	9%	4%	0.30

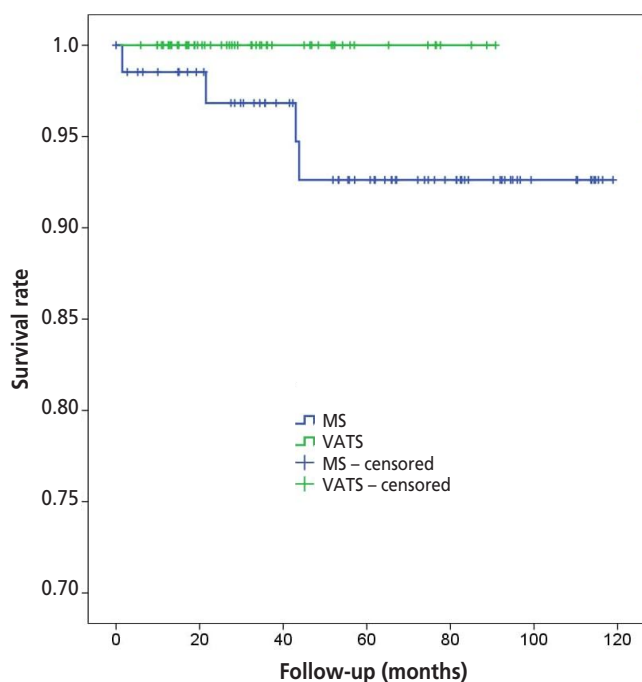


Fig. 2 – Kaplan–Meier analysis of postoperative survival.

implantation, development of atrial fibrillation, length of hospitalization, neurological complications or need of CVVHD, no differences were observed between the groups (Table 2).

Survival was monitored for an average of 3 years in the VATS group with a survival rate of 100% and in the ST group for 5.2 years with a survival rate of 94%. Kaplan–Meier survival analysis and log-rank test showed no statistically significant difference in survival ($p = 0.12$) (Fig. 2). The median follow-up for MACE incidence in the ST

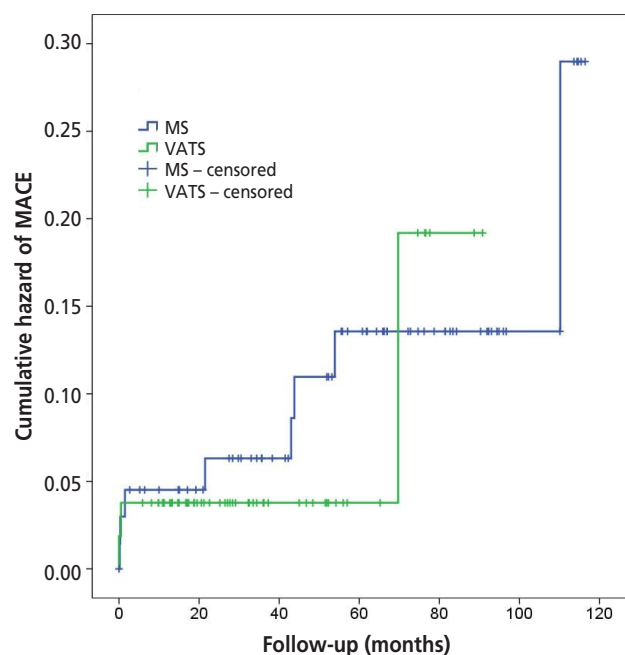


Fig. 3 – Kaplan–Meier analysis of MACE event.

Table 3 – Echocardiographic parameters after mitral valve repair surgery

Parameter	ST (n = 37)	VATS (n = 51)	p-value
Pre-operative			
LVEF	59.6%	60.6%	0.74
LKd	56.0 mm	58.5 mm	0.12
LKs	38 mm	39.6 mm	0.42
3 months post-OP			
LVEF	54.2%	55.5%	0.50
LKd	50 mm	51 mm	0.13
LKs	37.50 mm	37.52 mm	0.48
Regurgitation	0.61	0.76	0.40
Mean gradient	3.1	2.9	0.25
1 year post-OP			
LVEF	55.7%	56.3%	0.77
LKd	49.6 mm	51.4 mm	0.03
LKs	35.53 mm	35.46 mm	0.35
Regurgitation	0.66	0.68	0.88
Mean gradient	3.1	3.3	0.17

group was 4.9 years with an incidence of 13%, and in the VATS group it was 2.8 years with an incidence of 6%, with no statistically significant difference ($p = 0.71$) (Fig. 3).

In the subgroup after exclusion of patients who underwent mitral valve replacement, no significant differences in ECHO parameters were found preoperatively. In the subsequent comparison of postoperative parameters, a larger left ventricular diameter in diastole was recorded one year after surgery in the VATS group (51.4 vs. 49.6 mm; $p = 0.03$). No other parameters showed statistically significant differences (Table 3).

Discussion

An interesting finding of the study is the difference in preoperative risk between the groups, with patients in the ST group having a higher EuroScore. This observed selection of patients probably reflects natural tendencies in surgical practice, where more complex or higher-risk patients are treated using a standard approach. A similar trend was described in a retrospective analysis by Pojar et al.⁷ with a higher EuroScore in the case of sternotomy by an average of 1.7, and in a British observational study by Jackson et al.⁸ by as much as 3.2. In contrast, in randomized and propensity score-matched studies that specifically balanced baseline characteristics, including EuroScore, no difference in preoperative risk between ST and VATS was demonstrated. In the multicenter UK Mini Mitral randomized clinical trial, the average EuroScore was identical in both groups (1.7 ± 1.6 vs. 1.7 ± 1.4).⁵

The incidence of infective endocarditis was higher in the ST group (12% vs. 2%), but the difference was not statistically significant ($p = 0.08$). This trend is consistent with the literature, according to which valve with infective endocarditis has long been considered a relative con-

traindication to a minimally invasive approach, and many centers have therefore preferred sternotomy.⁹ However, recent studies show that with careful patient selection, MIMVS is technically feasible in native infective endocarditis and provides comparable or even better results, including shorter ventilation and ICU stay, compared to sternotomy.^{9,10}

In the VATS group, we describe a valve-sparing surgery rate of 94%, compared to 55% in the ST group. Data from the STS and Euro Heart Survey databases indicate that the valve repair rate in the US and Europe was 41% and 46.5%, respectively.^{11,12} A study by Gammie et al. reports a 67% repair rate with ST and an 85% repair rate with VATS.¹³

Our echocardiographic follow-up found that, when valve replacements were excluded and only preservation surgeries (MVP group) were evaluated, there were no statistically significant differences in mitral valve pressure gradients between the two approaches throughout the follow-up period. This comparable medium-term valve function is clinically important because it shows that the quality of conservative surgery is not compromised by the minimally invasive approach.

The only statistically significant echocardiographic difference in the MVP subgroup was a larger end-diastolic left ventricular dimension (LVd) in the VATS group one year after surgery (51.4 mm vs. 49.6 mm, $p = 0.033$). Although this difference is statistically significant, its clinical impact is likely to be marginal (a difference of 1.8 mm), and it has not been shown to result into differences in left ventricular ejection fraction, other echocardiographic parameters, or patient survival. Longer-term follow-up would be useful to characterize this phenomenon.

In our study, we found no statistically significant differences between ST and VATS in terms of the need for surgical revision, wound infection, complications requiring fluidothorax puncture or pneumothorax drainage, the occurrence of atrial fibrillation, neurological complications or the need for CVVHD, with all these parameters ranging within the values described in larger studies.^{7,14}

The statistically significant longer CPB and aortic clamp times in the VATS group (by 54 and 34 min, respectively; $p < 0.0001$) is consistent with most published studies describing an increase in both of these times in MIMVS compared to sternotomy, reflecting the technical difficulty and longer learning curve of minimally invasive techniques. In the analysis by Iribarne et al.¹⁵, the CPB time in VATS was approximately 22–25 minutes longer and the clamp time was 9–14 minutes longer; similar differences are also reported in other comparative studies and meta-analyses.^{7,14} In the presented group, the prolongation of CPB and aortic clamp time is even more significant, which may be related to both the learning curve during the introduction of the VATS program and the higher complexity of procedures (higher incidence of repair operations) in the minimally invasive group. Nevertheless, this difference did not lead to a deterioration in survival, longer hospitalization or a higher incidence of renal failure or reoperations for bleeding, which is consistent with meta-analyses that do not con-

sider longer operating times in MIMVS to be clinically significant.^{14,16,17}

The meta-analysis by Spadini et al.¹⁷ reports a shorter length of hospital stay after VATS compared to ST, which was not statistically significant in our study (VATS 5.0 vs. ST 5.2 days in the ICU, VATS 11.9 vs. ST 12 days of hospital stay). This result may be due to similar postoperative care and patient management protocols in both groups at our center.

In our cohort, the average number of red blood cell units administered between the ST and VATS groups differed only slightly (ST 2.01 vs. VATS 1.41 units), with the difference not reaching statistical significance ($p = 0.09$). This result is consistent with published studies with smaller and medium-sized patient cohorts, in which MIMVS does not show a clear reduction in the consumption of erythrocyte concentrates, or the differences are only marginal and often not statistically significant.^{18,19} In contrast, meta-analyses with several hundred to thousands of patients more often demonstrate a slightly lower need for transfusions in MIMVS.²⁰

In the context of our data, there is a lower incidence of MACE in the VATS group (6% vs. 13% in ST), with no statistical significance ($p = 0.71$), in line with several studies reporting a long-term absence of MACE at a level of approximately 85–95% in both groups during medium- to long-term follow-up.^{14,18} The fact that no significant difference was demonstrated between the groups despite different median follow-up times suggests that even with longer follow-up, there is no accumulation of MACE in the ST group that would fundamentally disadvantage this approach, but at the same time supports the hypothesis of the long-term safety of VATS.

In the medium-term follow-up, the survival analysis in our cohort reached 100% after 3 years in the VATS group and 94% after an average follow-up of 5.2 years in the ST group ($p = 0.12$), which is consistent with several large studies where 5-year survival is most often around 93–96% in both groups, with no significant difference between MIMVS and sternotomy.^{7,21,22}

Conclusion

Our results show that video-assisted thoracoscopic mitral valve surgery provides clinical results comparable to standard median sternotomy. Despite longer cardiopulmonary bypass and aortic cross-clamp times, no increase in serious postoperative complications was observed. The minimally invasive group had a higher proportion of mitral valve repairs and similar echocardiographic results in the repair surgery subgroup. Long-term survival and the incidence of major adverse cardiac events (MACE) did not differ between the two approaches. Our findings support the position of the minimally invasive VATS approach as a safe and effective alternative to sternotomy in specialized centers with sufficient experience.

Conflict of interest

The authors declare that there are no financial or personal relationships that could inappropriately influence (bias) the work reported in this manuscript. The authors

confirm that they have no conflicts of interest relevant to the content of this article.

Funding

This research received no external funding.

Ethical statement

The processing of the retrospective study was approved by the Ethics Committee in compliance with the principles of the Declaration of Helsinki and ICH Guidelines for Good Clinical Practice and applicable regulatory requirements (protocol code: 2026003 and date of approval: February 13, 2026).

Informed consent

During hospitalization, patients provided written consent for the healthcare received. According to the recommendation of the Ethics Committee, due to the retrospective nature of the study, no further patient consents were required.

Literature

- Aluru JS, Barsouk A, Saginala K, et al. Valvular heart disease epidemiology. *Med Sci (Basel)* 2022;10:232.
- Toporcer T, Lukan , Kraus A, et al. Bioprostheses and mechanical prostheses for aortic valve replacement in patients aged 50 to 65 years offer similar long-term survival rates. *J Cardiovasc Dev Dis* 2025;12:44.
- Douedi S, Douedi H. Mitral regurgitation. In: StatPearls. Online. Treasure Island (FL): StatPearls Publishing; 2024 Apr 30. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK553135/>. [cited 2026-10-03].
- Vahanian A, Beyersdorf F, Praz F, et al. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. *EuroIntervention* 2022;17:e1126–e1196.
- Akokuwah EF, Maier RH, Hancock HC, et al. Minithoracotomy vs conventional sternotomy for mitral valve repair: a randomized clinical trial. *JAMA* 2023;329:1957–1966.
- Seeburger J, Borger MA, Falk V, et al. Minimal invasive mitral valve repair for mitral regurgitation: results of 1339 consecutive patients. *Eur J Cardiothorac Surg* 2008;34:760–765.
- Pojar M, Karalko M, Dergel M, et al. Minimally invasive or sternotomy approach in mitral valve surgery: a propensity-matched comparison. *J Cardiothorac Surg* 2021;16:228.
- Jackson M, et al. Long-term outcomes comparing minimally invasive mitral valve repair versus conventional mitral valve surgery. *World J Cardiovasc Surg* 2018;8:127–139.
- Mikus E, Fiorentino M, Sangiorgi D, et al. Minimally invasive versus full sternotomy approaches in mitral valve surgery for infective endocarditis: a retrospective comparative analysis. *Diseases* 2025;13:35.
- Kofler M, Van Praet KM, Schambach J, et al. Minimally invasive surgery versus sternotomy in native mitral valve endocarditis: a matched comparison. *Eur J Cardiothorac Surg* 2021;60:1189–1194.
- Bolling SF, Li S, O'Brien SM, et al. Predictors of mitral valve repair: clinical and surgeon factors. *Ann Thorac Surg* 2010;90:1904–1912.
- Iung B, Baron G, Butchart EG, et al. A prospective survey of patients with valvular heart disease in Europe: The Euro Heart Survey on Valvular Heart Disease. *Eur Heart J* 2003;24:1231–1243.
- Gammie JA, Zhao Y, Peterson ED, et al. Less-invasive mitral valve operations: trends and outcomes from the Society of Thoracic Surgeons adult cardiac surgery database. *Ann Thorac Surg* 2010;90:1401–1410.
- Moscarello M, Fattouch K, Gaudino M, et al. Minimal access versus sternotomy for complex mitral valve repair: a meta-analysis. *Ann Thorac Surg* 2020;109:737–744.
- Iribarne A, Russo MJ, Easterwood R, et al. Minimally invasive versus sternotomy approach for mitral valve surgery: a propensity analysis. *Ann Thorac Surg* 2010;90:1471–1478.
- Badhwar V, Anastacio MM, Wei LM. Video-assisted minimally invasive mitral valve surgery: transitioning from sternotomy to mini-thoracotomy. *Multimed Man Cardiothorac Surg* 2013;2013:mmt016.
- Spadini FA, Lira KB, Delvaux RS, et al. Minimally invasive versus conventional mitral valve surgery: a systematic review and meta-analysis of randomised clinical trials. *Open Heart* 2026;13:e003612.
- Amin A, Kumar R, Mokhtassi SS, et al. Minimally invasive vs conventional mitral valve surgery: a meta-analysis of randomised controlled trials. *Front Cardiovasc Med* 2024;11:1437524.
- Wang Q, Xue X, Yang J, et al. Right mini-thoracotomy approach reduces hospital stay and transfusion of mitral or tricuspid valve reoperation with non-inferior efficacy: evidence from propensity-matched study. *J Thorac Dis* 2018;10:4789–4800.
- Hage A, Hage F, Al-Amadi H, et al. Minimally invasive versus sternotomy for mitral surgery in the elderly: a systematic review and meta-analysis. *Innovations (Phila)* 2021;16:310–316.
- Tungjitviboonkun S. Survival analysis of minimally invasive mitral valve surgery versus conventional median sternotomy in the United States. *Cureus* 2025;17:e81859.
- Olsthoorn JR, Heuts S, Houterman S, et al. Effect of minimally invasive mitral valve surgery compared to sternotomy on short- and long-term outcomes: a retrospective multicentre interventional cohort study based on Netherlands Heart Registration. *Eur J Cardiothorac Surg* 2022;61:1099–1106.