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Endoscopic mitral valve surgery: picture from the real world—sub-analysis from the Mini-Mitral International Registry

Paolo Berretta[1]^, Antonios Pitsis[2], Jorg Kempfert[3], Frank Van Praet[4], Tristan Yan[5], Mauro Rinaldi[6], Loris Salvador[7], Joseph Lamelas[8], Tom C. Nguyen[9], Torsten Doenst[10], Manuel Wilbring[11], Marc Gerdisch[12], Davide Pacini[13], Antonio Fiore[14], Nguyen Hoang Dinh[15], Pierluigi Stefano[16], Nikolaos Bonaros[17], Marco Di Eusanio[1]

[1]Cardiac Surgery Unit, Lancisi Cardiovascular Center, Polytechnic University of Marche, Ancona, Italy; [2]Cardiac Surgery Department, European Interbalkan Medical Center, Thessaloniki, Greece; [3]Department of Cardiothoracic and Vascular Surgery, German Heart Center Berlin, Germany; [4]Cardiac Surgery Department, Hartcentrum OLV Aalst, Aalst, Belgium; [5]Department of Cardiothoracic Surgery, The Royal Prince Alfred Hospital, Sydney, Australia; [6]Cardiac Surgery Unit, University of Turin, Turin, Italy; [7]Division of Cardiac Surgery, S. Bortolo Hospital, Vicenza, Italy; [8]Division of Cardiothoracic Surgery, University of Miami, Miami, FL, USA; [9]Baptist Health Miami Cardiac & Vascular Institute, Miami, FL, USA; [10]Department of Cardiothoracic Surgery, Jena University Hospital, Jena, Germany; [11]Center for Minimally Invasive Cardiac Surgery, University Heart Center Dresden, Dresden, Germany; [12]Franciscan Health Indianapolis, Indianapolis, IN, USA; [13]Cardiac Surgery Department, Sant'Orsola Malpighi Hospital, University of Bologna, Bologna, Italy; [14]Department of Cardiac Surgery, Hôpitaux Universitaires Henri Mondor, Assistance Publique-Hôpitaux de Paris, Créteil, France; [15]University of Medicine and Pharmacy, Ho Chi Minh City, Vietnam; [16]Cardiac Surgery Unit, Careggi University Hospital, Firenze, Italy; [17]Department of Cardiac Surgery, Medical University of Innsbruck, Innsbruck, Austria

Contributions: (I) Conception and design: P Berretta, M Di Eusanio; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: P Berretta; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Paolo Berretta, MD. Cardiac Surgery Unit, Lancisi Cardiovascular Center, Polytechnic University of Marche, Via Conca 71, Ancona 60126, Italy. Email: p.berretta@icloud.com.

Background: In the field of minimally invasive mitral valve surgery (MVS), recent technical and technological advances have made endoscopic approaches increasingly popular. However, enthusiasm for endoscopic cardiac surgery has not translated into routine clinical usage likely due to the perceived complexity of the technique and the lack of robust supporting evidence. This study aims to evaluate operative results, and assess the overall effectiveness of endoscopic approaches in current surgical practice using data from the Mini-Mitral International Registry (MMIR).

Methods: This is a retrospective multicenter cohort study based on data from the MMIR, a collaborative effort including 7,957 patients who underwent minimally invasive mitral procedures. For this analysis, patients who did not receive a full endoscopic approach were excluded. Clinical and procedural outcomes were defined according to Mitral Valve Academic Research Consortium (MVARC) standards. Primary outcome measures included the rate of valve repair, in-hospital mortality, and the incidence of postoperative complications. Logistic regression was applied to assess the multivariable association between covariates and in-hospital mortality.

Results: Between 2015 and 2022, 2,563 patients underwent full endoscopic mitral surgery [median age 64 years; interquartile range (IQR), 53–73 years]. The etiology of mitral disease was degenerative in 70.5% of patients, functional in 13.7%, rheumatic in 6.6%, endocarditis in 3.3%, failure of previous mitral surgery in 3.8% and failure of previous transcatheter procedure in 1.2%. Mitral valve repair was performed in 2,107 cases (82.2%) and valve replacement in 439 (17.1%). A conversion to full sternotomy was required in 1.7% of cases. The overall in-hospital mortality rate was 2.5% (n=63), with a stroke rate of 1.1% (n=27). These were 1.7% and 0.8%, respectively, in patient who underwent isolated MVS. Risk analysis revealed that patient comorbidities and clinical status, rather than the technical aspects of the endoscopic approach,

^ ORCID: 0000-0003-3662-0415.

predominantly determined operative outcomes. Subgroup analysis of patients with degenerative mitral valve disease (n=1,800) revealed a younger cohort (62 years) with a low-risk profile (EuroSCORE II 1.1%). The valve repair rate was 94.9%. Overall, in-hospital mortality and stroke rates were 1.4% and 0.6%, respectively. Among patients who underwent valve repair, 98.8% had no or mild regurgitation at discharge.

Conclusions: Endoscopic MVS is an effective technique for managing a broad range of mitral valve diseases, with excellent valve repair outcomes. The technique demonstrated satisfactory operative mortality and morbidity, even in high-risk patients and complex valve anatomies. Future studies should focus on long-term outcomes and the development of training programs to facilitate wider implementation.

Keywords: Endoscopic cardiac surgery; endoscopic mitral valve repair; Mini-Mitral International Registry (MMIR); minimally invasive mitral valve surgery (mini-MVS)

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Introduction

In recent years, mitral valve operations have advanced significantly with the introduction of less invasive techniques that better preserve thoracic integrity and minimize surgical trauma. Multiple evidence suggests that minimally invasive mitral valve surgery (mini-MVS), when compared with conventional surgery through a full sternotomy, is associated with an important patient's clinical benefit including a lower rate of post-operative atrial fibrillation (AF), bleeding, blood product transfusion and sternal wound infection, with a reduced ventilation time and intensive care unit (ICU) length of stay (1-7). In the field of mini-MVS, recent technical and technological advances have made endoscopic approaches increasingly popular. However, enthusiasm for endoscopic cardiac surgery has not translated into routine clinical usage. According to the Endoscopic Cardiac Surgeons Club (8), contemporary endoscopic mitral valve surgery (MVS) is practiced by only about 50–60 expert surgeons and well-trained centers globally. This limited uptake can be attributed to several challenges, including the perceived complexity of the technique, which may potentially impact clinical and valve repair outcomes, the steep learning curve, the necessity for specialized equipment, increased costs, and the lack of robust supporting evidence. Indeed, due to the limited adoption and short follow-up periods, the current evidence on endoscopic MVS is scarce and primarily derived from single-center series. To overcome these limitations and provide robust data on mini-MVS, the Mini-Mitral International Registry (MMIR) was created by a group of 17 research centers (9). In this article we comprehensively analyzed the outcomes associated with endoscopic MVS using data from the MMIR. By examining a large cohort of patients who underwent these procedures across multiple referral centers worldwide, this study aims to evaluate operative results, and assess the overall effectiveness of endoscopic approaches in current surgical practice. We present this article in accordance with the STROBE reporting checklist (available at https://jovs.amegroups.com/article/view/10.21037/jovs-24-43/rc).

Highlight box

Key findings

- Overall mortality 2.5%, stroke 1.1%. In degenerative cohort: valve repair rate 95%, mortality 1.4%, stroke 0.5% conversion to full sternotomy 1.7%.

What is known and what is new?

- Patient-related factors remain crucial in determining operative outcomes in mitral valve surgery (MVS).
- Endoscopic MVS is an effective approach for managing a wide range of mitral valve pathologies, including complex cases and concomitant procedures.

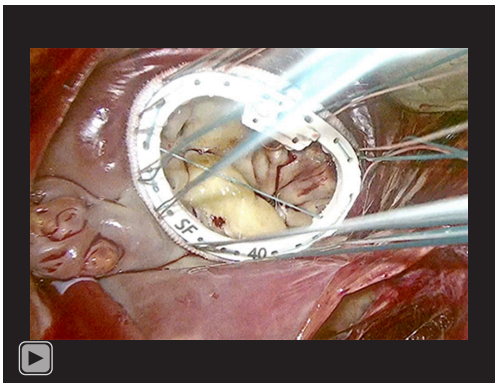
What is the implication, and what should change now?

- Endoscopic mitral surgery achieves favorable valve repair rates and clinical outcomes in specialized referral heart valve centers. The development of dedicated training programs is essential to support its broader adoption.

Methods

The MMIR

The MMIR was launched in 2020 through a collaboration of research institutions to assess the contemporary



Video 1 Full endoscopic mitral valve repair.

approaches and results of less invasive mitral valve interventions (9). The Coordinating Center, based at the Polytechnic University of Marche, Lancisi Cardiovascular Center in Ancona, Italy, oversees the registry's concept, design, clinical database maintenance, statistical analysis, and the coordination of research projects. Presently, 17 specialized heart valve centers worldwide participate in the registry. Centers were initially selected through a literature review of internationally recognized hubs of expertise in minimally invasive cardiac and mitral surgery, which demonstrated consistent academic output. Further guidance on center recruitment was sought from the Research Steering Committee. The MMIR cohort consists of patients undergoing less invasive mitral valve procedures for various indications, using any of the available techniques (direct vision, video-assisted, full endoscopic, or robotic) and materials. The MMIR database was specifically designed to collect data on patients with mitral valve disease undergoing mini-MVS, covering clinical data, risk assessments, surgery-related variables, perioperative outcomes, echocardiographic results, and long-term follow-up. Data collection across all centers followed uniform definitions and assessment standards in line with the European Society of Cardiology or American College of Cardiology/American Heart Association/Heart Rhythm Society (ACC/AHA/HRS) Guidelines, the EuroSCORE II model, and Mitral Valve Academic Research Consortium (MVARC) endpoint definitions (10-12). Data forms were completed retrospectively and submitted to the coordinating center for validation and completeness. The protocol for the registry was previously outlined. The study protocol was approved by the institutional review boards of all participating centers, with approval from the coordinating center (No. 2020189, July 30th, 2020), and informed consent was obtained from patients when required.

Study population and definitions

From 2015 and 2022, 7,957 patients were included in the registry. Patients who did not receive a full endoscopic approach (direct vision, video-assisted and robotic) as well as those with missing data regarding the surgical approach were excluded from the analysis. Full endoscopic MVS is defined as an approach that does not allow for direct vision of the operative field, with the surgical procedure relying solely on the endoscopic view. This requires the surgeon to perform the operation using exclusively endoscopic visualization (*Video 1*). Preoperative, intraoperative and postoperative outcome variables were reported. The outcomes were defined based on MVARC criteria and the EuroSCORE II (11,12).

Operative mortality, as defined by EuroSCORE II, was considered as death occurring in the same hospital where the surgery was performed, prior to discharge. Stroke was defined as a focal or global neurological deficit lasting ≥24 hours, or less than 24 hours if neuroimaging reveals a new intracranial or subarachnoid hemorrhage, central nervous system infarction, or if the neurological deficit leads to death. Low cardiac output was defined by the need for inotropic support for more than 24 hours, the use of an intra-aortic balloon pump, or extracorporeal membrane oxygenation. Myocardial infarction was categorized as either periprocedural (within 48 hours of the operation) or spontaneous (more than 48 hours after the operation), according to MVARC. Dialysis was defined as postoperative acute kidney injury requiring renal replacement therapy. Conversion to full sternotomy is defined as the intraoperative change from a planned minimally invasive endoscopic approach to a median sternotomy.

MVARC technical success was defined by the absence of procedural mortality, successful approach, correct placement of the initially planned device, and no need for emergency operation or re-operation linked to the implanted device or access.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables as percentages. When continuous variables did not follow a normal

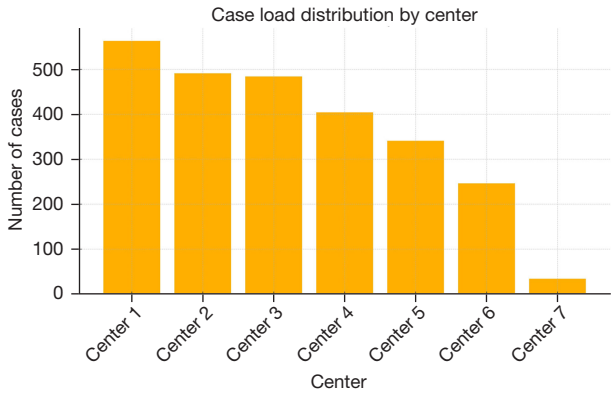


Figure 1 Case volume across participating centers.

distribution, they were reported as median and interquartile range (IQR). In all instances, missing data were not assumed to be negative, and denominators only included reported cases. The multivariable association between covariates and in-hospital mortality was evaluated with binary logistic regression. The model was adjusted for potential confounders identified in advance based on existing literature, established clinical guidelines, and their previously demonstrated association with surgical outcomes in MVS. These included factors such as age, sex, chronic lung disease, diabetes, AF, peripheral and cerebrovascular arteriopathy, pulmonary hypertension, renal dysfunction, reduced left ventricular ejection fraction (LVEF), New York Heart Association (NYHA) III–IV classification, previous cardiac surgery, urgent/emergent status, mitral valve disease etiology, tricuspid regurgitation, type of surgery (repair *vs.* replacement), myocardial protection method [cardioplegia *vs.* ventricular fibrillation (VF) *vs.* beating heart], cross-clamp time, and center volume. The final models were constructed using the backward stepwise selection approach. The results were presented as adjusted odds ratio (OR) with a 95% confidence interval (CI). Multicollinearity was evaluated using the variance inflation factor. A significance level of $\alpha=0.05$ was applied. Statistical analyses were conducted with IBM SPSS Statistics for Macintosh, Version 29.0 (IBM Corp. Released 2021, Armonk, NY, USA).

Ethical consideration

The study was conducted in accordance with the principles of the Declaration of Helsinki and its subsequent amendments. The study protocol was approved by the local institutional review board of all centers based on the approval of the coordinating center (No. 2020189, July 30th, 2020) and patients gave informed consent when required.

Results

Demographics

A total of 2,563 consecutive patients received a full endoscopic mitral operation from 2015 and 2022 (*Figure 1*). Patients who received direct vision (n=2,296, 28.9%), video-assisted (n=3,034, 38.2%), and robotic (n=56, 0.7%) as well as those with missing data regarding the surgical approach (n=8, 0.1%) were excluded. Demographics are summarized in *Table 1*. The median age was 64 years (IQR, 53–73 years), 40% (n=1,026) of patients were females, and 49.3% (n=1,259) were in NYHA class III or IV. The etiology of mitral disease was degenerative in 1,800 (70.5%) patients, functional in 347 (13.7%), rheumatic in 167 (6.6%), endocarditis in 83 (3.3%), failure of previous mitral valve repair or replacement in 99 (3.8%), failure of previous transcatheter repair/replacement in 32 (1.2%) and tumor in 3 (0.1%). Two hundred and fifty-four (9.9%) patients had prior cardiac surgery, including mitral surgery in 150 cases, aortic valve replacement in 74, coronary artery bypass graft in 57 and root/ascending aorta replacement in 22. Preoperative AF was observed in 705 (35.3%) of cases, concomitant severe tricuspid regurgitation in 174 (6.8%) and 158 (6.4%) patients had mild to moderate tricuspid regurgitation with annular dilatation. The median EuroSCORE II was 1.36% (IQR, 0.8–2.9%).

Operative data

Intraoperative findings are detailed in *Table 2*. Surgical access was obtained via anterolateral (n=1,526, 59.6%), periareolar (n=1,031, 40.3%), or transaxillary (n=4, 0.2%) minithoracotomy. A conversion to full sternotomy was required in 1.7% of cases (n=44). The main causes of conversion were bleeding (n=15), vascular complications (n=8), pleura adhesion (n=6) and poor exposure (n=3).

Cardiopulmonary bypass (CPB) was predominantly performed via femoral artery cannulation (98.1%) and was achieved percutaneously in 97 patients (3.8%). Transthoracic clamping was used in 66.5% of cases and endoaortic balloon occlusion in 30.7%. Sixty-nine patients were operated on during VF and 16 patients underwent surgery during beating heart CPB.

Table 1 Patients' characteristics

Variables	Values (n=2,563)
Male	1,537 (60.0)
Age, years	64 [53–73]
NYHA class	
I	306 (12.0)
II	990 (38.7)
III	1,097 (42.9)
IV	162 (6.3)
Hypertension	1,126 (55.4)
Diabetes	
On insulin	82 (3.2)
Oral therapy	106 (4.1)
Dyslipidemia	594 (29.2)
Smoking	239 (11.8)
Obesity	335 (13.1)
Atrial fibrillation	705 (35.3)
Pacemaker	70 (2.7)
Renal impairment (eGFR <85 mL/min)	
Moderate (eGFR >50 to <85 mL/min)	1,023 (40.0)
Severe (eGFR <50 mL/min)	322 (12.6)
Dialysis	19 (0.7)
Coronary artery disease	331 (12.9)
Chronic lung disease	187 (7.3)
Active endocarditis	76 (3.0)
Cerebrovascular disease	33 (1.3)
Peripheral arteriopathy	105 (4.1)
Previous cardiac surgery	254 (9.9)
Previous mitral transcatheter procedure	32 (1.2)
Critical preoperative state	36 (1.4)
Mitral valve disease	
Degenerative	1,800 (70.5)
Functional	347 (13.7)
Rheumatic	167 (6.6)
Endocarditis	83 (3.3)
Failure previous MV repair	63 (2.5)
Failure previous MV replacement	33 (1.3)
Failure previous transcatheter mitral procedure	32 (1.2)
Tumor	3 (0.1)
Tricuspid valve regurgitation	
Mild	485 (18.9)
Moderate	452 (17.7)
Severe	174 (6.8)
Pulmonary hypertension	1,282 (50.0)
Reduced LVEF (<50%)	375 (14.7)
Urgent/emergent status	158 (6.1)
Preoperative CT scan	660 (33.8)
EuroSCORE II (%)	1.36 [0.8–2.9]

Data are presented as n (%) or median [IQR]. CT, computed tomography; eGFR, estimated glomerular filtration rate; IQR, interquartile range; LVEF, left ventricular ejection fraction; MV, mitral valve; NYHA, New York Heart Association.

Mitral valve repair was performed in 2,107 cases (82.2%) and valve replacement in 439 (17.1%), with 16 cases (0.6%) being converted to replacement due to a failed attempt at repair. A second run of CPB was required in 51 patients (2%). The most frequently used repair technique was chordal replacement (n=1,113, 58.2%) followed by resection (n=255, 10.2%), edge-to-edge (n=34, 1.4%), and sliding plasty (n=19, 0.8%). Concomitant procedures included tricuspid valve surgery (n=349, 13.6%), AF ablation (n=486, 19%) and aortic valve replacement (n=34, 1.3%). The MVARC technical success rate was 97.4%.

In-hospital outcomes

In-hospital results are given in *Table 3*. The overall in-hospital mortality rate was 2.5% (n=63), with a stroke rate of 1.1% (n=27). These were 1.7% and 0.8%, respectively, in patient who underwent isolated MVS.

AF was the most frequent postoperative complication, occurring in 25.5% of patients, followed by acute kidney injury in 6.7%, with 1.6% of cases requiring dialysis. Bleeding was observed in 6% of patients. Prolonged ventilation for more than 24 hours was required in 8.7% of cases (163 patients). The median duration of intubation was 8 hours (IQR, 5–13 hours), while the median hospital stay was 7 days (IQR, 6–9 days). Half of the patients were discharged directly to their homes. Thoracic wound complications occurred in 0.6% (n=16) of patients and groin wound complications in 1.9% (n=48) (lymphocele, n=43,

Table 2 Operative data

Variables	Values (n=2,563)
Surgical access	
Anterolateral	1,526 (59.6)
Periareolar	1,031 (40.3)
Transaxillary	4 (0.2)
Conversion to full sternotomy	44 (1.7)
Arterial cannulation site	
Femoral artery	2,514 (98.1)
Axillary artery	33 (1.3)
Ascending aorta	13 (0.5)
Other	3 (0.1)
Percutaneous arterial cannulation	97 (3.8)
Venous cannulation site	
Femoral vein	1,866 (72.8)
Femoral + giugular vein	674 (26.3)
Femoral + superior vena cava	4 (0.2)
Other	19 (0.7)
Percutaneous venous cannulation	102 (4.0)
Myocardial protection	
Cardioplegia	2,477 (96.6)
Ventricular fibrillation	69 (2.7)
Beating heart	16 (0.6)
Aortic cross-clamping type	
External clamp	1,704 (66.5)
Endoclamp	786 (30.7)
Cardioplegia	
Blood	922 (36.0)
Crystalloid	1,551 (60.6)
Type of surgery	
Mitral valve repair	2,107 (82.2)
Mitral valve replacement	439 (17.1)
Replacement due to unsuccessful repair	16 (0.6)
Mitral valve repair technique	
Annuloplasty ring	2,056 (80.2)
Isolated annuloplasty	817 (31.9)
Artificial chords	1,113 (58.2)
Resection	255 (10.2)
Sliding	19 (0.8)
Edge to edge	34 (1.4)
Associated procedures	
Tricuspid surgery	349 (13.6)
AF surgery	486 (19.0)
Aortic valve replacement	34 (1.3)
LAA closure	
Internal	252 (9.8)
Clip	73 (2.8)
Repeated cross clamping	51 (2.0)
Automatic knotting device	1,125 (43.9)
Intraoperative SAM	28 (1.1)
Circumflex artery occlusion	3 (0.1)
CPB time (minutes)	143 [115–182]
Cross clamp time (minutes)	87 [67–111]
Technical success	2,062 (97.4)

Data are presented as n (%) or median [IQR]. AF, atrial fibrillation; CPB, cardiopulmonary bypass time; IQR, interquartile range; LAA, left atrial appendage; SAM, systolic anterior motion.

1.7%; dehiscence, n=5, 0.2%).

Predischarge echocardiography in patients who underwent valve repair revealed no or mild residual mitral regurgitation (MR) in 98.8% of patients, moderate MR in 1%, and severe MR in 0.2%. Reoperation for early failure was necessary in 18 patients (0.7%).

Multivariable analysis identified chronic lung disease (OR 3.351, 95% CI: 1.049–7.968), cerebrovascular disease (OR 6.709, 95% CI: 1.859–14.208), previous cardiac surgery (OR 4.542, 95% CI: 2.069–9.970), reduced LVEF (OR 2.167, 95% CI: 1.006–4.670), urgent status (OR 2.638, 95% CI: 1.098–6.342), NYHA III–IV (OR 2.701, 95% CI: 1.070–6.816) and severe renal impairment [estimated glomerular filtration rate (eGFR) <50 mL/min] (OR 3.313, 95% CI: 1.281–8.567) as independent predictors of in-hospital mortality (*Table 4*).

Degenerative mitral valve disease

Subgroup analysis of patients with degenerative mitral valve disease (n=1,800) revealed a younger cohort (median age 62 years) with a low-risk profile (EuroSCORE II 1.09) (*Table 5*). The valve repair rate was 94.9%, with 4.5% of patients undergoing primary valve replacement and 0.6%

Table 3 In-hospital outcomes

Variables	Values (n=2,563)
In-hospital mortality	63 (2.5)
Isolated mitral valve surgery	30 (1.7)
Stroke	27 (1.1)
Isolated mitral valve surgery	14 (0.8)
Delirium	76 (3.7)
Intubation time (hours)	8 [5–13]
Ventilatory support >24 h	163 (8.7)
Re-intubation/tracheostomy	91 (3.6)
Bleeding requiring revision	152 (6.0)
Same access	150 (5.9)
Full sternotomy	2 (0.1)
Transfusions (units)	0 [0–1]
New onset atrial fibrillation	509 (25.5)
Definitive PM implantation	51 (2.0)
Myocardial infarction	18 (0.7)
Low cardiac output syndrome	96 (3.8)
Acute kidney injury	133 (6.7)
Dialysis	32 (1.6)
Vascular complications	42 (1.9)
Major vascular complications	36 (1.6)
Minor vascular complications	6 (0.3)
Thoracic wound complications	16 (0.6)
Groin wound complications	48 (1.9)
Dehiscence	5 (0.2)
Lymphocele	43 (1.7)
MV insufficiency (after MV repair)	
No	1,826 (87.3)
Mild	241 (11.5)
Moderate	20 (1.0)
Severe	5 (0.2)
Redo for early valve repair failure	18 (0.7)
PVL (after MV replacement)	3 (1.0)
ICU stay (hours)	21 [18–29.75]
Hospital stay (days)	7 [6–9]
Home discharge	1,256 (50.0)

Data are presented as n (%) or median [IQR]. ICU, intensive care unit; IQR, interquartile range; MV, mitral valve; PM, pacemaker; PVL, paravalvular leak.

Table 4 Multivariable analysis for in-hospital mortality

Variables	P	OR	95% CI
Chronic lung disease	0.002	3.351	1.049–7.968
Cerebrovascular disease	0.01	6.709	1.859–14.208
Previous cardiac surgery	<0.001	4.542	2.069–9.970
Reduced LVEF	<0.001	2.167	1.006–4.670
Urgent status	0.003	2.638	1.098–6.342
NYHA III–IV	0.03	2.701	1.070–6.816
Severe renal impairment	<0.001	3.313	1.281–8.567

CI, confidence interval; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; OR, odds ratio.

(n=10) requiring valve replacement due to failed repair attempts. Chordal replacement was the most commonly employed repair technique (n=1,389, 77.6%), while resection, edge-to-edge repair, and sliding plasty were used more selectively. Concomitant procedures included tricuspid valve repair (n=163, 9.1%), AF ablation (n=274, 15.2%), and aortic valve replacement (n=12, 0.7%) (*Table 6*). Overall, in-hospital mortality and stroke rates were 1.4% and 0.6%, respectively. Among patients who underwent valve repair, 98.8% (n=1,679) had no or mild MR at discharge, 0.9% (n=16) had moderate MR, and 0.2% (n=3) had severe MR. Reoperation for early valve repair failure was required in 12 patients (0.7%) (*Table 7*).

Discussion

The MMIR is the first international, independent registry specifically designed to report outcomes of mini-MVS across a wide range of patient indications and risk profiles, employing all currently available surgical approaches and prosthetic materials. This collaborative effort offers a unique opportunity to evaluate the safety and efficacy of mini-MVS, minimizing the inherent biases typically associated with single-center studies or national databases that are not specifically focused on mini-MVS. This study provides a comprehensive analysis of contemporary endoscopic MVS, reporting patient characteristics, operative techniques, and valve repair and clinical outcomes.

The overall in-hospital mortality and stroke rates were 2.5% and 1.1%, respectively. These outcomes must be interpreted in the context of the MMIR population, which included a broad spectrum of mitral valve pathologies, such as endocarditis, functional and rheumatic disease,

Table 5 Demographics of patients with degenerative valve disease

Variables	Values (n=1,800)
Male	1,226 (68.1)
Age, years	62 [52–71]
NYHA class	
I	255 (14.2)
II	793 (44.2)
III	676 (37.7)
IV	70 (3.9)
Hypertension	780 (43.3)
Diabetes	
On insulin	49 (2.7)
Oral therapy	38 (2.1)
Dyslipidemia	409 (27.6)
Smoking	180 (12.1)
Obesity	201 (11.2)
Atrial fibrillation	393 (21.8)
Pacemaker	23 (1.3)
Renal impairment (eGFR <85 mL/min)	
Moderate (eGFR >50 to <85 mL/min)	679 (37.8)
Severe (eGFR <50 mL/min)	150 (8.4)
Dialysis	5 (0.3)
Coronary artery disease	176 (9.8)
Chronic lung disease	100 (5.6)
Active endocarditis	8 (0.4)
Cerebrovascular disease	17 (0.9)
Peripheral arteriopathy	50 (2.8)
Previous cardiac surgery	67 (3.7)
Previous mitral transcatheter procedure	5 (0.3)
Critical preoperative state	9 (0.5)
Tricuspid valve regurgitation	
Mild	334 (18.6)
Moderate	302 (16.8)
Severe	59 (3.3)
Pulmonary hypertension	869 (48.3)
Reduced LVEF (<30%)	165 (9.2)
Urgent/emergent status	69 (3.8)
Preoperative CT scan	468 (32.8)
EuroSCORE II (%)	1.09 [0.69–1.95]

Data are presented as n (%) or median [IQR]. CT, computed tomography; eGFR, estimated glomerular filtration rate; IQR, interquartile range; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

as well as high-risk cases, including reoperations, urgent procedures, and combined surgeries. When focusing on patients with degenerative mitral valve disease, the outcomes were particularly favorable, with an in-hospital mortality rate of 1.4% and a stroke rate of 0.6%. These results are in line with, and often exceed, those reported by other multicentric studies on conventional MVS (13-15). Multiple factors may explain these outcomes. Firstly, the well-documented clinical advantages of less invasive mitral techniques are likely a significant contributor. Previous research has indicated that mini-mitral procedures are linked to lower short-term morbidity and faster recovery times when compared to traditional full sternotomy mitral surgeries (1,2). Secondly, the advanced expertise in MVS and endoscopic cardiac techniques within the MMIR participating centers might be another crucial determinant. It is widely acknowledged that improved outcomes are strongly linked to both higher individual surgeon volumes and greater experience at the center level (2,16,17).

Risk analysis further revealed that patient comorbidities and clinical status, rather than the technical aspects of the endoscopic approach, predominantly determined operative outcomes. Importantly, while CPB and cross-clamp times were slightly longer for endoscopic MVS compared to conventional techniques, they did not emerge as significant predictors of mortality, which supports the safety and reliability of endoscopic techniques even in complex cases.

A 6% rate of surgical revision for bleeding was observed in this cohort. Although within the expected range for minimally invasive approaches, this remains an area for potential improvement. Optimizing intraoperative hemostasis, refining surgical techniques, and tailoring perioperative anticoagulation protocols may help reduce this complication.

A notable finding of our study is the applicability of endoscopic approach to a wide range of mitral valve pathologies and surgical techniques. In this series, all types of mitral valve pathologies (degenerative, functional, rheumatic, endocarditis, failure of previous valve repair/replacement) were addressed effectively, using the complete array of repair and replacement techniques, including concomitant procedures. Notably, tricuspid valve surgery was conducted in 14% of patients, while AF ablation was carried out in 41.8% of cases with presenting with AF, outcomes that align with those reported in patients undergoing MVS via full sternotomy (13). Degenerative mitral valve regurgitation was associated with a high repair rate of 95%, with nearly 99% of patients showing no or

Table 6 Operative data of patients with degenerative valve disease

Variables	Values (n=1,800)
Surgical access	
Anterolateral	1,011 (56.2)
Transaxillary	3 (0.2)
Periareolar	784 (43.6)
Conversion to full sternotomy	27 (1.5)
Arterial cannulation site	
Femoral artery	1,781 (98.9)
Axillary artery	12 (0.7)
Ascending aorta	5 (0.3)
Other	2 (0.1)
Percutaneous arterial cannulation	72 (4)
Venous cannulation site	
Femoral vein	1,387 (77.1)
Femoral + giugular vein	399 (22.2)
Femoral + superior vena cava	4 (0.2)
Other	10 (0.6)
Percutaneous venous cannulation	67 (3.7)
Myocardial protection	
Cardioplegia	1,787 (99.3)
Ventricular fibrillation	12 (0.7)
Aortic cross-clamping type	
External clamp	1,310 (72.8)
Endoclamp	479 (26.6)
Cardioplegia	
Blood	658 (36.6)
Crystalloid	1,127 (62.7)
Type of surgery	
Mitral valve repair	1,708 (94.9)
Mitral valve replacement	81 (4.5)
Replacement due to unsuccessful repair	10 (0.6)
Mitral valve repair technique	
Annuloplasty ring	1,486 (93.7)
Artificial chords	1,389 (77.6)
Resection	239 (13.4)
Sliding	17 (1.0)
Edge to edge	22 (1.2)
Associated procedures	
Tricuspid surgery	163 (9.1)
AF surgery	274 (15.2)
Aortic valve replacement	12 (0.7)
LAA closure	
Internal	134 (7.4)
Clip	49 (2.7)
Repeated cross clamping	40 (2.2)
Automatic knotting device	736 (40.9)
Intraoperative SAM	26 (1.4)
Circumflex artery occlusion	3 (0.2)
CPB time (minutes)	142 [115–180]
Cross clamp time (minutes)	88 [70–112]
Technical success	1,674 (98.1)

Data are presented as n (%) or median [IQR]. AF, atrial fibrillation; CPB, cardiopulmonary bypass time; IQR, interquartile range; LAA, left atrial appendage; SAM, systolic anterior motion.

mild residual regurgitation postoperatively.

Furthermore, only 0.6% of patients initially considered for valve repair required replacement, leading to a valve repair success rate of 99.4% among those valves identified as reparable before surgery. All these findings confirm that minimally invasive and endoscopic techniques do not compromise valve repair outcomes, enabling excellent repair rates while maintaining significant versatility across a broad range of clinical scenarios (18).

Despite these promising results, it is important to acknowledge the barriers to broader adoption of endoscopic MVS, such as the augmented technical complexity, the steep learning curve, the necessity for specialized equipment, and superior upfront expenses. Overcoming these challenges will require the institution of dedicated simulation and training programs, as well as the standardization of technology to expand the accessibility of endoscopic techniques. In this regard, the routine use of advanced tools, such as three-dimensional endoscopic cameras with high-definition monitors and automatic knotting devices, may prove helpful in streamlining certain steps, thereby improving procedural efficiency and reproducibility. Future studies should aim to assess long-term outcomes and validate these findings in

Table 7 In-hospital outcomes of patients with degenerative valve disease

Variables	Values (n=1,800)
In-hospital mortality	25 (1.4)
Stroke	11 (0.6)
Delirium	46 (3.1)
Intubation time (hours)	7 [5–12]
Ventilatory support >24 h	78 (5.6)
Re-intubation/tracheostomy	38 (2.1)
Bleeding requiring revision	
Same access	83 (4.6)
Full sternotomy	1 (0.1)
Transfusions (units)	0 [0–0]
New onset atrial fibrillation	383 (26.3)
Definitive PM implantation	26 (1.4)
Myocardial infarction	12 (0.7)
Low cardiac output syndrome	45 (2.5)
Acute kidney injury	94 (6.5)
Dialysis	16 (1.1)
Vascular complications	
Major vascular complications	24 (1.5)
Minor vascular complications	3 (0.2)
Thoracic wound complications	8 (0.4)
Groin wound complications	
Dehiscence	5 (0.3)
Lymphocele	30 (1.7)
MV insufficiency (after MV repair)	
No	1,503 (88.5)
Mild	176 (10.4)
Moderate	16 (0.9)
Severe	3 (0.2)
Redo for early valve repair failure	12 (0.7)
PVL (after MV replacement)	– (–)
ICU stay (hours)	21 [18–24]
Hospital stay (days)	7 [6–8]
Home discharge	897 (50.4)

Data are presented as n (%) or median [IQR]. ICU, intensive care unit; IQR, interquartile range; MV, mitral valve; PM, pacemaker; PVL, paravalvular leak.

broader populations, including lower-volume centers. This will help to further delineate the role of endoscopic MVS in the evolving landscape of MVS.

Limitations

This study is subject to several limitations inherent in observational registries. One such limitation is the absence of centralized adjudication for patient selection and data gathering. Imaging data were not independently reviewed by a core laboratory, and all information was provided directly by investigators from their respective institutions. Since MMIR is based on voluntary participation, the data are limited to centers with established mini-mitral programs that chose to contribute, potentially excluding other centers with less experience. Furthermore, the participating centers are tertiary referral hospitals, which may reduce the applicability of our findings to non-tertiary or lower-volume institutions. Lastly, the registry currently lacks long-term follow-up data, preventing a thorough evaluation of outcomes over prolonged periods.

Conclusions

Our findings indicate that endoscopic MVS is a reasonably safe and effective technique for managing a wide range of mitral valve pathologies, including complex and concomitant procedures. In this large, multicenter experience, valve repair was achieved with high success rates and low residual regurgitation. Operative outcomes were primarily determined by patient-related factors and comorbidities, rather than by the technical aspects of the endoscopic approach.

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Footnote

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