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ORIGINAL RESEARCH

STRUCTURAL

Surgical Mitral Valve Repair vs Replacement After Failed Mitral Transcatheter Edge-to-Edge Repair

The CUTTING-EDGE Registry

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ABSTRACT

BACKGROUND The impact of mitral valve (MV) surgery type after failed mitral transcatheter edge-to-edge repair (M-TEER) has not been well studied.

OBJECTIVES The aim of this study was to compare the outcomes of MV repair vs replacement after failed M-TEER.

METHODS From 2009 to 2020, a total of 332 patients across 34 centers from the CUTTING-EDGE registry underwent MV surgery after M-TEER. Outcomes were compared between MV repair and replacement. Primary outcomes included 30-day mortality and 1-year survival after MV surgery.

RESULTS Among enrolled patients (mean age 73.8 ± 10.1 years, median Society of Thoracic Surgeons Predicted Risk of Mortality 3.9% [Q1-Q3: 2.2%-6.8%]), 25 (7.5%) underwent repair and 307 (92.5%) underwent replacement. The replacement group had a significantly higher rate of comorbidities, including atrial fibrillation, prior cardiac surgery, more secondary mitral regurgitation, and more devices implanted at index M-TEER ($P < 0.05$ for all). Replacement patients showed a trend toward higher 30-day mortality (17.7% [52 of 294] vs 4.0% [1 of 25]; $P = 0.094$). The observed-to-expected ratio of 30-day mortality was 3.6 (95% CI: 1.9-5.3) overall, 3.8 (95% CI: 2.1-5.5) in the replacement group, and 1.7 (95% CI: 0.7-3.3) in the repair group. Replacement patients had higher 1-year mortality (33.3% [65 of 195] vs 10.5% [2 of 19]; $P = 0.041$). Significantly lower survival rates were observed after replacement at 2 years ($P = 0.033$) and persisted in the risk-adjusted Cox regression analysis (HR for replacement: 4.24; 95% CI: 1.04-17.31; $P = 0.044$).

CONCLUSIONS MV surgery after failed M-TEER is a high-risk procedure associated with higher than expected 30-day mortality, with higher mortality associated with MV replacement. Compared with repair, replacement is associated with higher 1-year mortality and a lower 2-year survival. (JACC Cardiovasc Interv. 2025;18:912-923) © 2025 by the American College of Cardiology Foundation.

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Mitral transcatheter edge-to-edge repair (M-TEER) is widely adopted, with more than 200,000 procedures performed worldwide and more than 10,000 performed annually in the United States.[1] Current guidelines state that M-TEER should be considered in patients with severe secondary mitral regurgitation (MR) with symptoms despite optimal guideline-directed medical therapy and meeting criteria from the COAPT (Cardiovascular Outcomes Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients With Functional Mitral Regurgitation) study (Class 2a).[2,3] In addition, M-TEER is an option for patients with primary MR who are at high or prohibitive surgical risk and have suitable anatomy for transcatheter edge-to-edge repair (TEER) (Class 2a in American guidelines and Class 2b in European guidelines).[2,3] Procedural success rates range from 68% to 89% at 30 days, with increasing success in recent years.[4,5] Parallel to the increase in M-TEER procedures, the number of patients requiring mitral valve (MV) surgery because of failed M-TEER has increased in recent years.[6] Although more patients are undergoing MV surgery after M-TEER, data on outcomes and best treatment strategies are limited to small single-center analyses.[6-9] Data on the impact of the type of MV surgery (ie, repair vs replacement) on patient outcomes are particularly limited. The CUTTING-EDGE registry is a multicenter, international registry of patients who underwent MV surgery after failed M-TEER. The aim of the present study was to compare the outcomes of patients undergoing MV repair or replacement after failed TEER on the basis of the data from the CUTTING-EDGE registry.

METHODS

DATA COLLECTION. From July 2009 to July 2020, a total of 332 patients across 34 international centers who underwent MV surgery after M-TEER were included in the CUTTING-EDGE registry. Anonymized patient data were obtained from each center, including clinical characteristics, echocardiographic data, timing and indication for MV surgery, and postoperative outcomes. All centers received local Institutional Review Board approval, with the requirement to obtain patient consent waived. Follow-up was performed by each participating institution. Follow-up was conducted by phone communication with patients, close family members, and/or treating general practitioners or cardiologists in the outpatient setting. The median follow-up duration was 9.1 months (Q1-Q3: 1.1-25.8 months) after MV surgery, and follow-up was 96.1% complete at 30 days and 81.1% complete at 1 year.

ABBREVIATIONS AND ACRONYMS

MR = mitral regurgitation

MV = mitral valve

M-TEER = mitral transcatheter edge-to-edge repair

O/E = observed-to-expected

STS-PROM = Society of Thoracic Surgeons Predicted Risk of Mortality

TEER = transcatheter edge-to-edge repair

TR = tricuspid regurgitation

TV = tricuspid valve

PATIENT SELECTION. All adult patients who underwent MV surgery after M-TEER during the study period were included. The M-TEER devices used are summarized in Supplemental Table 1. Indications for surgery included residual or recurrent significant MR, significant mitral stenosis, leaflet injury, endocarditis, device detachment, and inability to place a device or device embolization. The definitions of these indications have been previously reported.[10] The scenarios of M-TEER failure leading to MV surgery further were classified as follows: 1) aborted M-TEER (the M-TEER procedure was attempted but was unsuccessful, leading to MV surgery in the same or different hospital admission); 2) acute MV surgery (MV surgery after M-TEER was performed in the same index admission); and 3) delayed MV surgery (MV surgery after M-TEER was performed in a separate admission).

After reviewing preoperative imaging and clinical findings, the local multidisciplinary heart team evaluated each patient's surgical indication and the cause of M-TEER failure. The primary surgeon made the decision to proceed with MV repair or replacement, considering the patient's clinical status, the mode of M-TEER failure, the surgeon's expertise, and the technical complexity of the procedure, aiming for the best possible outcomes. To assess surgical risk, the Society of Thoracic Surgeons Predicted Risk of

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This study was presented as a late-breaking clinical presentation at the Transcatheter Valve Therapies annual meeting in June 2023.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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Mortality (STS-PROM) and the European System for Cardiac Operative Risk Evaluation II score were calculated for each patient.

OUTCOMES OF INTEREST AND DEFINITIONS. Patients were stratified by type of MV surgery, either repair or replacement. Primary outcomes of interest included in-hospital and 30-day mortality and 1-year and 2-year survival after MV surgery. Secondary outcomes were median interval from M-TEER to MV surgery, major in-hospital complications (new-onset atrial fibrillation, pacemaker implantation, stroke, vascular complications, major bleeding, or life-threatening bleeding), intensive care unit stay, hospital length of stay, and 30-day stroke and readmission rates. All clinical endpoints were reported according to the Mitral Valve Academic Research Consortium definitions.[11,12] Mitral Valve Academic Research Consortium outcomes at 30 days and 1 year were compared between MV repair and replacement.

Emergency MV surgery was defined as surgery performed within 6 hours of diagnosis during the same hospital admission, while surgery performed beyond 6 hours after diagnosis within the same admission was classified as urgent, as described previously.[10,13,14] The time interval from the index M-TEER procedure to the MV operation was calculated in months. Survival time was measured in months from the date of MV surgery to the date of mortality or the last follow-up if the patient was still alive.

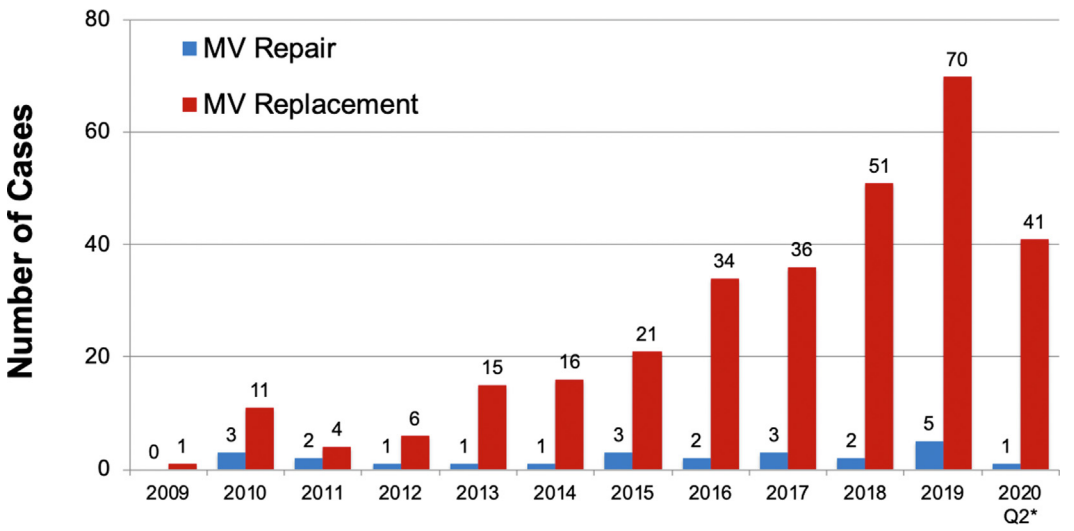
STATISTICAL ANALYSIS. Baseline demographic, clinical, procedural, and echocardiographic characteristics were collected for all patients before the M-TEER procedure and subsequent MV surgery and compared between the MV repair and replacement groups. Depending on the data distribution, continuous variables are reported as mean ± SD or median (Q1-Q3), whereas categorical variables are reported as frequencies and proportions. The observed-to-expected (O/E) ratio for 30-day mortality was calculated as the ratio of the observed 30-day mortality to the median STS-PROM score at the time of MV surgery. Differences between the 2 groups were detected using Student's 2-sample *t*-test or the Mann-Whitney *U* test for continuous variables and the chi-square or Fisher exact test for categorical variables.

Kaplan-Meier survival analysis was used to assess actuarial all-cause mortality separately for the overall paired cohort and stratified by type of surgery (repair vs replacement). Multivariable Cox regression analysis was performed to examine the impact of the type of surgery (repair vs replacement) on all-cause mortality, adjusting for baseline differences between groups in addition to clinically relevant variables chosen a priori and deemed to influence the outcomes of interest, including age, atrial fibrillation, prior cardiac surgery, MR etiology, mechanism of TEER failure, and timing of surgery. Because model building was limited by the relative number of mortality events, forward, stepwise, multivariable Cox regression models were developed. Additional unadjusted and minimally adjusted Cox regression analyses on all-cause mortality using a set of prespecified relevant baseline confounders deemed clinically relevant (age, atrial fibrillation, prior cardiac surgery and MR etiology) was performed. Proportional hazards assumptions were verified using Schoenfeld residuals. Logistic regression analysis was used to identify factors associated with MV repair vs replacement after M-TEER. A 2-sided P value <0.05 was considered to indicate statistical significance, and all statistical analyses were performed using SPSS version 24.0 (IBM).

RESULTS

BASELINE AND PROCEDURAL CHARACTERISTICS AT INDEX M-TEER. A total of 332 patients underwent MV surgery after M-TEER among, of whom 155 (47%) had primary MR and 175 (53%) had secondary MR (2 patients did not have MR etiology reported in the in the retrospective CUTTING-EDGE database). A total of 25 patients (7.5%) underwent MV repair, and the remaining 307 (92.5%) underwent replacement. Repair rates were constantly low throughout the study period despite an overall increase in procedures after M-TEER (**Figure 1**). Baseline characteristics are summarized in Supplemental Table 1. The mean age was 73.8 ± 10.1 years, median overall STS-PROM risk at initial M-TEER was 3.9% (Q1-Q3: 2.2%-6.8%), and median European System for Cardiac Operative Risk Evaluation II score was 4.6% (Q1-Q3: 2.7%-7.5%), with 88 patients (26.5%) having undergone prior cardiac surgery (repair, n = 2 [8.0%]; replacement, n = 86 [28.0%]; $P = 0.03$). The replacement group had more comorbidities, such as atrial fibrillation and prior cardiac surgery. The etiology of MR was significantly different between groups ($P = 0.048$), with primary MR being predominant in the repair group (70.8% vs 42.5%) and secondary MR in the replacement group. More M-TEER devices were implanted in the replacement group (1.7 ± 0.8 vs 1.2 ± 0.6; $P = 0.002$). There were no differences in the generation or type of device used or the site of implantation. Procedural details of the M-TEER procedure are also depicted in Supplemental Table 1. The echocardiographic characteristics at the time of M-TEER are presented in Supplemental Table 2.

FIGURE 1 Temporal Trends in Annual Mitral Valve Surgery by Type of Surgery



Trends in the annual number of mitral valve (MV) procedures between 2009 and 2020 stratified by MV repair and replacement among all patients in the CUTTING-EDGE registry. *The study period ended in the second quarter of 2020.

CHARACTERISTICS AT THE TIME OF MV SURGERY. Preoperative echocardiographic characteristics at the time of MV surgery are shown in Table 1. Preoperative echocardiography revealed moderate to severe and severe MR in 32.6% (103 of 332) and 57.3% (181 of 332) of patients, respectively, while 55.3% of patients (172 of 332) had concomitant moderate or greater tricuspid regurgitation (TR) and 21.8% (57 of 332) had at least moderate right ventricular dysfunction. There were no differences between the 2 groups with regard to MR severity (Figure 2), TR severity, or right ventricular dysfunction before M-TEER, after M-TEER, and before surgery. The median interval between M-TEER and MV surgery was 3.5 months (Q1-Q3: 0.5-11.9 months) (Figures 3A and 3B), with no significant differences between surgical groups ($P = 0.41$). There were also no differences in procedural characteristics at MV surgery between the 2 groups (Table 2), with the exception of fewer elective procedures in the replacement group (198 [64.5%] vs 21 [84.0%]; $P = 0.05$). The predominant reason for M-TEER failure was recurrent (111 of 332 [33.5%]) and residual (95 of 332 [28.7%]) MR. The intraoperative echocardiographic characteristics during MV surgery are summarized in Supplemental Table 3. More specific details among patients who underwent MV repair are summarized in Supplemental Table 4.

EARLY AND MID-TERM OUTCOMES. In-hospital and short-term outcomes after MV surgery are depicted in Table 3. In-hospital and 30-day mortality rates were 15.1% (50 of 332) and 16.6% (53 of 332), respectively,

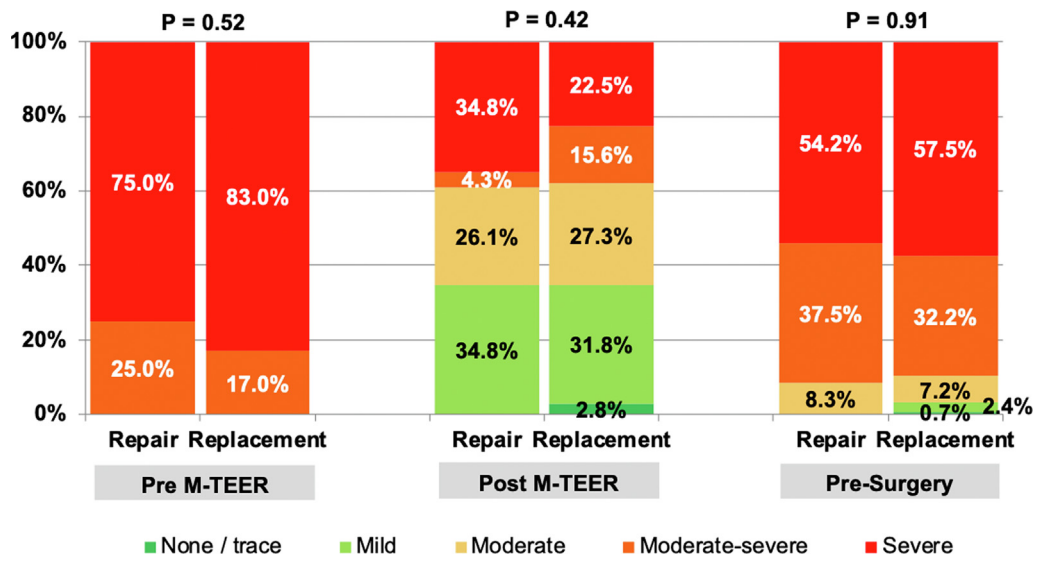
TABLE 1 Preoperative Echocardiographic Characteristics at MV Surgery

	Overall (N = 332)	MV Repair (n = 25)	MV Replacement (n = 307)	*P* Value
Imaging type				0.83
TTE	163 (52.1)	11 (47.8)	152 (52.4)	
TEE	150 (47.9)	12 (52.2)	138 (47.6)	
MR severity				0.91
None	2 (0.6)	0 (0)	2 (0.7)	
Mild	7 (2.2)	0 (0)	7 (2.4)	
Moderate	23 (7.3)	2 (8.3)	21 (7.2)	
Moderate to severe	103 (32.6)	9 (37.5)	94 (32.2)	
Severe	181 (57.3)	13 (54.2)	168 (57.5)	
TR severity				0.84
None	36 (11.6)	3 (12.5)	33 (11.5)	
Mild	103 (33.1)	9 (37.5)	94 (32.8)	
Moderate	94 (30.2)	6 (25.0)	88 (30.7)	
Moderate to severe	50 (16.1)	5 (20.8)	45 (15.7)	
Severe	28 (9.0)	1 (4.2)	27 (9.4)	
RV dysfunction severity				0.40
None	136 (52.1)	9 (52.9)	127 (52)	
Mild	68 (26.1)	5 (29.4)	63 (25.8)	
Moderate	39 (14.9)	1 (5.9)	38 (15.6)	
Moderate to severe	11 (4.2)	2 (11.8)	9 (3.7)	
Severe	7 (2.7)	0 (0)	7 (2.9)	
LVEF, %	47.9 ± 13.2	49.1 ± 10.7	47.8 ± 13.4	0.66
MV MG, mm^2	5.4 ± 3.5	4.3 ± 2.4	5.4 ± 3.5	0.24
MVA, cm^2	2.8 ± 1.3	3.8 ± 1.1	2.7 ± 1.3	0.034
RVSP, mm Hg	48.8 ± 15.6	45.2 ± 15.3	49.1 ± 15.6	0.40
ASD presurgery				0.18
Closed	99 (32.1)	9 (45.0)	90 (31.3)	
Open	176 (57.1)	11 (55.0)	165 (57.3)	
Did not assess	33 (10.7)	0 (0)	33 (11.5)	

Values are n (%) or mean ± SD.

ASD = atrial septal defect; LVEF = left ventricular ejection fraction; MG = mean gradient; MR = mitral regurgitation; MV = mitral valve; MVA = mitral valve area; RV = right ventricular; RVSP = right ventricular systolic pressure; TEE = transesophageal echocardiography; TR = tricuspid regurgitation; TTE = transthoracic echocardiography.

FIGURE 2 Distribution of Mitral Regurgitation Severity Before Mitral Valve Surgery



There were no differences in mitral regurgitation severity before mitral transcatheter edge-to-edge repair (M-TEER) ($P = 0.52$), after M-TEER ($P = 0.42$), and before surgery ($P = 0.91$) between the mitral valve repair and replacement groups.

with a trend toward higher in-hospital (16.0% [49 of 307] vs 4.0% [1 of 25]; $P = 0.15$) and 30-day (17.7% [52 of 307] vs 4.0% [1 of 25]; $P = 0.094$) mortality among MV replacement patients that did not reach statistical significance. The O/E ratio for 30-day mortality was 3.6 (95% CI: 1.9-5.3) in the overall cohort, 3.8 (95% CI: 2.1-5.5) in the replacement group, and 1.7 (95% CI: 0.7-3.3) in the repair group. Overall median length of hospital stay was 12.0 days (8.0-20.0 days); 44 patients (13.3%) developed new-onset atrial fibrillation, 31 (9.3%) patients required pacemakers, and 9 (2.7%) of patients experienced postoperative stroke. Prior to discharge, no patients had significant residual MR, and 9 patients (3.6%) had significant (moderate or greater) residual TR. Echocardiographic outcomes at predischarge and 30-day follow-up after MV surgery are summarized in Supplemental Table 5.

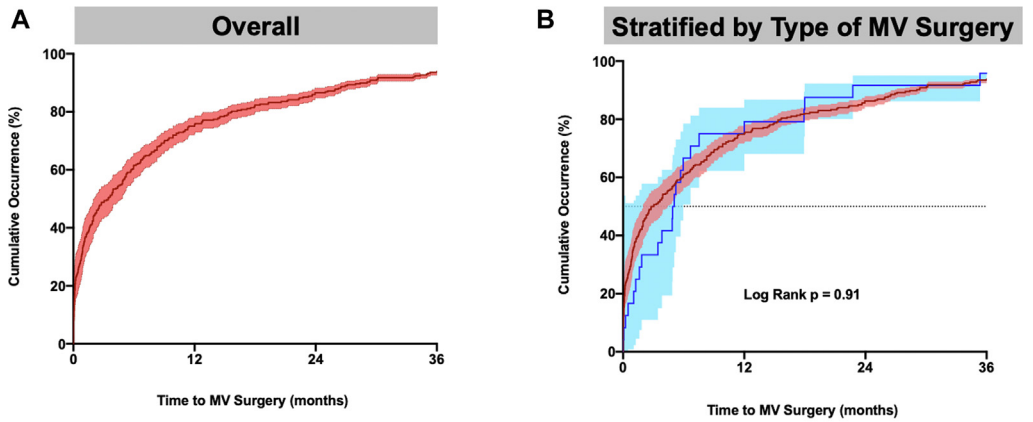
The trend toward higher 30-day mortality in patients who underwent MV replacement persisted at 1 year and was significantly higher compared with patients who underwent MV repair (33.3% [65 of 195] vs 10.5% [2 of 19]; $P = 0.04$). As shown in the Kaplan-Meier curves in the **Central Illustration**, actuarial estimates of survival were 75.9% at 1 year and 72.3% at 2 years, with significantly lower 2-year survival in the replacement group (70.4% vs 90.3%; log-rank $P = 0.03$), which persisted in the risk-adjusted Cox regression analysis (adjusted HR for MV replacement: 4.24; 95% CI: 1.04-17.31; $P = 0.044$). Additional unadjusted and minimally adjusted Cox regression analyses using a set of pre-specified relevant baseline confounders are reported in Supplemental Table 6.

Factors associated with MV repair (vs replacement) after M-TEER are depicted in **Figure 4**. MV repair was more likely to be performed in patients with lower surgical risk, fewer comorbidities (such as atrial fibrillation and prior cardiac surgery), and primary MR at index TEER, in addition to those with fewer devices implanted, lower postprocedural transmitral gradients, and higher MV areas. Lower surgical risk at MV surgery, along with elective surgery, and absence of concomitant tricuspid valve (TV) surgery also favored MV repair vs replacement after M-TEER.

DISCUSSION

In the present study we analyzed patients from the CUTTING-EDGE multicenter international registry

FIGURE 3 Timing of MV Surgery After M-TEER



	MV Repair	MV Replacement	p value
Median Interval (months)	5.0 (IQR: 1.5 – 8.6)	2.9 (IQR: 0.4 – 11.9)	0.41

Cumulative probability plot with 95% CI showing the timing of MV surgery after M-TEER in the CUTTING-EDGE registry (A) and stratified by type of MV surgery (B). The median interval from M-TEER to MV surgery was 3.5 months (Q1-Q3: 0.5-11.6 months) overall, with no significant differences between the surgical groups ($P = 0.41$). Abbreviations as in Figures 1 and 2.

undergoing MV repair or replacement after failed M-TEER and made several key findings (Central Illustration). First, the median interval between M-TEER and MV surgery was only 3.5 months, and 92.5% of patients underwent replacement. Second, there was a trend toward higher 30-day mortality in patients undergoing replacement that was significant at 1 year, although overall mortality was higher than the expected STS-PROM. Third, patients who underwent replacement had lower 2-year survival compared with those who underwent repair, which persisted after risk adjustment. Finally, a higher rate of successful MV repair after M-TEER was seen in patients with primary MR, fewer comorbidities, and fewer M-TEER devices implanted and in those undergoing elective surgery without concomitant TV surgery.

SURGICAL MANAGEMENT AFTER TEER FAILURE. There is currently no standard surgical strategy for patients undergoing MV surgery after failed M-TEER. In one of the first reports on this patient subset, Argenziano et al[9] analyzed 107 patients undergoing M-TEER in the EVEREST (Endovascular Valve Edge-to-Edge Repair Study) multicenter trial, of whom 32 (30%) required subsequent surgery after an attempted MitraClip (Abbott) procedure. The surgical MV repair rate was 62.5%. However, more recent studies have reported lower repair rates ranging from 0% to 11%.[6-8] Our findings align with these recent studies, showing that repair is only possible in a small fraction of patients after M-TEER. Mitral repair following M-TEER is complicated by endothelization and ingrowth of the device into the MV leaflet and subvalvular tissue (Figure 5). Histopathologic analyses suggest that the M-TEER devices are encapsulated with fibrous tissue, with a significant surrounding inflammatory reaction, fibrous tissue bridges, and partial fusion with the MV chordae.[15,16] These extensive histologic changes, and the M-TEER device ingrowth into the MV tissue complicates the removal of the device and oftentimes results in significant defects in the leaflet and subvalvular apparatus, particularly if larger or multiple devices are implanted during the index M-TEER procedure. MV replacement is frequently the only surgical option available and is associated with a relatively quick and predictable outcome, which is particularly desirable in a high-risk population such as our study cohort, with nearly one-half of patients deemed at high or extreme surgical risk at the time of the M-TEER. It is not surprising that patients undergoing successful

TABLE 2 Procedural Characteristics at MV Surgery

	Overall (N = 332)	MV Repair (n = 25)	MV Replacement (n = 307)	*P* Value
Scenario of M-TEER failure				0.48
Attempted M-TEER	70 (21.2)	6 (26.1)	64 (20.8)	0.60
Acute M-TEER	58 (17.6)	2 (8.7)	56 (18.2)	0.39
Delayed M-TEER	202 (61.2)	15 (65.2)	187 (60.9)	0.83
Mechanism of M-TEER failure				
Loss of leaflet insertion (SLDA)	83 (25.1)	5 (20.0)	78 (25.5)	0.64
Partial detachment	72 (21.8)	6 (24.0)	66 (21.6)	0.80
Clip embolization	7 (2.1)	1 (4.0)	6 (2)	0.43
Mitral stenosis	48 (14.5)	1 (4.0)	47 (15.4)	0.15
Residual MR	95 (28.7)	6 (24.0)	89 (29.1)	0.65
Recurrent MR	111 (33.5)	9 (36.0)	102 (33.3)	0.83
Others	44 (13.3)	4 (16.0)	40 (13.1)	0.76
Timing of surgery				
Elective	219 (66.0)	21 (84.0)	198 (64.5)	0.050
Urgent	80 (24.1)	3 (12.0)	77 (25.1)	0.22
Emergency	33 (9.9)	1 (4.0)	32 (10.4)	0.49
Concomitant TV repair or replacement	140 (42.2)	6 (24.0)	134 (43.6)	0.061
Surgical approach				
Sternotomy	225 (68.0)	14 (56.0)	211 (69.0)	0.19
Right thoracotomy	103 (31.1)	10 (40.0)	93 (30.4)	0.37
Cannulation				
Central	201 (60.5)	12 (48.0)	189 (61.6)	0.20
Femoral	123 (37)	12 (48.0)	111 (36.2)	0.28
Others	6 (1.8)	1 (4.0)	5 (1.6)	0.38
CPB time, min	124 (100-156)	128 (110-158)	124 (97-155)	0.25
Cross-clamp time, min	79 (60-101)	89 (78-102)	78 (60-101)	0.66
Use of IABP				0.38
No	298 (89.8)	25 (100)	273 (88.9)	
Preoperative	14 (4.2)	0 (0)	14 (4.6)	
Postoperative	11 (3.3)	0 (0)	11 (3.6)	
Pre- and postoperative	9 (2.7)	0 (0)	9 (2.9)	

Values are n (%) or median (Q1-Q3).

CPB = cardiopulmonary bypass; IABP = intra-aortic balloon pump; SLDA = single-leaflet device attachment; M-TEER = mitral transcatheter edge-to-edge repair; TV = tricuspid valve; other abbreviations as in Table 1.

MV repair in our study had lower surgical risk, fewer comorbidities, and a lower prevalence of urgent or emergency surgical timing, resulting in surgeons' being more willing to perform a longer and more complex reparative procedure. Furthermore, the observed survival benefits of MV repair over replacement in our study should be interpreted with caution, as there may have been an allocation bias in the selection of surgical therapy. Although the baseline characteristics between groups are comparable, several relevant clinical details that significantly influence decision making and surgical outcomes cannot easily be compiled in retrospective databases.

A higher rate of successful MV repair after M-TEER was seen in patients with primary MR. This can be explained by the lack of redundant MV tissue in patients with secondary MR, limiting the amount of available leaflet for a complex surgical repair after device excision. In our study, more than 40% of patients required concomitant TV surgery, with 55% having more than moderate preoperative TR. MV replacement may also help mitigate the risk for prolonged cross-clamp and cardiopulmonary bypass times in patients undergoing concomitant tricuspid surgery, as evidenced by more valve replacements than repairs in these patients.

IN-HOSPITAL AND SHORT-TERM MORTALITY. The early mortality observed in our study (15.1%) is notably higher than that reported by Chikwe et al[6] (10.2%), which could be explained by the inclusion of patients undergoing emergency surgery in our cohort. This increased mortality in our study was driven primarily by patients undergoing MV replacement compared with those undergoing MV repair (16.0% vs 4.0%), while the expected mortality of both replacement and repair groups was comparable. The O/E for mortality was considerably higher in the replacement group compared with the repair group. Our findings suggest a need for improvement in the application of preoperative risk assessment tools or scores for patients undergoing MV surgery after M-TEER, with a higher predicted risk for mortality in those patients in whom MV replacement is the expected outcome.

Our overall 1-year survival rate of 75.9% in the CUTTING-EDGE registry and the increased survival rates in patients undergoing MV repair compared with MV replacement are consistent with findings by other groups.[6-8] It is important to note that repeat M-TEER is a possible alternative to surgery in select anatomically suitable patients with failed initial M-TEER. Shechter et al[17] reported a 1-year mortality rate of 17.3% among patients undergoing repeat M-TEER for recurrent MR after initially successful M-TEER procedures. However, the STS-PROM risk score strongly underestimated the observed risk of these patients, with a mean value of 6.6%. Hence, considering the superior survival rates of MV repair over repeat M-TEER, heart teams should consider the likelihood of a successful surgical MV repair, as well as acceptable surgical risk, when deciding the best strategy.

IMPLICATIONS ON FUTURE PATIENT SELECTION. Different factors should be considered at the time of the initial M-TEER procedure, in case the operator suspects that the procedure may not be ultimately successful. For example, the number of devices deployed during index M-TEER influenced the chance of future MV repair success, with smaller numbers of devices in the repair group. Similarly, increased transmitral gradients and decreased MV areas were

TABLE 3 In-Hospital, 30-Day, and 1-Year Outcomes After MV Surgery

	Overall (N = 332)	MV Repair (n = 25)	MV Replacement (n = 307)	*P* Value
In-hospital outcomes				
Ventilator, h	17 (9.0-48.0)	9.8 (7.0-19.5)	18.0 (9.0-49.0)	0.20
ICU LOS, h	60.0 (19.0-120.0)	42.0 (7.8-96.0)	61.0 (19.0-120.0)	0.13
Hospital LOS, d	12.0 (8.0-20.0)	10.5 (8.0-15.0)	13.0 (8.0-21.0)	0.089
New-onset atrial fibrillation	44 (13.3)	2 (8.0)	42 (13.7)	0.55
New pacemaker	31 (9.3)	1 (4.0)	30 (9.8)	0.49
Stroke	9 (2.7)	1 (4.0)	8 (2.6)	0.51
Vascular complication	14 (4.2)	1 (4.0)	13 (4.2)	1.00
Life-threatening bleeding	29 (8.7)	0 (0)	29 (9.4)	0.15
Major bleeding	52 (15.7)	1 (4.0)	51 (16.6)	0.15
Intraoperative mortality	3 (0.9)	0 (0)	3 (1.0)	1.00
In-hospital mortality	50 (15.1)	1 (4.0)	49 (16.0)	0.15
30-d outcomes	(N = 319)	(n = 25)	(n = 294)	
Mortality	53 (16.6)	1 (4.0)	52 (17.7)	0.094
Stroke	9 (2.8)	1 (4.2)	8 (2.7)	0.51
Readmission	16 (6.1)	0 (0)	16 (6.7)	0.37
Observed-to-expected ratio[a]	3.6 (1.9-5.3)	1.7 (0.7-3.3)	3.8 (2.1-5.5)	
1-y outcomes	(N = 214)	(n = 19)	(n = 195)	
Mortality	67 (31.3)	2 (10.5)	65 (33.3)	0.041
Stroke	13 (6.0)	1 (5.3)	12 (6.1)	1.00
LVEF, %	46.2 ± 13.8	52.8 ± 4.8	45.5 ± 14.2	0.16
MG, mm Hg	4.1 ± 1.8	3.6 ± 1.2	4.1 ± 1.8	0.54
PG, mm Hg	8.9 ± 4.4	7.8 ± 3.9	9 ± 4.5	0.58
MVA, cm^2	2.9 ± 1.2	3.2 ± 0.8	2.8 ± 1.3	0.68
RVSP, mm Hg	35 ± 10.3	35 ± 5.7	35 ± 10.6	1.00
Survival at last follow-up	239 (74.7)	21 (91.3)	218 (73.4)	0.079

Values are median (Q1-Q3), n (%), or mean ± SD. [a]Numbers in parentheses are 95% CI.
LOS = length of stay; PG = peak gradient; other abbreviations as in Table 1.

associated with a higher risk for future MV replacement. Furthermore, early referral after M-TEER in patients with borderline results could also facilitate MV repair because of less extensive histologic changes. Finally, new M-TEER device iterations should consider the issue of repeat surgical interventions, with modifications to ease potential device removal in their design.

Local heart teams should also consider the low MV repair rates after failed M-TEER and, in suitable candidates, opt for primary surgical therapy in patients with anatomy that is borderline for M-TEER. Application of M-TEER in younger and lower risk patients should consider lifetime management consequences of their specific valvular disease. Among high-risk patients unsuitable for MV repair after failed M-TEER, novel transcatheter strategies such as leaflet modification and MV replacement should be considered.

STUDY LIMITATIONS. Despite the strengths of this large global registry-based study, there are several limitations. First, the retrospective nature of this study has inherent biases, including time bias, as different M-TEER device generations were included. Approximately 70% of the M-TEER failures were observed in patients receiving the older MitraClip classic and NT systems.

Second, eligibility for the index M-TEER procedure and subsequent MV surgery was assessed independently by the respective heart teams at the local institutions, and the choice of surgical procedure was at the surgeon's discretion, resulting in possible selection bias. Especially valvular anatomical considerations, for example, severe calcifications and large leaflet tears, patient-specific characteristics such as preoperative hemodynamic instability and timing of surgery, and surgeon and institutional specifics, especially experience, could contribute to the outcome difference between groups. Because of the lack of this information, we could not adjust for it. Unfortunately, we did not have access to data on patients with failed M-TEER therapy who did not undergo MV surgery.

Third, the small absolute number of patients undergoing MV repair (n = 25), including only 7 patients with secondary MR, limits the feasibility of meaningful subgroup analysis stratified by MR etiology. Fourth, there was no independent echocardiographic core laboratory to assess the echocardiographic parameters before and after the procedure.

CENTRAL ILLUSTRATION **MV Surgery After Failed TEER: The CUTTING-EDGE Registry**

Mitral Valve Repair Versus Replacement After TEER: Insights From the CUTTING-EDGE International Registry, N = 332

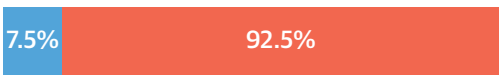
Index TEER Procedure

2005-2020

Median Time: 3.5 Months (IQR: 0.5-11.6)

MV Surgery

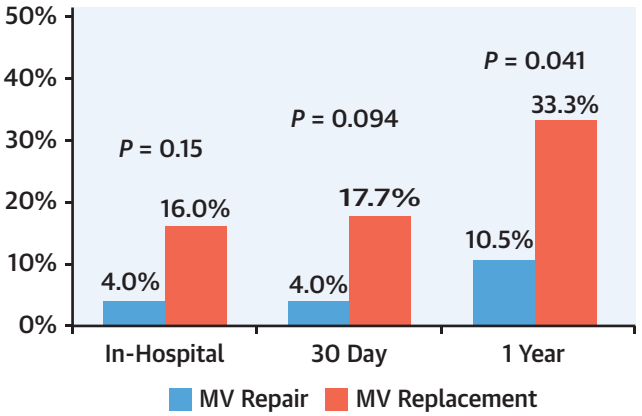
2009-2020



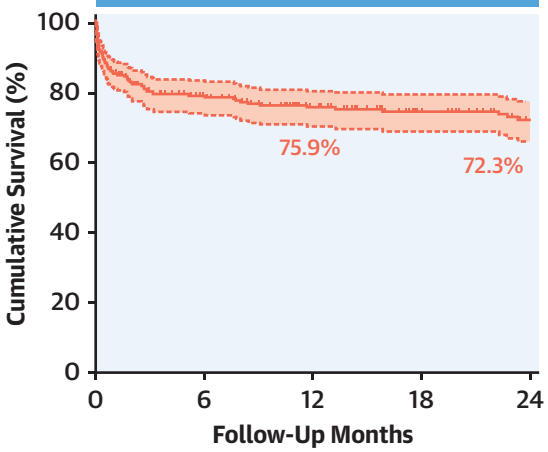
MV Repair | MV Replacement

Median Follow-Up: 9.1 Months (IQR: 1.1-25.8)

Mortality Stratified by MV Surgery Type



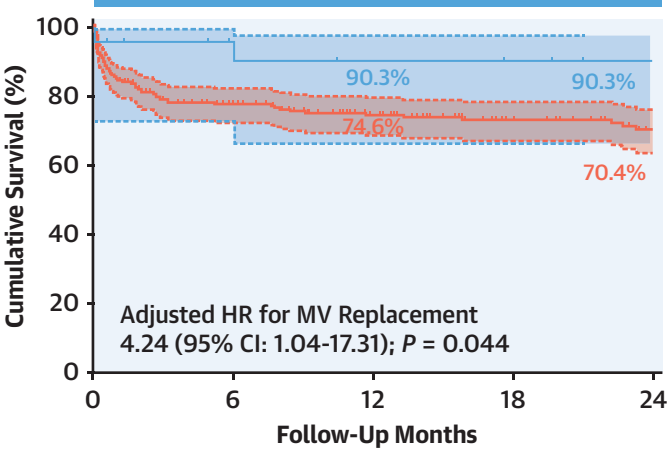
Cumulative Survival After MV Surgery



No. at Risk:

MV Repair	332	180	138	106	84

Cumulative Survival Stratified by MV Surgery Type



No. at Risk:

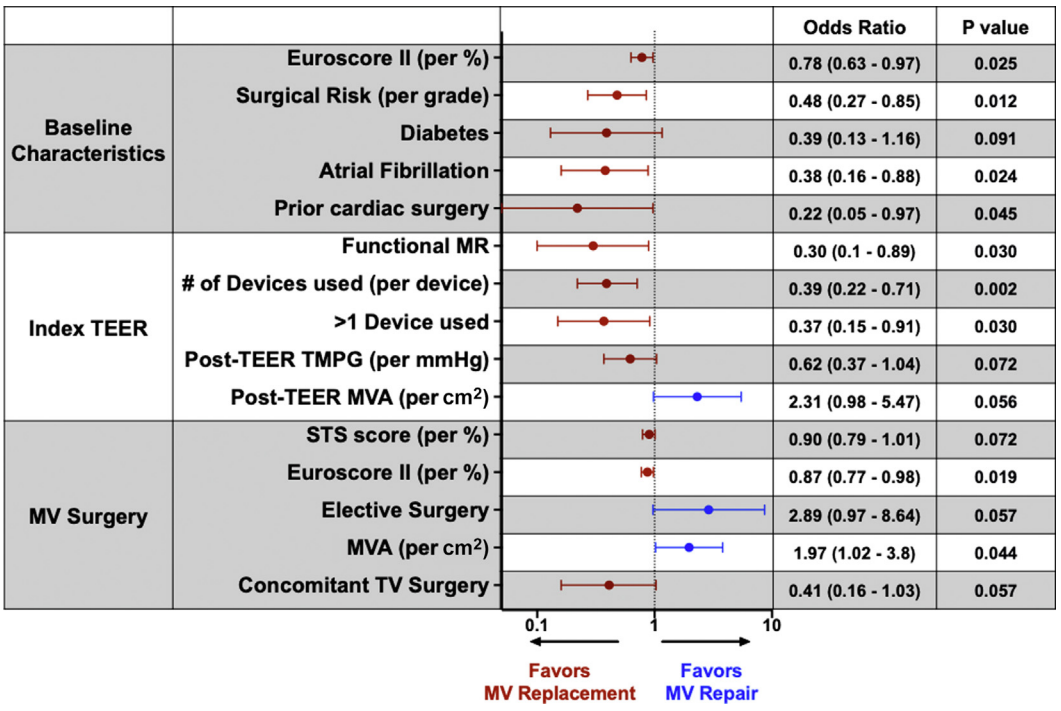
Repair	25	18	16	15	13
Replacement	307	162	122	91	71

- **MV surgery after failed M-TEER is a high-risk procedure associated with higher-than-expected 30-day mortality (observed-to-expected ratio 3.6 [95% CI: 1.9-5.3])**
- **Compared to repair, replacement is associated with higher 1-year mortality (33.3% vs 10.5%; *P* = 0.041) and a lower 2-year survival (70.4% vs 90.3%; *P* = 0.044)**

Marin-Cuartas M, et al. JACC Cardiovasc Interv. 2025;18(7):912-923.

Among 332 patients undergoing mitral valve (MV) surgery after failed mitral transcatheter edge-to-edge repair (M-TEER) across 34 centers, replacement had significantly higher 1-year mortality (33.3% vs 10.5%; $P = 0.041$) that persisted at 2 years in the risk-adjusted Cox regression (HR for replacement: 1.66; 95% CI: 1.06-2.61; $P = 0.028$). TEER = transcatheter edge-to-edge repair.

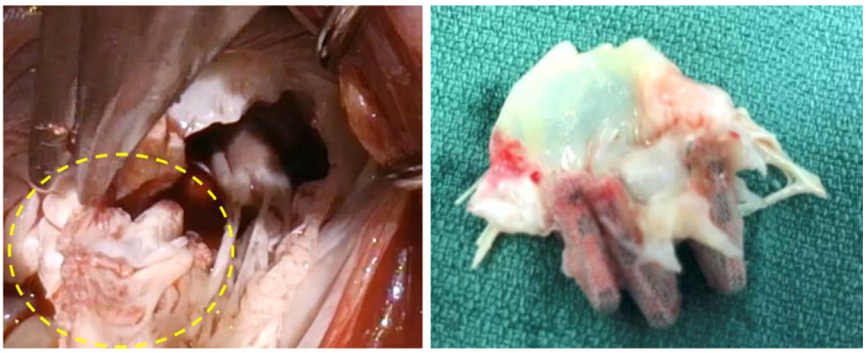
FIGURE 4 Forest Plot of Predictors of MV Replacement vs Repair After Failed Mitral TEER



Forest plot showing logistic regression analysis of factors associated with mitral valve (MV) replacement vs repair after mitral transcatheter edge-to-edge repair (TEER). Euroscore = European System for Cardiac Operative Risk Evaluation; MR = mitral regurgitation; MVA = mitral valve area; TMPG = transmitral pressure gradient; TR = tricuspid regurgitation; TV = tricuspid valve.

Finally, although the granularity of the database was robust, we were unable to account for the provider- or center-level variations in transcatheter and surgical techniques, as well as the impact of procedural volume (either surgeon or hospital level) on outcomes. In addition, the data must be interpreted in the context that it is a rare procedure, as 34 centers recruited 332 patients over 10 years. Because of its rare nature, referral to high-volume heart valve centers should be considered, and primarily experienced

FIGURE 5 Intraoperative Pictures of Removed Mitral Transcatheter Edge-to-Edge Repair Devices With Significant Ingrowth Into the Mitral Valve Tissue



MV repair surgeons should manage these patients to achieve the best possible results and standardize these procedures.

CONCLUSIONS

MV surgery after failed M-TEER is a high-risk procedure associated with higher than expected 30-day mortality. On the basis of data from the CUTTING-EDGE registry, MV replacement is associated with significantly higher 1-year mortality and lower 2-year survival compared with MV repair. Although our findings are hypothesis generating, they provide further insights into patients after M-TEER who may require MV surgery in the future and may help further define optimal clinical practice during these procedures as well as lifetime management of mitral valvular disease.

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Dr Falk has received institutional grants from Abbott, Abiomed, Medtronic, Biotronik, and Edwards Lifesciences. Dr Conradi has served as an advisory board member for Medtronic, Abbott, and JenaValve; and has received consultant fees from Edwards Lifesciences, Boston Scientific, Venus Medtech, MicroPort, Neovasc, MicroInterventions, 4C Medical, and Pi-Cardia. Dr Hagl has received speaker honoraria from Edwards Lifesciences. Dr Taramasso has been a consultant for Abbott Vascular, Boston Scientific, Edwards Lifesciences, 4tech, Mitraltech, Simulands, MTEx, Occlufit, CoreMedic, and Shenqi Medical. Dr Nguyen has received speaker honoraria from Edwards Lifesciences, Cryolife, and Abbott. Dr Lim has received research grants accepted by his institution on his behalf from Abbott, Boston Scientific, Corvia, Edwards Lifesciences, Medtronic, V-Wave, and W.L. Gore & Associates; and has received personal consulting fees from LagunaTech, Nyra Medical, Opus, Philips, Valgen, and Venus Medtech. Dr Ailawadi has served as a consultant for Medtronic, Edwards Lifesciences, Abbott, W.L. Gore & Associates, Anteris, AtriCure, CryoLife, Johnson & Johnson, Philips, and Jena. Dr Mack has served as co-primary investigator for the PARTNER (Placement of Aortic Transcatheter Valve) trial for Edwards Lifesciences and the COAPT trial for Abbott; and has served as study chair for the APOLLO (Transcatheter Mitral Valve Replacement With the Medtronic Intrepid™ TMVR System in Patients With Severe Symptomatic Mitral Regurgitation) trial for Medtronic. Dr Asgar is a consultant for Medtronic, Abbott, Edwards Lifesciences, and W.L. Gore & Associates; and has received research grants from Abbott. Dr Grubb is a physician proctor for Medtronic; and has severed as a consultant for Medtronic, Boston Scientific, Abbott, Ancora, OpSens Medical, and 4C Medical. Dr Pirelli is a physician proctor for and has received speaker honoraria from Edwards Lifesciences and Abbott; and is a consultant for Medtronic. Dr Denti has received speaker honoraria from Abbott and Edwards Lifesciences; and has received consultant fees from Approxima, HVR, InnovHeart and Pi-Cardia. Dr Modine is a physician proctor and consultant for Medtronic, Edwards Lifesciences, and Abbott. Dr Reardon is a consultant for Medtronic, Boston Scientific, Abbott, and W.L. Gore & Associates. Dr Nazif has equity in Venus Medtech; and has received consulting fees or honoraria from Keystone Heart, Edwards Lifesciences, Medtronic, and Boston Scientific. Dr Bapat has served as a consultant for Medtronic, Edwards Lifesciences, 4C Medical, and Boston Scientific. Dr Kaneko is a speaker for Edwards Lifesciences, Medtronic, Abbott, and Baylis Medical; and is a consultant for 4C Medical. Dr Borger's hospital has received speaker honoraria and/or consulting fees on his behalf from Edwards Lifesciences, Medtronic, Abbott, and Artivion. Dr Tang has received speaker honoraria and served as a physician proctor, consultant, advisory board member, TAVR publications committee member, APOLLO trial screening committee member, and IMPACT MR steering committee member for Medtronic; has received speaker honoraria and served as a physician proctor, consultant, advisory board member, and TRILUMINATE trial anatomic eligibility and publications committee member for Abbott Structural Heart; has served as an advisory board member for Boston Scientific and JenaValve; has served as a consultant for NeoChord, Shockwave Medical, Peija Medical, and Shenqi Medical Technology; and has received speaker honoraria from Siemens Healthineers. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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PERSPECTIVES

WHAT IS KNOWN? MV surgery for failed M-TEER procedures is a complex procedure with increased mortality. However, the optimal management strategy for these patients is not well studied.

WHAT IS NEW? MV surgery after failed M-TEER is a high-risk procedure with higher than expected mortality, especially in patients undergoing MV replacement.

WHAT IS NEXT? Future studies need to identify preoperative and preinterventional echocardiographic and patient-specific characteristics that predict the repairability in borderline M-TEER patients to further guide the decision making of the heart team and the ideal lifetime management strategies.

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KEY WORDS mitral valve repair, mitral valve replacement, mitral valve surgery, transcatheter edge-to-edge repair

APPENDIX For supplemental tables and a list of CUTTING-EDGE investigators, please see the online version of this paper.