ADULT

Second cross-clamp in less invasive mitral valve repair for degenerative mitral regurgitation: Predictors and outcomes

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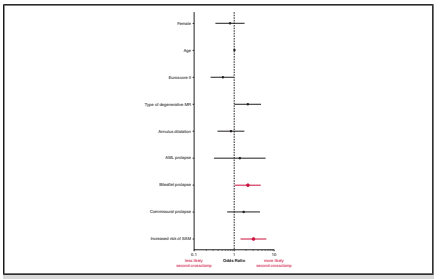
ABSTRACT

Objective: To evaluate the incidence, echocardiographic patterns, operative strategies, and results of patients receiving a second cross-clamping in the large population of the Mini Mitral International Registry.

Methods: We examined 4577 patients with degenerative mitral regurgitation (MR) who underwent less invasive mitral repair. Patients with nondegenerative disease, planned valve replacement, and surgery without cross-clamping were excluded. Multivariable logistic regression model was applied to investigate predictors of second cross-clamping and the relationship between second cross-clamping and outcomes.

Results: Second cross-clamping was used in 128 cases (2.8%). Reasons for re-cross-clamping included residual pathology in 71.9% of the patients (n = 92) and systolic anterior motion (SAM) in 28.1% (n = 36). Re-repair was performed in 104 patients (81.3%), and replacement was performed in 24 (18.7%). After re-repair, 92 patients (94.9%) had no or mild MR, 4 patients (4.1%) had moderate MR, and 1 patient (1%) had severe MR. A residual SAM was observed in 2 patients (2.3%). Bileaflet prolapse (odds ratio [OR], 2.21) and predicted risk of SAM (OR, 3.04) were identified as risk factors for second cross-clamping. No association between second cross-clamping and mortality or major postoperative complications was found; however, second cross-clamping was associated with an increased risk of respiratory insufficiency (OR, 4.6) and longer intensive care unit (ICU) stay ($\beta = 0.35$).

Conclusions: Second cross-clamping after less invasive mitral repair is infrequent but may be required, particularly in patients with bileaflet pathology or at increased risk of SAM. Most re-repairs were successful, with <20% of patients requiring replacement. Second cross-clamping was associated with higher risk of respiratory insufficiency and prolonged ICU stay. (J Thorac Cardiovasc Surg 2026;171:400-7)



Predictors of second cross clamp.

CENTRAL MESSAGE

Second cross-clamping during mini mitral repair is rare and primarily triggered by residual pathology or systolic anterior motion. Re-repair is often successful, although associated with increased respiratory morbidity.

PERSPECTIVE

This large multicenter study aimed to clinical impact of a second cross-clamping in minimally invasive mitral repair. The findings support the use of second cross-clamping to optimize repair quality and may guide intraoperative decision making in contemporary mitral valve surgery.

See Commentary on page 408.

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Abbreviations and Acronyms

AML = anterior mitral leaflet
CPB = cardiopulmonary bypass
FED = fibroelastic deficiency
ICU = intensive care unit
IQR = interquartile range
MMIR = Mini Mitral International Registry
MR = mitral regurgitation
MVARC = Mitral Valve Academic Research Consortium
OR = odds ratio
PML = posterior mitral leaflet
SAM = systolic anterior motion
SD = standard deviation

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Mitral valve repair is the gold standard treatment for patients with degenerative mitral regurgitation (MR), as it has been shown to provide superior outcomes compared to valve replacement.[1,2] However, the presence of residual MR has been associated with the need for reintervention, poorer clinical outcomes, and reduced survival.[3-6] Consequently, achieving a complete and competent repair during the initial surgery is crucial to avoid the negative consequences of persistent MR or the need for unplanned valve replacement.

When residual MR occurs, a second cross-clamping to optimize valve function and ensure a durable result may be required. The clinical impact of second cross-clamping remains unclear, however, particularly in the context of minimally invasive mitral valve repair, with concerns about increased operative time and associated risks.[7] This study aimed to evaluate the predictors, safety, and outcomes of second cross-clamping in patients undergoing less invasive mitral valve repair for degenerative MR, using data from the large cohort of the Mini Mitral International Registry (MMIR).

PATIENTS AND METHODS

Data Source and Study Cohort

The MMIR is an independent registry that includes patients from 17 heart valve centers worldwide. The rationale and methodology of the MMIR have been described previously.[8] The study population comprised patients undergoing minimally invasive mitral valve surgery for any indication, using various surgical approaches and materials. The MMIR database was specifically designed to collect comprehensive clinical, surgical, and echocardiographic data, as well as perioperative outcomes and risk assessment variables. Data collection across all participating centers followed standardized definitions and assessment criteria in accordance with European Society of Cardiology and American College of Cardiology/American Heart Association/Heart Rhythm Society guidelines, the EuroSCORE II model, and the Mitral Valve Academic Research Consortium (MVARC) endpoint definitions.[9-11] Retrospectively completed data forms were submitted by each participating center to the Coordinating Center, where they were reviewed for completeness and consistency. The study protocol was approved by the Institutional Review Board of each participating institution, following central approval from the Coordinating Center (2,020,189, approved July 30, 2020). Informed consent was obtained from patients when required.

At the time of this study, the MMIR had enrolled 7957 patients. The present analysis includes patients with degenerative MR who underwent initial mitral valve repair. Patients with nondegenerative MR (n = 2707), those scheduled for mitral valve replacement (n = 451), those who underwent surgery without cross-clamping (n = 57), and those with missing data for key inclusion/exclusion variables (n = 165) were excluded. Patients were classified based on whether a second cross-clamping was required due to residual MR. The causes of the need for a second cross-clamping, revising repair procedures, echocardiographic outcomes, and postoperative courses were assessed.

Outcomes

The study outcomes included the need for a second cross-clamping, all-cause operative mortality, stroke, low cardiac output, dialysis, respiratory failure, and length of stay. Outcomes were defined according to the MVARC endpoint definitions[10] and the EuroSCORE II model.[11] A second cross-clamping was defined as the need for a second aortic cross-clamping due to residual MR. Operative mortality was defined as death occurring in the same hospital in which the operation was performed, before discharge. Stroke was defined as a focal or global neurologic deficit lasting ≥24 hours or <24 hours if neuroimaging confirmed a new intracranial or subarachnoid hemorrhage, central nervous system infarction, or if the neurologic deficit resulted in death. Low cardiac output was defined as the need for inotropic support for >24 hours or the use of temporary mechanical circulatory support. Dialysis was defined as postoperative acute kidney injury requiring renal replacement therapy. Respiratory failure included prolonged mechanical ventilation (>24 hours), reintubation, or tracheostomy.

The study protocol was approved by the Institutional Review Board of each participating institution, following central approval from the Coordinating Center (2020189; July 30, 2020). Informed consent was obtained from patients where required.

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Statistical Analysis

Continuous variables are expressed as mean ± standard deviation (SD); categorical variables, as percentage. When continuous variables did not follow a normal distribution, they were reported as median and interquartile range (IQR). Missing data were not imputed as negative values, and denominators reflect only available cases (Table E1). Group comparisons were performed using the unpaired *t* test or Mann-Whitney U test for continuous variables and the χ^2 test for categorical variables. Predictors of a second cross-clamping were analyzed using multivariable logistic regression. The model was adjusted for clinical and anatomic confounders selected a priori based on their clinical relevance and potential impact on the outcome: age, sex, EuroSCORE II, type of valve disease (fibroelastic deficiency, Barlow, forme fruste), site of valve disease (posterior leaflet [PML], anterior leaflet [AML], bileaflet), annular dilatation, commissural prolapse, increased risk of systolic anterior motion [SAM], and center). Additionally, binary logistic regression was used to assess the association between second cross-clamping and study outcomes, adjusting for age, sex, chronic lung disease, atrial fibrillation, extracardiac arteriopathy, reduced left ventricular ejection fraction, pulmonary hypertension, New York Heart Association class III-IV, estimated glomerular filtration rate, previous cardiac surgery, urgent/emergent status, tricuspid regurgitation, and center. The final models were built using a backward stepwise selection method. To evaluate potential overfitting, internal validation was performed using a bootstrap approach, which showed no substantial

TABLE 1. Demographic data

Characteristic	Single cross-clamping group (N = 4449)	Second cross-clamping group (N = 128)	*P* value
Age, y, median (IQR)	62 (53-71)	59 (51.25-66)	.01
Male sex, n (%)	3005 (67.7)	90 (70.3)	.5
NYHA class III-IV, n (%)	1801 (41)	41 (32.8)	.08
Hypertension, n (%)	2230 (53.9)	65 (54.6)	.9
Diabetes, n (%)	241 (5.4)	6 (4.7)	1
Obesity (BMI >30), n (%)	492 (11.3)	19 (15.3)	.2
Atrial fibrillation, n (%)	1154 (27.7)	28 (22.8)	.3
Chronic lung disease, n (%)	271 (6.1)	6 (4.7)	.7
Pacemaker, n (%)	62 (1.4)	1 (0.8)	.8
eGFR, mL/min/1.73 m^2, median (IQR)	85.3 (66.3-106.5)	92.9 (74.7-109.4)	.03
Dialysis, n (%)	18 (0.4)	—	1
Cerebrovascular arteriopathy, n (%)	56 (1.3)	3 (2.4)	.2
Peripheral arteriopathy, n (%)	68 (1.5)	1 (0.8)	1
Previous cardiac surgery, n (%)	74 (1.7)	3 (2.3)	.5
Degenerative MR type, n (%)			.3
FED	1434 (45.9)	38 (50)	
Barlow	831 (26.6)	22 (28.9)	
Forme fruste	858 (27.4)	16 (21)	
Prolapse, n (%)			<.001
PML	2988 (71.6)	60 (50.8)	
AML	394 (9.4)	19 (16.1)	
Bileaflet	790 (18.9)	39 (33.1)	
Commissural prolapse, n (%)	219 (5.4)	14 (11.8)	.007
Annulus dilatation, n (%)	2573 (64.3)	68 (53.8)	.05
Increased risk for SAM, n (%)	288 (15.7)	15 (39.5)	<.001
Pulmonary hypertension, n (%)	1685 (39.3)	52 (41.3)	.6
Tricuspid regurgitation, n (%)			.6
No	2292 (52)	61 (47.7)	
Mild	1230 (27.9)	41 (32)	
Moderate	771 (17.5)	24 (18.8)	
Severe	115 (2.6)	2 (1.6)	
Reduced LVEF (<50%), n (%)	481 (10.9)	10 (7.8)	.3
Urgency, n (%)	162 (3.6)	4 (3.1)	1
Euroscore II, %, median (IQR)	1.01 (0.71-1.75)	0.92 (0.69-1.51)	.2

IQR, Interquartile range; *NYHA*, New York Heart Association; *BMI*, body mass index; *eGFR*, estimated glomerular filtration rate; *MR*, mitral regurgitation; *FED*, fibroelastic deficiency; *PML*, posterior mitral leaflet; *AML*, anterior mitral leaflet; *SAM*, systolic anterior motion; *LVEF*, left ventricular ejection fraction.

TABLE 2. Operative data

Characteristic	Single cross-clamping (N = 4449)	Second cross-clamping (N = 128)	*P* value
Surgical approach, n (%)			.006
Direct vision	1071 (24.1)	23 (18.1)	
Video-assisted	1652 (37.2)	66 (52)	
Totally endoscopic	1676 (37.7)	38 (29.9)	
Robotic	47 (1.1)	-	
Aortic cross-clamp type, n (%)			.007
External clamp	3835 (86.5)	116 (92.1)	
Endoclamp	599 (13.5)	10 (7.9)	
Mitral valve repair, n (%)	4419 (99.3)	104 (81.3)	<.001
Mitral valve replacement due to unsuccessful repair, n (%)	30 (0.7)	24 (18.7)	<.001
Repair techniques, n (%)			
Resection	731 (16.7)	24 (19.4)	.02
Artificial chords	3321 (75.3)	84 (67.2)	.003
Sliding	117 (2.7)	8 (6.4)	.03
Edge to edge	111 (2.5)	12 (9.7)	<.001
Concomitant procedure, n (%)			
Tricuspid surgery	492 (11.1)	13 (10.2)	.9
AF surgery	656 (14.7)	16 (12.5)	.5
Intraoperative SAM, n (%)	24 (0.5)	36 (28.1)	<.001
CPB time, min, median (IQR)	136 (108-174)	203 (149.5-267.25)	<.001
Cross-clamp time, min, median (IQR)	86 (64-111)	125 (93-167)	<.001

AF, Atrial fibrillation; *SAM*, systolic anterior motion; *CPB*, cardiopulmonary bypass; *IQR*, interquartile range.

overfitting. Results are presented as adjusted odds ratio (OR) with 95% confidence interval (CI). Multicollinearity was assessed using the variance inflation factor. A significance level of $\alpha < .05$ was considered. Statistical analyses were conducted using SPSS Statistics version 29.0 (IBM).

RESULTS

Baseline Characteristics and Procedural Outcomes

A total of 4577 consecutive patients with degenerative MR who underwent mitral valve repair between 2015 and 2023 were analyzed (Figure E1). A second cross-clamping was required in 128 cases (2.8%). The demographics of the single cross-clamping and the second cross-clamping groups are presented in Table 1. The risk profile was similar in the 2 groups (EuroSCORE II: 0.92% vs 1.01%; $P = .2$), except that patients requiring a second cross-clamping were younger. Anterior prolapse (16.1% vs 9.4%), bileaflet prolapse (33.1% vs 18.9%), and commissural lesions (11.8% vs 5.4%) were more common in the second cross-clamping group. An increased risk of SAM—defined preoperatively by at least 1 of the following criteria: end-diastolic diameter <45 mm, aorto-mitral angle <120°, coaptation-septum distance <25 mm, PML >15 mm, AML/PML <1.5 cm, basal septal diameter >15 mm, or A2 height differential >5 mm—was seen more frequently in the second cross-clamping group (39.5% vs 15.7%). Among patients identified as being at increased preoperative risk of SAM, 76.5% underwent an exclusive neochordal repair, 7.3% received a resectional strategy alone, and 3% underwent a combined approach. The others were treated with isolated annuloplasty or edge-to-edge techniques.

The cause of re-cross-clamping was residual pathology in 92 patients (71.9%) and SAM in 36 patients (28.1%). After the second cross-clamping, re-repair was performed in 104 patients (81.3%), while valve replacement was required in 24 patients (18.8%). Procedural details are outlined in Table 2. On multivariable analysis, independent predictors of a second cross-clamping were bileaflet prolapse (OR, 2.21; 95% CI, 1.03-4.73) and a predicted increased risk of SAM (OR, 3.04; 95% CI, 1.43-6.44) (Figure 1). Among patients with bileaflet prolapse who required a second cross-clamping, residual pathology was the most common cause (69.2%; n = 27), followed by SAM (30.8%; n = 12). Among patients with a predicted increased risk of SAM, 3.6% (n = 11) underwent a second cross-clamping because of intraoperative SAM. Of these, 10 were successfully treated with re-repair (edge-to-edge in 6 and neochordae in 4), and 1 ultimately required valve replacement.

In-Hospital Results

In-hospital outcomes are presented in Table 3. Overall mortality and stroke rates were 0.9% and 0.8%, respectively, with no significant differences between patients

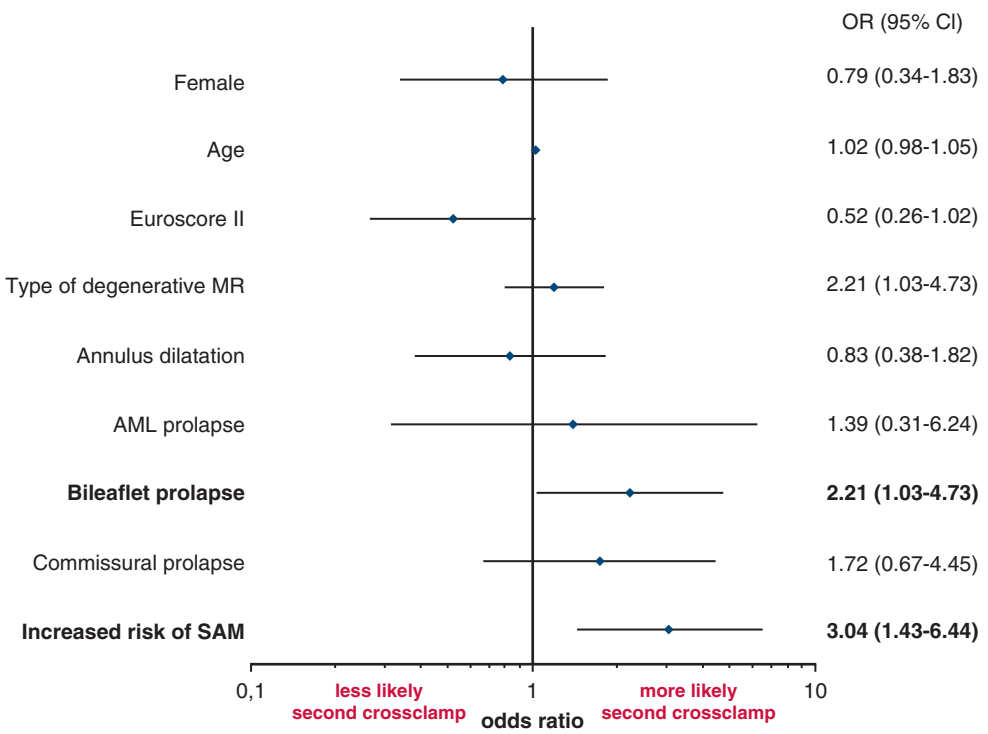

FIGURE 1. Predictors of second cross-clamping.

who required a second cross-clamping and those who did not. Second cross-clamping was more frequently associated with impaired postoperative pulmonary function. Among patients who underwent re-repair after a second cross-clamping, 68 (70.1%) had no residual MR, 24 (24.7%) had mild MR, 4 (4.1%) had moderate MR, and 1 (1%) had severe MR. Residual SAM was observed in 2 cases (2.3%). Two of these patients underwent reoperation during their index hospitalization.

After adjusting for potential confounders, no association was found between second cross-clamping and mortality or major postoperative complications. However, a second cross-clamping was significantly associated with an increased risk of respiratory insufficiency (OR, 4.61; 95% CI, 2.87-7.39) and a longer ICU stay (standardized $\beta = 0.35$; 95% CI, 0.021-0.058) (Table 4).

DISCUSSION

An optimal mitral valve repair outcome, defined by the absence of significant residual MR, is a well-established determinant of long-term surgical success.[3-6] In this context, while many surgeons advocate for intraoperative optimization of the repair result, even at the cost of prolonged cross-clamping time or a second cross-clamping,[12-15] the clinical implications of a second cross-clamping remain poorly defined, particularly in the setting of minimally invasive mitral surgery. This study provides critical insights into the predictors, safety, and outcomes of a second cross-clamping in patients undergoing less invasive mitral valve repair for degenerative MR. Our findings indicate that the need for a second cross-clamping is rare (2.8%) in mini mitral procedures performed at referral centers. This compares favorably with rates reported for full sternotomy approaches[12-15] and counters concerns that minimally invasive techniques might compromise the effectiveness or reproducibility of valve repair.

The reasons for needing a second cross-clamping were residual prolapse in 71.9% of the patients and SAM in 28.1%. Successful re-repair was achieved in the majority of patients (81.1%). Compared with the single cross-clamping cases, re-repairs more often required leaflet resection and edge-to-edge repair. The latter has been confirmed as a reliable bailout strategy, especially when the mechanism of MR is uncertain or cannot be adequately addressed with other techniques.[13] Valve re-repair was highly effective, with 95% of patients showing none or mild residual MR postoperatively. However, a second cross-clamping was associated with a higher incidence of moderate to severe MR (5.1% vs 1.7%), primarily due to persistent SAM (4.6%). This trade-off should be carefully considered during intraoperative decision making, with valve replacement remaining a reasonable option in selected cases to avoid suboptimal outcomes.

Predictors of the need for a second cross-clamping have been little investigated to date. De Bonis and colleagues identified bileaflet prolapse and the type of surgical tech-

TABLE 3. In-hospital results

Characteristics	Single cross-clamping (n = 4449), n (%)	Second cross-clamping (n = 128), n (%)	Absolute risk difference	*P* value
In-hospital mortality, n (%)	37 (0.8)	2 (1.6)	0.8	.3
Cardiovascular	15 (0.3)	2 (1.6)	1.3	
Noncardiovascular	19 (0.5)	-	−0.5	
Stroke, n (%)	36 (0.8)	2 (1.6)	0.8	.3
Delirium, n (%)	209 (5)	5 (4.1)	−0.9	.8
Intubation time, h, median (IQR)	7 (5-11.17)	10 (6-17.05)		<.001
Respiratory insufficiency, n (%)	302 (7.5)	26 (22.4)	14.9	<.001
Bleeding (requiring revision), n (%)	203 (4.6)	4 (3.2)	−1.4	.7
New-onset AF, n (%)	859 (20.7)	24 (19.7)	−1	.9
Definitive pacemaker, n (%)	63 (1.4)	1 (0.8)	−0.6	1
Myocardial infarction, n (%)				1
Periprocedural (≤48 h)	35 (0.8)	1 (0.8)	-	
Spontaneous (>48 h)	3 (0.1)	-	−0.1	
Low cardiac output, n (%)	113 (2.6)	5 (4)	1.4	.3
Acute kidney injury, n (%)	206 (5)	6 (4.9)	−0.1	1
Dialysis, n (%)	31 (0.7)	1 (0.8)	0.1	.6
Transfusions, units, median (IQR)	0 (0-0)	0 (0-2)		<.001
Vascular complications, n (%)				.8
Major	54 (1.3)	2 (1.6)	0.3	
Minor	20 (0.5)	1 (0.8)	0.3	
Wound complications, n (%)				
Thoracic	53 (1.2)	2 (1.6)	0.4	.7
Groin	96 (2.2)	3 (2.4)	0.2	1
Residual MR (after repair), n (%)				.006
None/trivial	3305 (81.7)	68 (70.2)	−11.5	
Mild	671 (16.6)	24 (24.7)	8.1	
Moderate	60 (1.5)	4 (4.1)	2.6	
Severe	8 (0.2)	1 (1)	0.8	
Postoperative SAM, n (%)	30 (0.8)	4 (4.6)	3.8	<.001
Redo for early failure, n (%)	28 (0.6)	2 (1.6)	1	.2
ICU stay, h, median (IQR)	21 (19-40)	24 (18-48)		.03
Hospital stay, d, median (IQR)	7 (6-10)	7 (6-11)		.1
Discharge destination, n (%)				.1
Home	1640 (39.9)	38 (31.1)	−8.8	
Cardiology/rehab	2468 (60.1)	84 (68.9)	8.8	

IQR, Interquartile range; *AF*, atrial fibrillation; *SAM*, systolic anterior motion; *ICU*, intensive care unit.

nique (with edge-to-edge repair emerging as protective) as key predictors of the need for a second cross-clamping.[13] Our data confirm that bileaflet pathology is an independent predictor (OR, 2.21), although, as reported previously,[16] this did not increase the risk of unsuccessful repair. Furthermore, a predicted high risk of SAM was associated with a threefold increase in the likelihood of requiring a second cross-clamping. In most cases, intraoperative SAM was successfully corrected through re-repair, except in 1 patient who underwent valve replacement. Thus, anticipating SAM during the initial repair strategy is crucial to minimize the need for a second cross-clamping and optimize the surgical outcome.

Despite longer cardiopulmonary bypass and myocardial ischemia times, a second cross-clamp can be safely applied to improve repair rates and minimize unnecessary valve replacements. Patients who received a second cross-clamp had similar low mortality and major complication rates to those undergoing a single cross-clamping. While longer cross-clamping times were associated with worse

TABLE 4. Multivariable associations between second cross-clamping and operative outcomes

Outcome	OR/β	95% CI	*P* value
In-hospital mortality	2.547	0.323-20.074	.4
Stroke	2.832	0.655-12.245	.2
Low cardiac output	2.133	0.839-5.419	.1
Dialysis	1.238	0.159-9.634	.8
Respiratory insufficiency	4.609	2.872-7.397	<.001
ICU stay (h)	0.035	0.021-0.058	.02
Hospital stay (d)	0.008	−0.285 to 0.306	.6

OR, Odds ratio; *CI*, confidence interval; *ICU*, intensive care unit.

outcomes,[7] our findings suggest that patients undergoing less invasive mitral valve repair for degenerative disease, who are generally younger and healthier, can tolerate a longer cross-clamping time without significant clinical implications. In this scenario, a second cross-clamping should be viewed as a deliberate surgical step aimed at ensuring optimal valve competence rather than as a failure. It should be noted, however, that second cross-clamping was performed more frequently in younger patients, which may partially reflect a selection bias toward individuals perceived as better able to tolerate additional ischemic time. This should be taken into account when interpreting the overall safety profile of this strategy. Nonetheless, even in this low-risk cohort, second cross-clamping was associated with an increased risk of respiratory insufficiency (OR, 4.61) and longer ICU stay (standardized $\beta = 0.35$). This may reflect the cumulative burden of prolonged CPB and mechanical ventilation, increased perioperative fluid administration, and greater systemic inflammation. Thus, the use of lung-protective ventilation strategies, goal-directed fluid management, and minimizing cross-clamping time may help limit the clinical impact of these factors. These risks should be carefully considered in elderly or high-risk patients, in whom the potential benefits of repair must be weighed against the added morbidity of a second cross-clamping. We believe the results of the present study can help implement risk-adapted surgical algorithms[14] in less invasive surgery, which may aid in identifying patients who are more likely to benefit from a repair attempt, taking into account the potential need for a second cross-clamping, as opposed to those for whom alternative strategies, including valve replacement, may be more appropriate.

Limitations

This study has the limitations of any observational registry involving no adjudication of patient inclusion and data collection. The retrospective design of the MMIR introduces the potential for selection bias and unmeasured confounding factors, despite efforts to adjust for known confounders. The participating centers are tertiary referral centers, and our findings might not reflect management or represent patients treated and followed at community hospitals. Data on individual surgeon volume were not available within the registry and could not be included in the analysis. As such, unmeasured operator-related factors may have influenced the decision to re-clamp and could not be fully accounted for. Finally, the study did not include long-term

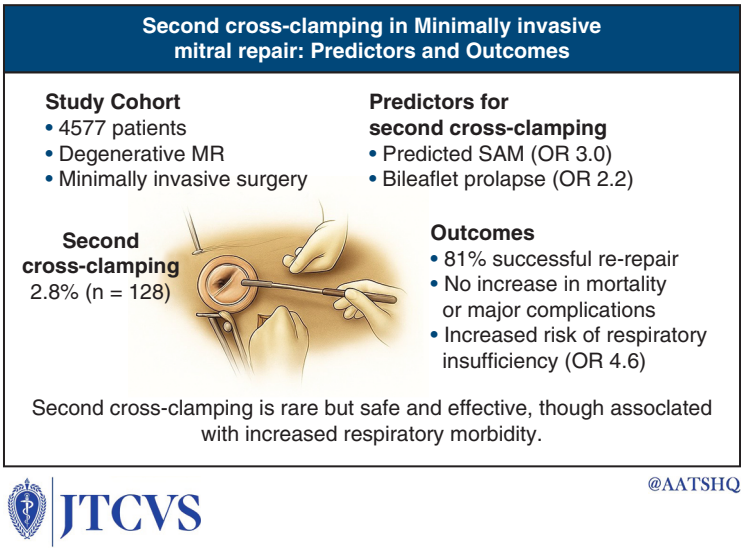

FIGURE 2. Graphical abstract.

follow-up data on the durability of repairs or outcomes related to late complications, which should be addressed in future prospective investigations.

CONCLUSIONS

Second cross-clamping after less invasive mitral valve repair is rare at expert centers but more common in patients with bileaflet pathology or predicted risk of SAM (Figure 2). Most re-repairs were successful, with minimal need for valve replacement. Although second cross-clamping does not increase mortality or major complications, it is associated with a higher risk of respiratory insufficiency and prolonged ICU stay. Therefore, it remains crucial to consider the trade-off between minimizing cross-clamping time and achieving the best possible valve repair outcome to enhance both short-term and long-term results.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/second-crossclamp-in-less-inva-9721.

Audio

Audio Recording: You can listen to the audio recording of the presentation and discussion associated with this paper: https://doi.org/10.1016/j.jtcvs.2025.07.031.

Conflict of Interest Statement

Dr Bonaros reported speaker's honoraria from Edwards Lifesciences and Medtronic, institutional grants from Edwards Lifesciences and Corcym, and travel grants from Abbott, Medtronic, and Edwards Lifesciences. Dr Kempfert reported speaker's honoraria from Edwards Lifesciences, Medtronic, Artivion, and Abbott. Dr Pitsis reported speaker's honoraria from Medtronic, Edwards Lifesciences, and Delacroix Chevalier. Dr Gollmann-Tepeköylü reported speaker's honoraria from Edwards Lifesciences. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: Mini Mitral International Registry (MMIR), minimally invasive mitral valve repair, minimally invasive mitral valve surgery, second cross-clamping

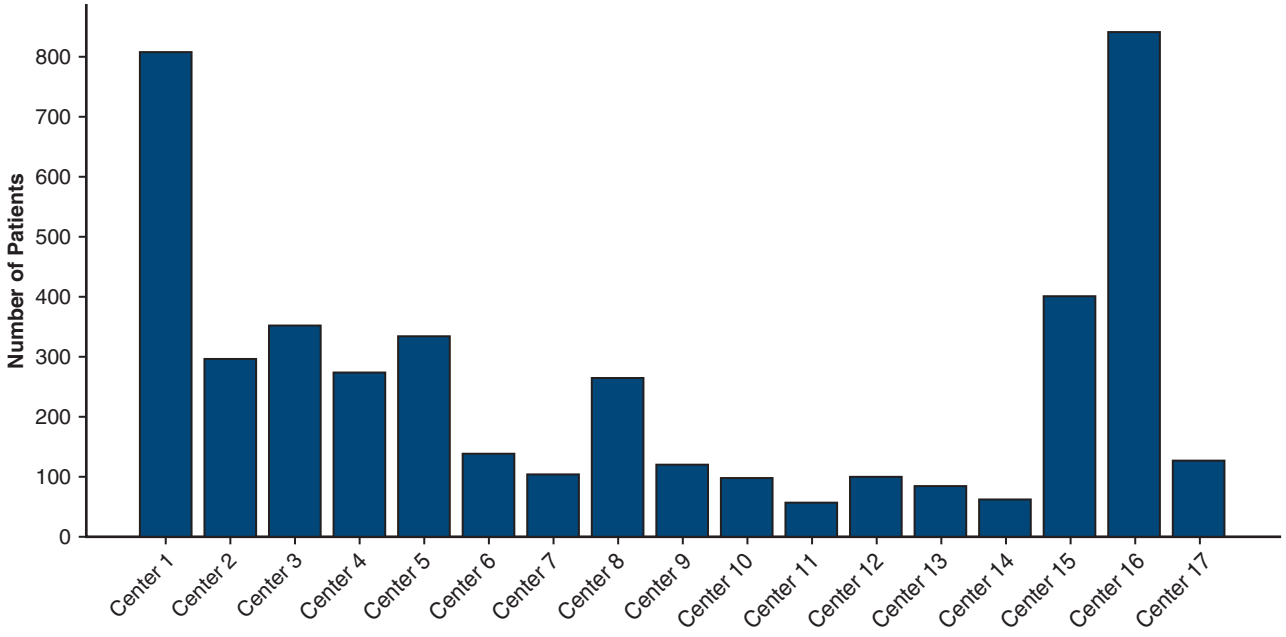

FIGURE E1. Case volumes across participating centers.

TABLE E1. Missing data per variable

Variable	Missing, %
Age	0
Male sex	0.2
NYHA class	1.3
Hypertension	7
Diabetes	0
Obesity (BMI >30)	2.2
Atrial fibrillation	6.3
Chronic lung disease	0.1
Pacemaker	0.5
eGFR	2.1
Dialysis	2.8
Cerebrovascular arteriopathy	3.1
Peripheral arteriopathy	0.1
Previous cardiac surgery	2.1
Prolapse	6.2
Commissural prolapse	8.8
Annulus dilatation	9.8
Pulmonary hypertension	3.6
Tricuspid regurgitation	0.9
Reduced LVEF (<50%)	0.8
Urgency	0
Euroscore II	4.6
Surgical approach	0
Aortic cross-clamp type	0.4
Mitral valve repair	0
Repair technique	
Resection	1.4
Artificial chords	1
Sliding	2
Edge to edge	2
Concomitant tricuspid surgery	0
Concomitant atrial fibrillation surgery	0
Intraoperative SAM	0
CPB time	1.8
Cross-clamp time	0.7
Cross-clamp time	0.0
In-hospital mortality	0.3
Stroke	0.3
Delirium	6.1
Intubation time	3.4
Respiratory insufficiency	9.3
Bleeding (requiring revision)	0.3
New-onset AF	6.6
Definitive pacemaker	0.3
Myocardial infarction	0.2
Low cardiac output	
Acute kidney injury	6.8
Dialysis	6.2
Transfusion units	12.3
Vascular complications	3.1
Wound complications	1.4
Residual MR	8.4
Postoperative SAM	12.4
Redo for early failure	1.5
ICU stay	4.3
Hospital stay	0.5
Discharge destination	7.6

NYHA, New York Heart Association; *BMI*, body mass index; *eGFR*, estimated glomerular filtration rate; *LVEF*, left ventricular ejection fraction; *SAM*, systolic anterior motion; *CPB*, cardiopulmonary bypass; *AF*, arterial fibrillation; *MR*, mitral regurgitation; *ICU*, intensive care unit.