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Valve: Research

Simplified Approach for Minimally Invasive Mitral Valve Surgery Through a Transaxillary Minithoracotomy Access

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ABSTRACT

BACKGROUND Concerns still exist regarding increased technical complexity and longer operative times associated with minimally invasive cardiac procedures. To help overcoming this view and the skepticism about the value of performing cardiac surgery through reduced incisions, we present and discuss our experience with a simplified minimally invasive surgical setup using right transaxillary minithoracotomy direct view access.

METHODS This is a retrospective study that was based on an institutional database and included consecutive patients who underwent transaxillary mitral valve surgery from January 2017 to December 2024.

RESULTS The study included 615 patients. Mitral valve repair for degenerative disease was performed in 94% of patients, and tricuspid valve surgery was associated in 16%. Mean cardiopulmonary bypass and cross-clamp times were 105 ± 32 and 65 ± 23 minutes, respectively. Thirty-day mortality and stroke or transient ischemic attack rates were 0.3% and 0.9%, respectively. Median postoperative intubation time was 2 hours (interquartile range [IQR], 0-6 hours), with 51% of patients extubated in the operating room. Median intensive care unit and hospital stays were 24 hours (IQR, 22-48 hours) and 7 days (IQR, 6-8 days), respectively. Residual mitral regurgitation was none or mild in 98% of patients who underwent repair procedures; recurrent moderate or greater regurgitation occurred in 1.4% of patients at 1 year and in 11% at 5 years. Survival probabilities at 1 and 6 years were 99% and 96%, respectively.

CONCLUSIONS Minimally invasive mitral surgery through the transaxillary approach ensures outstanding technical results with a low risk of perioperative complications. Increasing the perceived value of minimally invasive procedures through a simplified surgical setup can facilitate the initiation and wider adoption of a minimally invasive cardiac surgery program.

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Nearly 30 years have passed since the experiences producing the initial results of cardiac surgery through reduced chest incisions, which marked the dawn of minimally

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invasive cardiac surgery (MICS).[1-3] From the beginning, right minithoracotomy emerged as the favored approach for atrioventricular valve surgery,[4] albeit characterized by diverse solutions for valve exposure, myocardial protection, and deairing,[5,6] as well as incorporating robotic assistance and telemanipulation technologies.[7-10]

Despite these advancements, MICS adoption remains limited. National registries from the United States and The Netherlands show that only 20% to 30% of mitral valve surgical procedures use minithoracotomy or robotic techniques.[11-14] A higher percentage (60%) of minimally invasive single-valve operations has been reported in the last decade by German society annual reports; however, no data for combined procedures are available. Concerns about technical complexity, longer operating times, and required training may discourage broader implementation. This is despite demonstrations of high safety and excellent and durable technical results with MICS,[15,16] as well as added benefits such as reduced transfusion needs, a lower incidence of postoperative atrial fibrillation, shorter intensive care unit (ICU) stays, and faster recovery, especially within multidisciplinary care protocols.[17-20]

To address barriers to MICS adoption, operator-friendly techniques are essential. Since 2017, we have developed a minimally invasive mitral valve surgery (MIMVS) approach using right transaxillary access. This involves a posterolateral minithoracotomy along the anterior axillary line that offers direct view exposure of the mitral and tricuspid valves, ascending aorta, and left atrial appendage. It simplifies the procedure by eliminating the need for video assistance or additional transthoracic or endovascular tools.

In addition to treating mitral valve disease, this approach allows combined procedures, including aortic valve surgery, atrial fibrillation ablation, atrial septal defect closure, and tumor removal.[21,22] This report details the technique, presents our mitral valve surgery outcomes, and highlights factors supporting broader MICS adoption.

PATIENTS AND METHODS

ETHICAL STATEMENT. This study is a retrospective outcome evaluation from institutional records with prospective data entry. The consent for use of such data was obtained by all the patients. The study was approved by the Local Ethic Committee (CERM 2019 361 - 28.11.2019).

PATIENTS. The population of this study included consecutive patients who underwent transaxillary MIMVS with and without associated procedures at our academic center (University Hospital of Marche, Ancona, Italy) from January 2017 to December 2024.

DEFINITIONS. The definition of preoperative characteristics aligns with the notes about the European System for Cardiac Operative Risk Evaluation II (EuroSCORE II).[23] Early mortality and complications refer to events that occurred in the first 30 days after the operation.

TECHNIQUES. All patients underwent general anesthesia. Transesophageal echocardiography (TEE) was performed before and during the operation for monitoring and for evaluating the surgical result. Patients were placed in the supine position. After endotracheal intubation with a standard tube (no single-lung ventilation was required) and after arterial line and central line insertion, the right jugular vein was cannulated under TEE guidance with a 16F to 18F cannula as a part of bicaval cannulation for venous return.

Air-forced warming blankets were used in all cases. A pillow was then positioned under the patient's right scapula to allow the chest to be slightly elevated and rotated toward the left side. The right arm was generally slightly moved from the chest with no rotation. Alternatively, in the case of obese patients or those with large breasts, the right arm was suspended to facilitate the flattening of subcutaneous tissue and the widening of the intercostal space.

Once the surgeon had marked the site for chest incision, the anesthesiologist performed the serratus plane block. A 2-cm skin incision was made just above the inguinal fold (usually on the right side), and the common femoral artery and femoral vein were isolated. Both vessels were cannulated using the Seldinger technique and TEE guidance. For the arterial return, we used an 18F to 22F cannula, to allow a cardiac index of 2.4 L/min $\times$ body surface area, and for the venous drainage, a 25F to 27F multistage cannula was advanced in the right atrium with the end just above the opening of the inferior vena cava. A 4- to 5-cm incision was made on the anterior axillary line at the level of the third or fourth intercostal space. For isolated mitral valve procedure or in case of a combined aortic valve procedure, we favored the third intercostal space, whereas the fourth intercostal space was the choice in case of associated tricuspid valve surgery.

After we entered the pleural space, CPB was started and conducted, maintaining normothermia. Centrifugal pumps and a membrane oxygenator with integrated arterial filter were used in all cases. Vacuum-assisted venous drainage was invariably adopted with a mean pressure ranging from −20 to −25 mm Hg and never exceeding the value of −40 mm Hg. A minithoracotomy retractor was generally used only to facilitate the opening of the pericardium on top of the aorta. A soft tissue retractor was used to facilitate exposure afterward. Seven sutures were placed for pericardial suspension—3 on the upper or median part and 4 in the lower or lateral part—and anchored directly on the edge of the skin incision. Applying traction to these sutures shifted the heart toward the operator, thus reducing the distance between the surgical access and the target valve (typically 8-12 cm). A cannula for cardioplegia and aortic venting was placed above the sinutubular junction. Closure of the superior and inferior vena cava was achieved, when necessary, snaring the vessels by a tape mounted on a tourniquet. The aorta was occluded using a flexible clamp introduced through minithoracotomy access. For myocardial protection, antegrade histidine-tryptophan-ketoglutarate cardioplegia was used until December 2021, after which del Nido cardioplegia was given in all cases.

The left atrium was opened using a left atrial atriotomy in the interatrial groove. The mitral valve apparatus was exposed on direct vision with the aid of an atrial retractor; no video assistance tool was used. Mitral repair techniques included quadrangular leaflet resection (with or without sliding plasty), implantation of 5-0 polytetrafluoroethylene artificial chords, edge-to-edge suture, and annuloplasty with prosthetic rings. Mitral valve replacement was performed using the common stented biologic or mechanical prostheses anchored with 2-0 nonadsorbable interrupted sutures with pledgets. The pericardium was always closed, and 2 drains (pericardial and right pleura) were placed.

At the end of the procedure, before wound closure, a catheter for analgesia was placed above the ribs in the subcutaneous tissue and usually maintained in place for 24 to 48 hours. (The Video provides a demonstration of the transaxillary approach.)

STATISTICAL ANALYSIS. Survival probabilities were calculated using the Kaplan-Meier method. Reintervention (follow-up 98% complete) and recurrence of moderate or greater mitral regurgitation (MR) (follow-up 93% complete) probabilities were studied using cumulative incidence function with death as a competing outcome. The analysis was generated using SAS software version 3.8, SAS university edition (SAS Institute, Inc).

RESULTS

BASELINE CHARACTERISTICS. During the study period, 615 patients underwent MIMVS through a transaxillary approach. The preoperative characteristics of the overall population are summarized in Table 1. Degenerative disease was the most prevalent cause of mitral valve dysfunction (85% of the cases), followed by functional and rheumatic disease. Pure MR was the main indication for surgery in 93% of the patients.

SURGICAL DATA. A total of 521 patients among 576 (90%) who had pure MR underwent mitral valve repair. The rate of mitral repair for degenerative MR was 94% (485 of 517). Valve repair was deemed feasible, on the basis of TEE evaluation and surgical inspection, in 490 patients, and was successfully accomplished in 485 patients (5 patients had mitral replacement because of a suboptimal repair result). Mitral valve replacement was planned in the remaining 27 patients with degenerative MR for clinical or anatomical reasons) such as the following: fibrosis or calcification of leaflets, annulus, or subvalvular apparatus (n = 20; mainly octogenarian patients); complex mechanism of regurgitation in older adult patients (n = 4); comorbidity in older adult patients (n = 2); and an urgent operation in a patient with severe dysfunction of the right ventricle (n = 1). Table 2 contains details of the intraoperative data, repair techniques, and combined procedures.

PROCEDURAL COMPLICATIONS. Vascular injuries occurred in 4 patients (0.6%) and included the following:

- Complications during right jugular vein cannulation with hematoma limited at the site of puncture (n = 1) or also extended at the level of superior vena cava (n = 2). In these cases, the surgical procedure was interrupted, and a computed tomographic scan was performed to rule out any active bleeding. All the patients, after clinical and imaging monitoring, ultimately underwent transaxillary mitral valve surgery later during the same hospitalization;

TABLE 1 Preoperative Patients' Characteristics

Variables	Overall N = 615, Mean [SD], n, or n (%)
Age, y	64 [11]
Sex	
Male	375
Female	240
Body mass index, kg/m^2	24.9 [4.4]
Hypertension	343 (56)
Diabetes mellitus	36 (6)
Dyslipidemia	226 (37)
Smoking history	107 (17)
CKD (eGFR<50 mL/min/1.73 m^2)	76 (12)
Peripheral arteriopathy	10 (2)
Previous cerebrovascular accident	19 (3)
Previous CAD	43 (7)
Previous PCI	27 (4)
Previous cardiac surgery	6 (1)
Previous transcatheter mitral procedure	7 (1)
Active infective endocarditis	14 (2)
NYHA functional class ≥III	178 (29)
Permanent pacemaker	15 (3)
History of AF	155 (25)
Preoperative AF	129 (21)
Preoperative ventricular arrhythmia	18 (3)
Hemoglobin, g/dL	13.5 [1.5]
Hematocrit, %	41.1 [4.4]
LVEF, %	61 [8]
LVEF <50%	44 (7)
Origin of mitral disease	
Degenerative	524 (85)
Functional	34 (6)
Rheumatic	31 (5)
Infectious	20 (3)
From transcatheter mitral valve procedure failure	6 (1)
Pure mitral regurgitation	576 (93)
PAPs ≥30 mm Hg	241 (39)
Tricuspid regurgitation moderate or greater	140 (23)
EuroSCORE II, %	1.2 [0.8]

AF, atrial fibrillation; CAD, coronary artery disease; CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; EuroSCORE, European System for Cardiac Operative Risk Evaluation; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; PAPs, pulmonary artery pressure systolic; PCI, percutaneous coronary intervention.

- Type A aortic dissection (n = 1) after the removal of the cardioplegia cannula in the context of a slightly dilated ascending aorta (maximum diameter was 43 mm) in 1 case. This patient underwent emergency aortic dissection repair; the postoperative course was not favorable, and the patient died of multiple organ failure on postoperative day 5.

Coronary artery complications were registered in 5 cases (0.8%): occlusion by kinking of the left circumflex artery in 4 patients (all of whom underwent revascularization in the catheterization laboratory) and in 1 case injury of the right coronary artery requiring conversion to full sternotomy for coronary artery bypass grafting. All these patients were ultimately successfully discharged from the hospital.

Conversion to full sternotomy was necessary in 5 cases: the 2 previously mentioned patients with aortic dissection and right coronary artery injury, and, in the early stage of our experience, 2 patients who had uncontrollable bleeding—from the left atrial appendage (n = 1) and the left ventricular apex (n = 1)—and 1 patient with high-flow pressure in the arterial line despite double femoral artery cannulation.

POSTOPERATIVE OUTCOMES. The overall 30-day mortality rate was 0.3% (n = 2 patients): 1 patient who had iatrogenic type A aortic dissection and died of multiorgan failure syndrome; and 1 patient, who underwent operation for active infective mitral valve endocarditis complicated by cerebral embolism, experienced an extensive brain hemorrhage on postoperative day 7.

Median postoperative intubation time was 2 hours (interquartile range [IQR], 0-6 hours). Extubation within 6 hours since the end of the operation was achieved in 78% of the cases and 313 patients (51%) were extubated in theatre soon after the end of the surgical procedure. Median ICU stay was 24 hours (IQR, 22-48 hours). Median overall postoperative hospital stay was 7 days (IQR, 6-8 days), with 51% of the patients discharged home with no need for any further hospitalization for cardiology rehabilitation, nursing aid, or physiotherapy service (Table 3).

Survival probabilities of patients with degenerative MR who underwent mitral valve repair were 99% and 96% at 1-year and 6-year follow-up, respectively (Figure 1). Thirty patients had recurrence of moderate or greater MR ,for a cumulative incidence of 1.4% and 11% in the whole cohort (Figure 2), 0.9% and 10% in cases of isolated posterior leaflet involvement, and 4% and 17% in cases of anterior leaflet or commissure involvement, at 1 year and at 5 years, respectively (Figure 3). Among them, 11 patients underwent reoperation, with a cumulative incidence of 0.6% at 1 year and 4% at 5 years (Figure 4).

TABLE 2 Intraoperative Data

Variables	Overall N = 615, n, n (%), n/N (%) or Mean [SD]
Mitral repair	521
Mitral replacement	94
Concomitant procedures	
Tricuspid valve repair	82 (16)
Atrial fibrillation ablation	29 (5)
Left atrial appendage occlusion	97 (16)
Aortic valve replacement	8 (1)
Other(s)	22 (4)
Mitral repair for MR	521/576 (90)
Annuloplasty ring	
Complete	466/521 (89)
Partial	52/521 (10)
No ring	3/521 (1)
Attempted mitral repair for degenerative MR	490/517 (95)
Mitral replacement for degenerative MR for clinical and/or anatomic reason(s)	27/517 (6)
Mitral repair for degenerative MR	485/517 (94)
Repair techniques for degenerative MR	
Resection (with or without sliding)	39/485 (9)
Neochords	322/485 (66)
Edge-to-edge	31/485 (6)
Other(s)	20/485 (4)
Isolated annuloplasty	40/485 (8)
Multiple techniques	33/485 (7)
Neochords and edge-to-edge	26
Resection and neochords	7
Ring size (mm) for degenerative MR	
26-29	58/482 (12)
30-31	69/482 (14)
32-35	191/482 (40)
36-38	132/482 (27)
40-42	32/482 (7)
Vascular complications	4 (0.6)
Peripheral cannulation	3 (0.4)
RJV/SVC hematoma	3
Aortic dissection	1 (0.2)
Coronary artery complications	5 (0.8)
Left circumflex kinking/occlusion	4
RCA injury	1
Conversion to full sternotomy	5 (0.8)
Poor exposure	0
CPB management	1
Uncontrollable bleeding	2
Coronary artery complication(s)	1
Vascular complication(s)	1
Cardiopulmonary bypass time, min	105 [32]
Cross-clamp time, min	65 [23]
Cardiopulmonary bypass time, min, for isolated mitral valve surgery	100 [28]
Cross-clamp time, min, for isolated mitral valve surgery	61 [20]

CPB, cardiopulmonary bypass, IQR, interquartile range; MR, mitral regurgitation; RCA, right coronary artery; RJV, right jugular vein; SVC, superior vena cava.

TABLE 3 Postoperative Results

Variables	Overall N = 615, n (%), Mean (SD), Median (IQR), n, or n/N (%)
30-d mortality	2 (0.3)
Cerebral stroke	2 (0.3)
Transient ischemic attack	4 (0.6)
Delirium	25 (4)
Repeat thoracotomy	32 (5)
Postoperative bleeding	19 (3)
Late pleural or pericardial collection	13 (2)
CVVHD	3 (0.5)
Mechanical ventilation time, h	2 (0-6)
Ultrafast track with on-table extubation	313 (51)
Fast track with extubation within 6 h	481 (78)
ICU stay, h	24 (22-48)
New-onset AF (in preoperative SR)	134/486 (28)
Permanent pacemaker	
Overall	24 (4)
Isolated mitral surgery	11/473 (2)
Thoracic deep wound complication	4 (0.6)
Groin wound complication	6 (1)
Infection	1 (0.2)
Lymphocele	5 (0.8)
Red blood cell transfusion (number of patients)	172 (28)
Redo for early failure degenerative mitral regurgitation	7 (1)
Repeat mitral valve repair	4
Repeat mitral valve replacement	3
Grade of residual regurgitation[a]	
None or trace	366 (76)
Mild	108 (22)
Moderate	7 (2)
Mean mitral valve gradient, mm Hg	3.2 [1.4]
Hospital stay, d	7 (6-8)
Discharge home	312 (51)

[a]After repair of degenerative mitral regurgitation, excluding 1 patient who died before discharge and 3 patients who had early redo mitral valve replacement during the same hospitalization. AF, atrial fibrillation; CVVHD, continuous venovenous hemodialysis; ICU, intensive care unit; IQR, interquartile range; SR, sinus rhythm.

COMMENT

Our experience with MIMVS through a transaxillary approach was characterized by low rates of 30-day mortality and postoperative complications. Mitral valve repair was performed in 94% of degenerative MR cases, with 98% of patients discharged with no or mild residual MR. These findings compare favorably with those reported in contemporary mitral surgery series.[11,12]

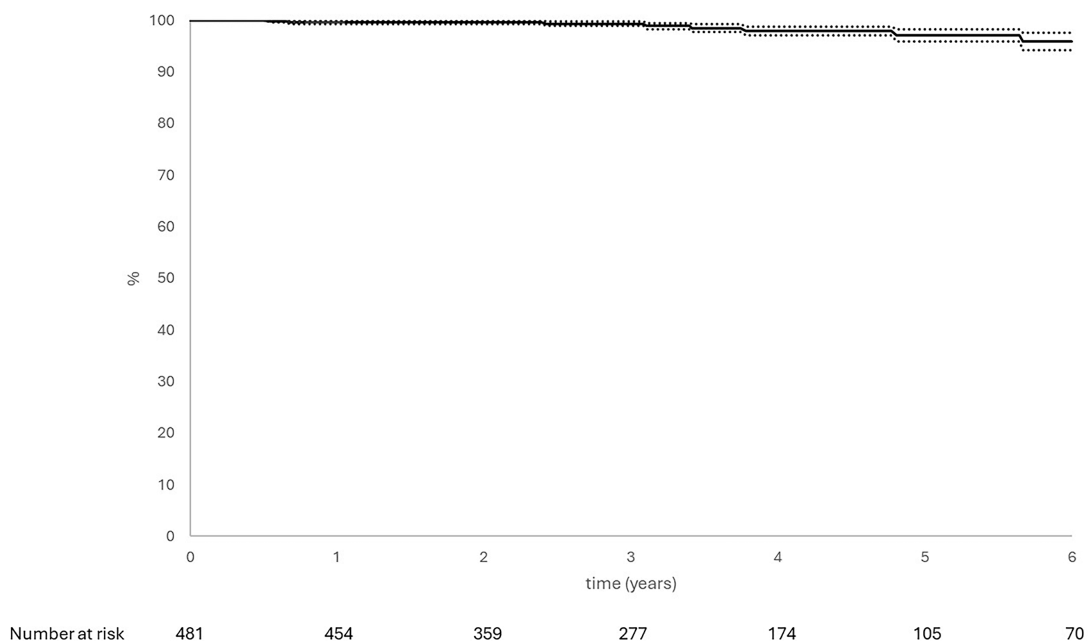

FIGURE 1 Kaplan-Meier survival probabilities.

Freedom from recurrent moderate or greater MR was 89% at 5 years, a finding consistent with outcomes from high-volume mitral valve centers reporting recurrence rates of severe MR and moderate or greater MR at 5 years of 7% and 14%, respectively.[24,25]

In addition, our experience sought to provide a more comprehensive perspective on MICS that,

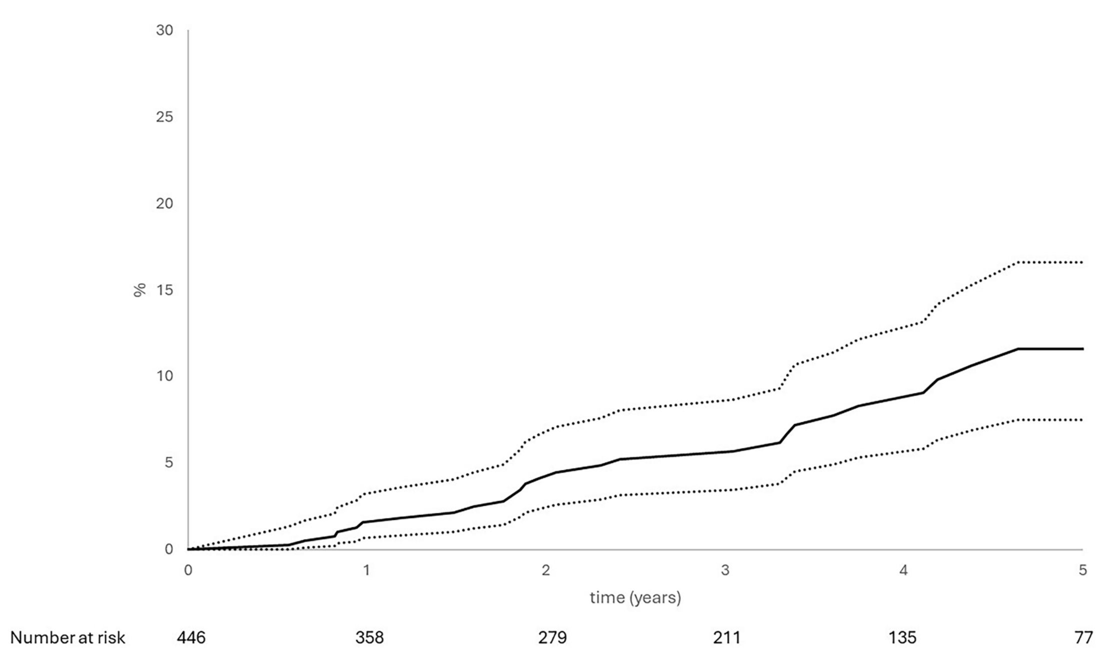

FIGURE 2 Cumulative incidence of the probability of recurrence of moderate or greater mitral regurgitation with death as a competing outcome.

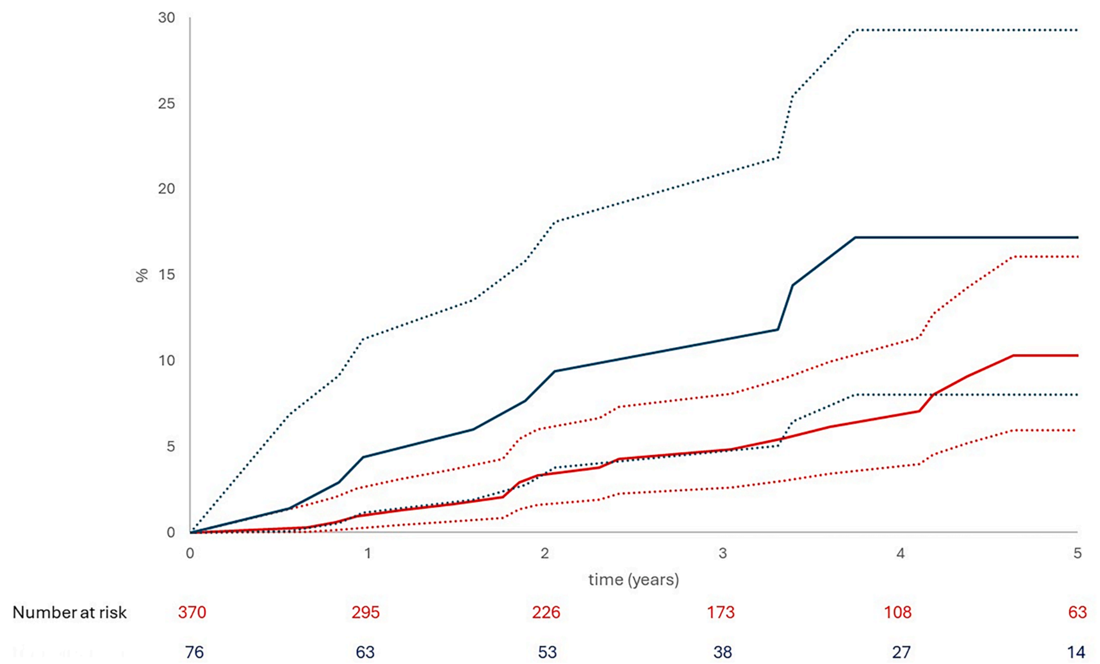

FIGURE 3 Cumulative incidence of the probability of recurrence of moderate or greater mitral regurgitation with death as a competing outcome for posterior leaflet disease (red line) or other than posterior leaflet disease (blue line).

beyond reducing tissue trauma, should be considered a cornerstone of a modern multidisciplinary approach aligned with the principles of Enhanced Recovery After Surgery (ERAS).[26] To promote the adoption of MICS, we have developed a simplified minithoracotomy surgical setup that enhances the surgical experience for both patients and health care providers.

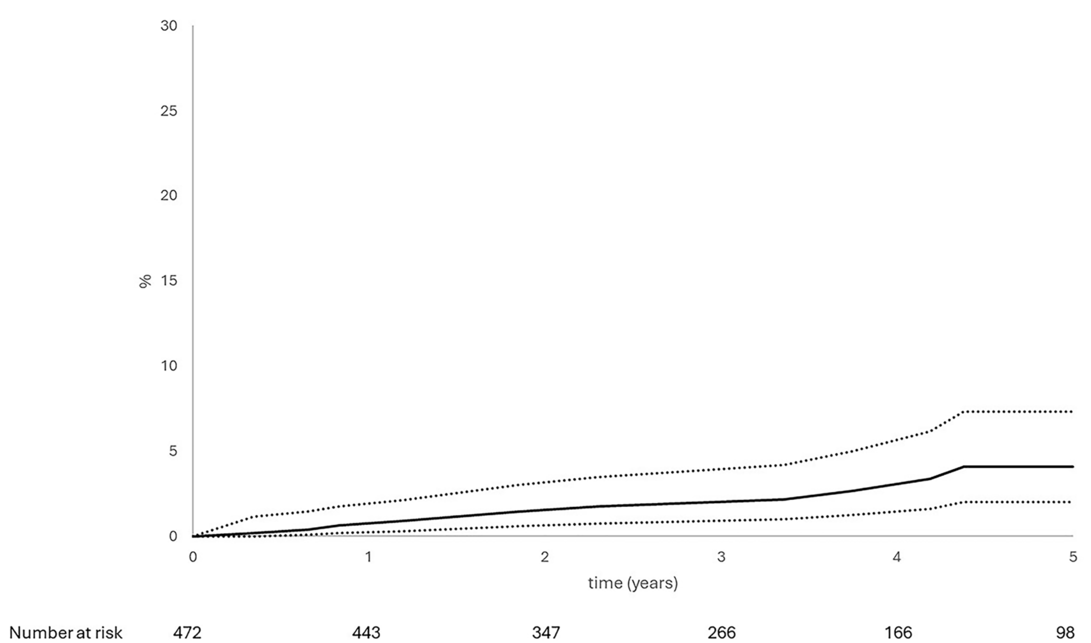

FIGURE 4 Cumulative incidence of the probability of reoperation with death as a competing outcome.

The transaxillary approach does not require expensive equipment for video assistance or telemanipulation, nor does it demand the development of new skills specific to mastering such technologies. Through a single posterolateral chest wall incision, this technique provides the operating surgeon with a 90° visual trajectory to the mitral valve apparatus, thereby allowing direct-view exposure of the annulus, leaflets, and subvalvular structures with the advantage of performing all steps of the surgical procedure relying on natural hand-eye coordination and alignment.

As a result, it can be more easily integrated into clinical practice, thus making MIMVS more sustainable and accessible to a broader range of patients and surgeons in a variety of health care environments while promoting and supporting the pursuing of excellent results in terms of technical outcomes and enhanced recovery. In addition, the tricuspid valve and the left atrial appendage can be visualized and handled. This feature enables complete treatment of mitral valve disease; we reported that nearly 16% of patients also underwent tricuspid valve procedures and left atrial appendage occlusion, consistent with reports from large populations of patients with mitral valve operations.[11,27]

Although the transaxillary approach avoids the need for specialized tools, it nevertheless entails a procedural learning curve inherent to any new surgical access. Importantly, the rate of intraoperative complications in our series was low and did not indicate specific limitations of this approach. Conversion to sternotomy was necessary in 0.8% of cases—a finding that is in line with previously published results[16,28,29]—and, in our experience, was not the result of poor or difficult exposure. Complications from peripheral cannulation were seldomly encountered (0.4%) and were the consequence of puncture or cannulation of the right jugular vein. These complications required no intervention and ultimately did not prevent us from performing surgery through the transaxillary access. One patient experienced iatrogenic aortic dissection from a cardioplegia needle. This was an unfortunate event and should not be considered a specific complication of the MICS approach because it was not uncommonly reported in the early stages of minimally invasive cardiac surgery.[30] Furthermore, we found no excessive risk of coronary artery complications (0.6%).[16]

Alongside providing to be safe and effective, our simplified approach allows us to perform mitral valve operations with operative times that are generally shorter compared with times reported for other minimally invasive settings[16,31] and, furthermore, similar to times we have historically recorded in our practice for mitral surgery performed through median sternotomy.[21] The benefit of contained cross-clamp and cardiopulmonary bypass (CPB) times extends beyond the undeniable reduction in postoperative risks, a correlation that has been well documented even in typical cohorts of middle-aged mitral patients.[31] Drawing on this advantage, we have progressively implemented an ultrafast-track protocol aimed at an early recovery from surgery.[20] As a result, more than 50% of patients were extubated in the operating room at the end of the surgical procedure, with physiotherapy initiated within the first 3 to 6 hours postoperatively. This protocol has been already associated with shorter ICU stay and hospitalization facilitating direct discharge home.[20] Enhancing the perceived value of MICS through a simplified surgical setup can foster greater support from all health care professionals involved in surgical care. This can facilitate the initiation of a minimally invasive program for operators already proficient in mitral procedures through sternotomy. Additionally, it can enable them to perform more complex and combined valve operations, ultimately overcoming the remaining resistance to a broader adoption of minimally invasive surgery in daily practice.

Our findings are derived from a population that did not include high-risk cases, such as patients with infective endocarditis with perivalvular involvement or complex redo procedures. Nevertheless, this group is representative of most of patients who routinely undergo surgery for mitral valve disease. For these patients, whether they are young or middle-aged individuals eager to return quickly to normal activities or older adult patients prone to longer postoperative recovery, a minimally invasive procedure that minimizes the tissue trauma and respects physiology can ensure outstanding technical results with a low risk of perioperative complications and enhance postoperative recovery. Adopting this broader perspective is the only way both to affirm and to further advance the excellence developed through decades of surgical improvements and innovations.

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DISCLOSURES

The authors have no conflicts of interest to disclose.

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