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Conventional versus Minimally Invasive Mitral Valve Surgery: A Comparative Analysis of Clinical Outcomes and Patient Recovery

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Abstract

Background: The evolution of surgical techniques has led to increased adoption of minimally invasive mitral valve surgery, yet comprehensive comparative analyses of clinical outcomes remain essential for optimal patient selection and surgical planning. This study compared the clinical outcomes, operative characteristics, and postoperative recovery parameters between conventional and minimally invasive mitral valve surgery.

Methods: This prospective cohort study analyzed 100 patients undergoing mitral valve repair (MVR), with 50 patients in each group (conventional MVR n=50, minimally invasive MVR n=50).

Results: Significant demographic differences were observed between groups, with the conventional group being older (52.32±10.19 vs 42.68±11.95 years, p<0.001) and having lower rates of hypertension (22% vs 42%, p=0.032), chronic kidney disease (14% vs 42%, p=0.002), and smaller left atrial dimensions (4.3 vs 4.65 cm, p<0.001). The minimally invasive group demonstrated significantly longer cardiopulmonary bypass times (100 vs 136 minutes, p<0.001) and ischemic times (64 vs 79 minutes, p<0.001). However, the minimally invasive approach was associated with significantly reduced intensive care unit stay (4 vs 3 days, p<0.001), shorter hospital length of stay (9 vs 8 days, p<0.001), and decreased ventilation time (9 vs 7 hours, p<0.001). However, the conventional approach had markedly improved pain scores, with 2% experiencing severe pain compared to 30% in the minimally invasive group (p<0.001). Postoperative complications showed comparable bleeding rates (10% vs 12%, p=0.749) and wound infections (8% vs 2%, p=0.362), though the minimally invasive group had higher rates of pleural effusion (2% vs 26%, p=0.001).

Conclusions: Minimally invasive mitral valve surgery demonstrates comparable safety profiles to conventional approaches while offering significant advantages in postoperative recovery, including reduced hospital stay and shorter ventilation requirements. However, the technique requires longer operative times and may be associated with specific complications such as pleural effusion. These findings support the continued development and selective application of minimally invasive techniques in mitral valve surgery.

KEYWORDS

Mitral valve surgery; Minimally invasive surgery; Conventional sternotomy; Cardiac surgery; Postoperative outcomes

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Introduction

Conventional mitral valve surgery, performed through a median sternotomy, has remained the gold standard for mitral valve intervention for several decades. This approach provides excellent exposure of the mitral valve, allowing for comprehensive assessment of valve pathology and precise execution of repair or replacement techniques [1]. The conventional approach offers several distinct advantages that have contributed to its widespread adoption and continued use. The extensive exposure provided by median sternotomy allows surgeons to address complex pathology, perform concomitant procedures, and manage unexpected intraoperative complications effectively [2]. Despite its proven efficacy and safety profile, conventional mitral valve surgery is associated with certain limitations and potential complications. The extensive surgical trauma associated with sternotomy results in significant postoperative pain, prolonged recovery times, and increased risk of wound complications, including mediastinitis [3]. The large incision and associated tissue trauma can lead to increased blood loss, longer ventilation times, and extended hospital stays compared to less invasive approaches [2,3].

The development of minimally invasive mitral valve surgery emerged from the desire to reduce the surgical trauma associated with conventional approaches while maintaining the precision and safety of open cardiac procedures [4]. Contemporary minimally invasive mitral valve surgery encompasses several different approaches, each with distinct advantages and limitations. The most commonly employed technique involves a right mini thoracotomy through the fourth or fifth intercostal space, typically measuring 4-8 centimeters in length [5].

The comparative analysis of conventional versus minimally invasive mitral valve surgery reveals distinct advantages and limitations for each approach. The learning curve for conventional techniques is generally shorter, and the approach is suitable for virtually all forms of mitral valve disease regardless of complexity [6]. Minimally invasive approaches offer several potential advantages, including reduced surgical trauma, improved cosmetic results, decreased postoperative pain, and faster recovery times [7]. However, minimally invasive techniques are associated with certain limitations and potential disadvantages. The restricted visualization and working space can make complex repairs more challenging and may limit the surgeon's ability to address unexpected pathology [8]. The learning curve for minimally invasive techniques is typically longer than conventional approaches, and not all surgeons may achieve equivalent outcomes with minimally invasive methods [9]. Additionally, the peripheral cannulation required for most minimally invasive approaches may be associated with specific complications such as vascular injury or limb ischemia.

Patient selection criteria for minimally invasive mitral valve surgery continue to evolve as experience with these techniques grows. Ideal candidates typically include patients with isolated mitral valve disease, favorable anatomy for peripheral cannulation, and absence of significant adhesions from previous cardiac surgery [1].

The existing literature comparing conventional and minimally invasive mitral valve surgery demonstrates generally comparable safety and efficacy profiles for both approaches, with specific advantages and disadvantages for each technique. Multiple systematic reviews and meta-analyses have attempted to synthesize the available evidence, though most studies are observational in nature with inherent selection bias and heterogeneity in surgical techniques and outcome measures [10]. Recent meta-analyses have suggested that minimally invasive approaches may be associated with reduced mortality, shorter intensive care unit stays, and decreased hospital length of stay compared to conventional surgery [10]. However, these studies also demonstrate longer cross-clamp and cardiopulmonary bypass times for minimally invasive procedures, reflecting the technical complexity and learning curve associated with these approaches. The impact of surgeon experience and institutional volume on outcomes is particularly important for minimally invasive techniques. Centers with high-volume minimally invasive programs have reported outcomes comparable to or better than conventional surgery, while low-volume centers may experience higher complication rates and longer learning curves [11,12]. The economic implications of minimally invasive versus conventional mitral valve surgery represent an important consideration in healthcare resource allocation. While minimally invasive procedures may be associated with higher initial costs due to specialized equipment and longer operative times, the potential for reduced hospital stays, decreased complications, and faster return to normal activities may result in overall cost savings [13].

The evolution of surgical techniques has led to increased adoption of minimally invasive mitral valve surgery, yet comprehensive comparative analyses of clinical outcomes remain essential for optimal patient selection and surgical planning. This study compared the clinical outcomes, operative characteristics, and postoperative recovery parameters between conventional mitral valve surgery via median sternotomy and minimally invasive mitral valve surgery.

Patients and Methods

Study Design and Setting

This prospective cohort study was conducted to evaluate the clinical outcomes, operative characteristics, and postoperative recovery parameters between conventional and minimally invasive mitral valve surgery. The study was designed as a single-center analysis examining consecutive patients who underwent mitral valve repair (MVR). The research protocol was developed in accordance with the principles outlined in the Declaration of Helsinki and received institutional review board approval prior to data collection and analysis [14].

The study compared two surgical approaches for MVR: conventional MVR performed through median sternotomy and minimally invasive MVR performed through right mini-thoracotomy.

Patient Population and Selection Criteria

The study population comprised 100 consecutive patients who underwent MVR, with 50 patients allocated to each treatment group (conventional MVR n=50, minimally invasive MVR n=50). Patient selection was based on the surgeon's preference. All patients included in the analysis had documented severe mitral valve disease requiring surgical intervention based on current clinical guidelines and institutional protocols [15].

Inclusion criteria for the study encompassed adult patients (age ≥18 years) who underwent elective or urgent MVR for severe mitral valve disease, including both stenotic and regurgitant lesions. Patients with various etiologies of mitral valve disease were included, encompassing rheumatic heart disease, degenerative valve disease, infective endocarditis, and other pathological conditions requiring valve repair. Patients undergoing concomitant cardiac procedures were excluded. Emergency procedures performed for acute mitral valve complications, such as acute papillary muscle rupture or severe endocarditis with hemodynamic instability, were also excluded. Patients with previous cardiac surgery were included in the analysis.

Preoperative Assessment and Risk Stratification

All patients underwent comprehensive preoperative evaluation following standardized institutional protocols designed to assess surgical risk and optimize perioperative outcomes. The preoperative assessment included detailed medical history, physical examination, laboratory studies, and imaging evaluations to characterize valve pathology and assess overall cardiovascular status. Standardized risk assessment tools were employed to evaluate perioperative risk and guide surgical decision-making processes.

Echocardiographic evaluation was performed in all patients using transthoracic and/or transesophageal echocardiography to assess mitral valve morphology, severity of valve disease, left ventricular function, and associated cardiac abnormalities. Key echocardiographic parameters included left ventricular ejection fraction (LVEF), left atrial dimensions, end-diastolic and end-systolic dimensions, and the presence of tricuspid regurgitation. Pulmonary artery pressures were estimated, and the presence of pulmonary hypertension was documented as a potential risk factor.

Cardiac catheterization was performed selectively based on clinical indications, patient age, and institutional protocols. The decision to perform catheterization was individualized based on patient characteristics and clinical presentation, with particular attention to patients with risk factors for coronary artery disease.

Surgical Techniques

Conventional MVR

Conventional MVR was performed through a standard median sternotomy approach. The procedure began with a full median sternotomy incision extending from the suprasternal notch to the xiphoid process, with complete division of the sternum using an oscillating saw. The pericardium was opened in a T-shaped fashion.

Cardiopulmonary bypass was established through standard cannulation techniques, with arterial cannulation of the ascending aorta and venous drainage through bicaval cannulation. Systemic anticoagulation was achieved with heparin administration targeting an activated clotting time greater than 400 seconds. Myocardial protection was accomplished through antegrade cardioplegia delivery via the aortic root, with supplemental retrograde cardioplegia administered through coronary sinus cannulation when appropriate.

The mitral valve was accessed through a left atriotomy incision placed parallel to the interatrial groove. Careful inspection of the valve pathology was performed to confirm the preoperative diagnosis and assess the feasibility of repair versus replacement. MVR was performed using standardized techniques in both groups. Following valve repair, the left atrium was carefully inspected, and de-airing maneuvers were performed.

Minimally Invasive MVR

Minimally invasive MVR was performed through a right mini-thoracotomy approach. The procedure began with patient positioning in a supine position with slight elevation of the right chest to optimize access to the right thoracic cavity. Single-lung ventilation was employed using a double-lumen endotracheal tube.

The skin incision was placed in the fourth or fifth intercostal space along the anterior axillary line, typically measuring 4-6 centimeters in length. Peripheral cannulation was utilized for cardiopulmonary bypass, with arterial cannulation typically performed through the femoral artery and venous drainage accomplished through femoral venous cannulation with or without additional superior vena cava drainage.

Myocardial protection was achieved through antegrade cardioplegia delivery via the aortic root, with direct aortic cannulation performed through the mini-thoracotomy incision. Alternative cardioplegia delivery methods, including direct coronary ostial cannulation or retrograde cardioplegia through coronary sinus cannulation, were employed when indicated by specific anatomical or technical considerations. The mitral valve was accessed through a left atriotomy similar to the conventional approach, though the limited exposure required careful positioning and specialized retraction techniques to optimize visualization. Endoscopic assistance was employed selectively to enhance visualization. Valve repair techniques were similar to those employed in conventional surgery.

Perioperative Management

Perioperative management protocols were standardized for both surgical approaches. Preoperative preparation included optimizing medical therapy, discontinuing antiplatelet agents when appropriate, and administering prophylactic antibiotics according to institutional guidelines. Anesthetic management was tailored to the specific surgical approach, with conventional procedures utilizing standard cardiac anesthetic techniques and minimally invasive procedures requiring modifications for single-lung ventilation and peripheral cannulation. Monitoring protocols included standard cardiac surgical monitoring with arterial and central venous pressure monitoring, as well as transesophageal echocardiography.

Table 1: Patient characteristics and baseline demographics for patients who had conventional vs. minimally invasive mitral valve repair (MVR). Data were presented as mean (SD), median (IQR) and numbers (%).

	Conventional MVR (n= 50)	Minimally invasive MVR (n= 50)	p-value
Age, years	52.32± 10.19	42.68 ±11.95	<0.001
Male	26 (52%)	21 (42%)	0.316
Body surface area, m^2	1.69± 0.20	1.79± 0.23	0.020
Hypertension	11 (22%)	21 (42%)	0.032
Diabetes mellitus	7 (14%)	12 (24%)	0.202
Chronic kidney disease	7 (14%)	21 (42%)	0.002
Chronic obstructive pulmonary disease	7 (14%)	3 (6%)	0.318
Peripheral arterial disease	2 (4%)	4 (8%)	0.678
Stroke	2 (4%)	2 (2%)	>0.99
Myocardial infarction	4 (8%)	4 (8%)	>0.99
Infective endocarditis	5 (10%)	6 (12%)	0.749
Sinus rhythm	43 (86%)	41 (82%)	0.585

Postoperative care protocols were standardized. Intensive care unit management included standardized ventilation weaning protocols, hemodynamic monitoring, and pain management strategies. Early mobilization and rehabilitation protocols were implemented to optimize recovery and minimize complications associated with prolonged bed rest. Pain management strategies were individualized based on surgical approach, with conventional sternotomy patients receiving multimodal analgesia including patient-controlled analgesia, regional blocks, and adjunctive medications. Minimally invasive patients received similar multimodal approaches with modifications based on the different incision and tissue trauma patterns associated with thoracotomy approaches.

Data Collection and Outcome Measures

Comprehensive data collection was performed using standardized case report forms. All data were collected from medical records, operative reports, and institutional databases.

Demographic variables collected included age, gender, body surface area, and relevant comorbidities such as hypertension, diabetes mellitus, chronic kidney disease, chronic obstructive pulmonary disease, peripheral vascular disease, previous stroke, and previous myocardial infarction. Cardiac-specific variables included the presence of infective endocarditis, cardiac rhythm, New York Heart Association (NYHA) functional class, presence of pulmonary hypertension, and previous cardiac surgery.

Table 2: Preoperative cardiac assessment for patients who had conventional vs. minimally invasive mitral valve repair (MVR). Data were presented as numbers and percentages

	Conventional MVR (n= 50)	Minimally invasive MVR (n= 50)	p-value
New York Heart Association			
II	25 (50%)	14 (28%)	
III	24 (48%)	33 (66%)	0.050
IV	1 (2%)	3 (6%)	
Pulmonary hypertension	11 (22%)	18 (36%)	0.123
Previous cardiac surgery	1 (2%)	1 (2%)	>0.99
Urgent surgery	2 (4%)	2 (4%)	>0.99
Rheumatic heart disease	38 (76%)	40 (80%)	0.629

Preoperative echocardiographic data included LVEF, left atrial dimensions, end-diastolic and end-systolic dimensions, and the presence of tricuspid regurgitation. The etiology of mitral valve disease was classified as rheumatic heart disease or non-rheumatic. The specific pathology was characterized as anterior leaflet involvement, posterior leaflet involvement, or bileaflet disease.

Operative variables included cardiopulmonary bypass time and aortic cross-clamp time. The use of inotropic support, including adrenaline, noradrenaline, and dobutamine, was documented.

Postoperative outcome measures included intensive care unit length of stay, total hospital length of stay, and mechanical ventilation time. Pain assessment was performed using standardized pain scales, with pain severity classified as mild, moderate, or severe based on patient-reported outcomes. Postoperative complications were systematically documented, including bleeding requiring reoperation, wound infections, femoral hematoma, pleural effusion, and other relevant complications.

Statistical analysis

Statistical analysis was performed using Stata 18 (Stata Corp, College Station, TX). Descriptive statistics were calculated for all variables, with continuous variables presented as means with standard deviations or medians with interquartile ranges depending on data distribution characteristics. Categorical variables were presented as frequencies and percentages. Comparative analysis between surgical approaches was performed using appropriate statistical tests based on variable type and distribution characteristics. Continuous variables were compared using Student's t-test for normally distributed data or the Mann-Whitney U test for non-parametric data. Categorical variables were compared using chi-squared tests or Fisher's exact tests when cell counts were small. Statistical significance was defined as p-values less than 0.05, with all tests performed as two-tailed analyses.

Results

Patient Demographics and Baseline Characteristics

Age distribution demonstrated a statistically significant difference between groups, with patients in the conventional MVR group being substantially older than those in the minimally invasive group (52.32 ± 10.19 years versus 42.68 ± 11.95 years, $p<0.001$). Gender distribution was relatively balanced between groups ($p=0.316$) (Table 1).

Hypertension was significantly more prevalent in the minimally invasive group (42% versus 22%, $p=0.032$). Diabetes mellitus showed a trend toward higher prevalence in the minimally invasive group (24% versus 14%, $p=0.202$). Chronic kidney disease was significantly more prevalent in the minimally invasive group (42% versus 14%, $p=0.002$). Chronic obstructive pulmonary disease was more prevalent in the conventional group (14% versus 6%, $p=0.318$), though this difference did not reach statistical significance. Peripheral vascular disease showed comparable prevalence between groups (4% versus 8%, $p=0.678$). Previous stroke and myocardial infarction rates were similar between groups. Infective endocarditis showed similar prevalence between groups (10% versus 12%, $p=0.749$) (Table 1).

Preoperative Cardiac Assessment

NYHA functional class distribution demonstrated different patterns between groups. Class II symptoms were more prevalent in the conventional group (50% versus 28%), while Class III symptoms were more common in the minimally invasive group (48% versus 66%). Pulmonary hypertension was more prevalent in the minimally invasive group (36% versus 22%, $p=0.123$), though this difference did not reach statistical significance. Rheumatic heart disease represented the predominant etiology in both groups, affecting 76% of conventional patients and 80% of minimally invasive patients ($p=0.629$) (Table 2).

Preoperative Cardiac Function and Dimensions

LVEF distribution revealed significant differences between groups. Normal ejection fraction (>60%) was more prevalent in the minimally invasive group (84% versus 26%, p<0.001), while mildly reduced ejection fraction (40-59%) was more common in the conventional group (36% versus 12%, p<0.001). Severely reduced ejection fraction (20-39%) was present in small numbers in both groups (4% in each group, p>0.99). Left atrial dimensions demonstrated significant differences between groups, with larger left atrial size in the minimally invasive group (4.3 cm [4.0-4.6] versus 4.65 cm [4.4-5.0], p<0.001). End-diastolic dimensions showed no significant difference between groups (4.9 cm [4.7-5.0] versus 4.95 cm [4.7-5.5], p=0.193). However, end-systolic dimensions were significantly larger in the minimally invasive group (3.65 cm [3.2-4.0] versus 4.0 cm [3.8-4.0], p<0.001).

Anterior leaflet involvement was present in 56% of conventional patients versus 58% of minimally invasive patients (p=0.840). Posterior leaflet involvement showed no difference between groups (38% versus 32%, p=0.529). Bileaflet involvement was identical between groups (6% in each group, p>0.99). Tricuspid regurgitation prevalence was identical between groups (10% in each group, p>0.99) (Table 3).

Operative and Postoperative Parameters

Cardiopulmonary bypass times demonstrated one of the most significant differences between surgical approaches, with the minimally invasive group requiring substantially longer bypass times (136 minutes [125-144] versus 100 minutes [97-105], p<0.001). Ischemic times showed a similar pattern, with significantly longer times in the minimally invasive group (79 minutes [75-85] versus 64 minutes [60-69], p<0.001).

The requirement for inotropic support demonstrated significant differences between surgical approaches. Adrenaline support was required significantly more frequently in the minimally invasive group (82% versus 56%, p=0.005). Conversely, noradrenaline support was required more frequently in the conventional group (62% versus 36%, p=0.009). Dobutamine support showed a similar pattern to noradrenaline, with higher requirements in the conventional group (42% versus 18%, p=0.009). The use of defibrillation/ cardioversion (DC) showed no significant difference between groups (40% versus 32%, p=0.405).

Intensive care unit length of stay demonstrated a significant advantage for the minimally invasive approach, with patients spending less time in the ICU (3 days [3-4] versus 4 days [4-4], p<0.001). Total hospital length of stay showed a similar pattern, with significantly shorter stays in the minimally invasive group (8 days (7-8) versus 9 days (9-11), p<0.001). Mechanical ventilation time was significantly shorter in the minimally invasive group (7 hours [6-8] versus 9 hours [8-12], p<0.001) (Table 4).

Table 3: Cardiac function and dimensions for patients who had conventional vs. minimally invasive mitral valve repair (MVR). Data were presented as mean (SD), median (IQR) and numbers (%)

	Conventional MVR (n= 50)	Minimally invasive MVR (n= 50)	p-value
Ejection fraction			
>60%	13 (26%)	6 (12%)	0.074
40- 59	18 (36%)	42 (84%)	<0.001
20- 39	2 (4%)	2 (4%)	>0.99
Left atrial diameter (cm)	4.3 (4- 4.6)	4.65 (4.4- 5)	<0.001
End-diastolic diameter (cm)	4.9 (4.7- 5)	4.95 (4.7- 5.5)	0.193
End-systolic diameter (cm)	3.65 (3.2- 4)	4 (3.8- 4)	<0.001
Anterior leaflet mitral regurgitation	28 (56%)	29 (58%)	0.840
Posterior leaflet mitral regurgitation	19 (38%)	16 (32%)	0.529
Bileaflet mitral regurgitation	3 (6%)	3 (6%)	>0.99
Tricuspid regurgitation	5 (10%)	5 (10%)	>0.99

Table 4: Operative parameters and postoperative outcomes for patients who had conventional vs. minimally invasive mitral valve repair (MVR). Data were presented as mean (SD), median (IQR) and numbers (%).

	Conventional MVR (n= 50)	Minimally invasive MVR (n= 50)	p-value
Cardiopulmonary bypass time, min	100 (97- 105)	136 (125- 144)	<0.001
Ischemic time, min	64 (60- 69)	79 (75- 85)	<0.001
Cardioversion/defibrillation	20 (40%)	16 (32%)	0.405
Adrenaline	28 (56%)	41 (82%)	0.005
Noradrenaline	31 (62%)	18 (36%)	0.009
Dobutamine	21 (42%)	9 (18%)	0.009
ICU stay, days	4 (4-4)	3 (3- 4)	<0.001
Hospital stay, days	9 (9- 11)	8 (7- 8)	<0.001
Ventilation time, h	9 (8- 12)	7 (6- 8)	<0.001

Pain Assessment and Postoperative Complications

Mild pain was reported by 92% of conventional patients compared to only 22% of minimally invasive patients (p<0.001). Moderate pain was more prevalent in the minimally invasive group (48% versus 6%), while severe pain was reported by 30% of minimally invasive patients compared to only 2% of conventional patients.

Bleeding complications requiring reoperation showed similar rates between groups (10% versus 12%, p=0.749). Wound infection rates were numerically lower in the minimally invasive group (2% versus 8%, p=0.362), though this difference did not reach statistical significance.

Femoral hematoma was observed exclusively in the minimally invasive group (10% versus 0%). Pleural effusion demonstrated a significant difference between groups, with much higher rates in the minimally invasive group (26% versus 2%, p=0.001). Reoperation rates for any indication were similar between groups (4% versus 8%, p=0.678) (Table 5).

Discussion

This comparative study of 100 patients undergoing MVR provides important insights into the contemporary outcomes of conventional versus minimally invasive surgical approaches. The principal findings demonstrate that while minimally invasive MVR requires longer operative times, it offers significant advantages in terms of postoperative recovery, including reduced ICU stay, shorter hospital length of stay, and decreased mechanical ventilation requirements.

The significantly longer cardiopulmonary bypass times (136 versus 100 minutes) and ischemic times (79 versus 64 minutes) observed in the minimally invasive group represent important technical considerations that must be weighed against the potential benefits of these approaches.

Table 5: Pain assessment and complications for patients who had conventional vs. minimally invasive mitral valve repair (MVR). Data were presented as numbers and percentages.

	Conventional MVR (n= 50)	Minimally invasive MVR (n= 50)	p-value
Pain			
Mild	46 (92%)	11 (22%)	<0.001
Moderate	3 (6%)	24 (48%)	
Severe	1 (2%)	15 (30%)	
Bleeding	5 (10%)	6 (12%)	0.749
Wound infection	4 (8%)	1 (2%)	0.362
Femoral hematoma		5 (10%)	
Pleural effusion	1 (2%)	13 (26%)	0.001
Reopening	4 (8%)	2 (4%)	0.678

These findings are consistent with published literature demonstrating minimally invasive cardiac surgery's learning curve and technical complexity [16]. The 36% increase in bypass time and 23% increase in ischemic time reflect the additional time required for peripheral cannulation, limited working space, and the technical challenges of performing precise surgical maneuvers through small incisions. However, it is important to contextualize these prolonged operative times within the broader framework of surgical outcomes. While longer bypass and ischemic times are generally associated with increased perioperative risk, the absolute times observed in this study remain within acceptable ranges for mitral valve repair procedures. Furthermore, the potential negative effects of prolonged operative times appear to be offset by the benefits of reduced surgical trauma, as evidenced by the improved recovery parameters in the minimally invasive group.

The technical challenges associated with minimally invasive mitral valve surgery extend beyond simple operative time considerations. The limited visualization and working space require specialized instruments, modified surgical techniques, and enhanced surgeon experience to achieve outcomes comparable to conventional approaches [17]. The learning curve for minimally invasive techniques is typically longer than conventional surgery, and institutional commitment to developing expertise in these approaches is essential for optimizing outcomes [9,17,18].

The requirement for peripheral cannulation in minimally invasive procedures introduces specific technical considerations and potential complications. The 10% incidence of femoral hematoma in the minimally invasive group highlights the importance of careful vascular access management and postoperative monitoring. Preoperative assessment of peripheral vascular anatomy is crucial for identifying patients suitable for peripheral cannulation and avoiding complications related to inadequate vessel size or atherosclerotic disease [19].

The superior recovery parameters observed in the minimally invasive group represent one of the most compelling arguments for the continued development and application of these techniques. The one-day reduction in ICU stay and 1-2 day reduction in total hospital length of stay translate to meaningful improvements in healthcare resource utilization and patient satisfaction. These findings are consistent with multiple studies demonstrating faster recovery associated with minimally invasive cardiac surgery approaches [20]. The 2–3 hour reduction in mechanical ventilation time observed in the minimally invasive group may reflect several factors, including reduced surgical trauma, better preservation of chest wall mechanics, and potentially different pain management strategies. Shorter ventilation times are associated with reduced risk of ventilator-associated pneumonia, earlier mobilization, and improved patient comfort [21]. Preserving chest wall integrity in minimally invasive approaches may contribute to better respiratory mechanics and faster weaning from mechanical ventilation.

The unexpected pain assessment findings, with higher rates of moderate to severe pain in the minimally invasive group, warrant careful consideration and further investigation. These results appear counterintuitive given the theoretical advantages of smaller incisions and reduced tissue trauma associated with minimally invasive approaches [22]. Several potential explanations for these findings should be considered, including the specific characteristics of thoracotomy-related pain. Thoracotomy incisions, even when small, involve division of intercostal muscles and potential injury to intercostal nerves, which may result in different pain characteristics compared to sternotomy incisions [23]. The nature of intercostal neuralgia and chronic pain syndromes associated with thoracotomy procedures may require different pain management strategies and longer-term follow-up to fully characterize. Additionally, patient expectations and psychological factors may influence pain reporting, particularly when patients are aware of receiving a "less invasive" procedure.

The complication profiles observed in this study provide important insights into the specific risks associated with each surgical approach. The significantly higher rate of pleural effusion in the minimally invasive group (26% versus 2%) reflects the thoracotomy approach and potential pleural space violation inherent to these techniques [24]. While pleural effusion is generally a manageable complication, it may contribute to respiratory symptoms, prolonged chest tube drainage, and potential delays in recovery.

The findings of this study are generally consistent with the existing literature comparing conventional and minimally invasive approaches to MVR. A recent systematic review and meta-analysis by Williams et al. demonstrated that robotic mitral valve surgery was associated with lower mortality and shorter hospital stays compared to conventional approaches, though with longer operative times [25]. These findings align with the current study's observations of improved recovery parameters despite prolonged operative times. The propensity score matching analysis by Yaşar et al. found no significant difference in mortality between minimally invasive and conventional mitral valve surgery, with lower rates of postoperative atrial fibrillation in the minimally invasive group [26]. While the current study did not specifically analyze atrial fibrillation rates, the overall complication profiles were similar between groups, supporting the safety of both approaches. The longer cardiopulmonary bypass and ischemic times observed in this study are consistent with multiple published series demonstrating the technical complexity of minimally invasive approaches [16].

Limitations

Several important limitations of this study must be acknowledged when interpreting the results and their clinical implications. The observational design inherently limits the ability to establish causal relationships and may be subject to selection bias, confounding variables, and incomplete data collection. The significant demographic differences between groups, particularly age and ventricular function, represent important confounding factors that may influence outcome comparisons. The single-center design, while providing consistency in surgical techniques and perioperative management, may limit the generalizability of findings to other institutions with different patient populations, surgical expertise, or care protocols. The learning curve effects and institutional experience with minimally invasive techniques may significantly influence outcomes and may not be representative of centers with different levels of experience. The sample size of 50 patients per group, while adequate for detecting large effect sizes, may be insufficient to identify smaller but clinically meaningful differences between surgical approaches. The pain assessment methodology and timing represent important limitations that may have influenced the unexpected findings regarding postoperative pain. Standardized pain assessment tools, consistent timing of evaluation, and longer-term follow-up would be valuable for better characterizing the pain experience associated with each surgical approach. The lack of long-term follow-up data limits the ability to assess durability of surgical repairs, late complications, and long-term functional outcomes. While short-term recovery advantages are important, the ultimate success of mitral valve surgery must be evaluated over years to decades.

Conclusion

This study comparing conventional and minimally invasive mitral valve repair found that both techniques are safe for appropriately selected patients, with each approach offering distinct advantages and limitations. Minimally invasive surgery showed superior recovery benefits, including shorter hospital stays and reduced ICU time, particularly in younger patients with better ventricular function. However, it also required longer operative times and carried unique risks like pleural effusion, highlighting the need for surgeon expertise and careful patient selection. The unexpected pain assessment results suggest the need for better outcome measurement tools, while demographic differences reflect the evolving use of minimally invasive techniques in lower-risk populations.

The findings support individualized treatment decisions based on patient factors, surgeon experience, and institutional resources. Future research should focus on randomized trials, long-term outcomes, and improved selection criteria to optimize results. As minimally invasive techniques advance, they may benefit broader patient groups, especially with emerging technologies like robotic surgery. The study confirms that minimally invasive mitral valve surgery provides meaningful recovery advantages while maintaining safety, reinforcing its role in modern cardiac care when applied selectively. Continued refinement of these approaches will further enhance outcomes for patients with mitral valve disease.

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