Mitral valve surgery after failed transcatheter edge-to-edge repair

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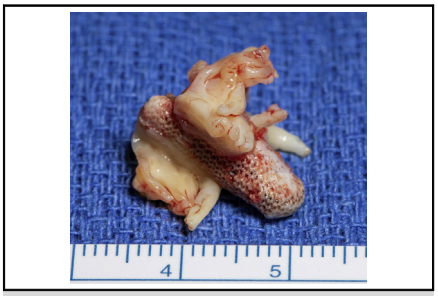
ABSTRACT

Objective: Mitral valve operations for failed transcatheter edge-to-edge repair (TEER) are increasing. This study investigated the indications, surgical procedures, and outcomes after surgery for failed TEER.

Methods: We analyzed records of patients who underwent mitral valve operations after TEER between January 2013 and September 2021. Patient characteristics, clip number and location, indications, timing, surgery type, and outcomes were evaluated.

Results: A total of 41 patients (median age, 77 years; 14 women; median Society of Thoracic Surgeons predicted risk of mortality score, 9.4% [5.6%-12.6%]; and previous cardiac surgery in 21 patients) underwent mitral valve surgery at a median of 8 months (range, 4-16 months) after TEER. One clip was implanted in 24 patients and 2 or more in 17 patients. Indications for surgery were severe mitral regurgitation in 33, severe mitral stenosis in 1 patient, and both in 7 patients. Operations were performed via sternotomy in 37 patients and lateral thoracotomy in 4 patients. The mitral valve was replaced in all patients (bioprosthesis in 35 patients and a mechanical valve in 6 patients). Concomitant procedures were performed in 30 patients. Operative mortality was 5% (observed to expected ratio, 0.53) and did not differ for primary procedures versus reoperations. Echocardiographic follow-up demonstrated no or trivial mitral regurgitation in 34 patients, mild mitral regurgitation in 5 patients, and moderate perivalvular mitral regurgitation in 1 patient with severe mitral annular calcification. At a median follow-up of 1.5 years (interquartile range, 4.7 months-2.7 years), the actuarial survival was 79%.

Conclusions: Mitral valve replacement can be performed safely after failed TEER with operative mortality lower than expected even in high-risk patients. (JTCVS Techniques 2022;14:79-88)



Mitral valve fibrosis after transcatheter edge-to-edge repair.

CENTRAL MESSAGE

Mitral valve replacement after failed transcatheter edge-to-edge repair is performed predominantly for mitral regurgitation causing heart failure and confers good outcomes even in reoperations.

PERSPECTIVE

Transcatheter edge-to-edge repair is increasingly used to treat patients with severe mitral regurgitation with high operative risk for standard surgery. A population of patients in whom this procedure fails is increasing. We provide a detailed description of the Mayo Clinic experience with operations in patients with failed transcatheter edge-to-edge repair.

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Abbreviations and Acronyms

ACC = American College of Cardiology
CABG = coronary artery bypass grafting
O/E = observed to expected
PROM = Predicted Risk of Operative Mortality
STS = Society of Thoracic Surgeons
TEER = transcatheter edge-to-edge repair
TVT = transcatheter valve therapy

Video clip is available online.

Transcatheter edge-to-edge repair (TEER) is used with increasing frequency to manage patients with severe mitral valve regurgitation who are considered to have a high operative risk for standard valve repair or replacement.[1,2] More than 33,000 TEERs have been performed in the United States alone since 2014.[3] Persistent or recurrent mitral regurgitation or mitral stenosis are common after TEER; moderate or severe mitral regurgitation has been reported in 15% of patients,[4] and some degree of mitral stenosis is seen in 25% to 35% of TEER patients postprocedure.[5,6] As a result, the number of surgical procedures following TEER has increased steadily.[7] Nevertheless, the indications and timing of surgery after failed TEER remain unclear, and the operations performed, and their outcomes are poorly described. We hypothesized that mitral valve surgery can be performed safely after failed TEER, and that most patients require prosthetic replacement. The present study details the Mayo Clinic experience with surgical management of patients with failed TEER. We analyze the indications and timing of surgery, the applied surgical techniques and outcomes.

MATERIALS AND METHODS

Patients

Between January 2013 and September 2021, 2697 patients underwent mitral valve surgery and 399 underwent TEER at Mayo Clinic, Rochester, Minn. Patients with previously performed TEER were included in the study. Patients in whom TEER was attempted but no device was implanted were excluded. The study was reviewed and approved by the Mayo Clinic Institutional Review Board (#20-010466, November 9, 2020). Medical records, the institution cardiac surgery database, and Society of Thoracic Surgeons (STS)/American College of Cardiology Transcatheter Valve Therapy Registry (ACC TVT) registry, and echocardiography databases were reviewed for clinical characteristics, echocardiographic data, TEER and surgical procedures, indications for TEER, surgery, and outcomes.

Mitral valve regurgitation was graded from 1+ (trivial) to 4+ (severe), and all echocardiographic studies analyzed were evaluated by a cardiologist at Mayo Clinic. The etiology of mitral regurgitation was recorded based on echocardiographic evaluation. The surgical risk was calculated using the STS Predicted Risk of Operative Mortality (PROM) score for isolated mitral valve replacement at the time of surgery. The observed/expected (O/E) ratio of 30-day mortality was calculated as the ratio of the observed 30-day mortality to the median STS-PROM score. The urgency of the procedure, as well as the comorbidities, were defined in accordance with STS Data Specifications. The interval from TEER to surgery was calculated from the date of the index TEER to the date of mitral valve surgery. Survival time was calculated from the date of surgery to mortality date or last recorded follow-up.

Statistical Analysis

Continuous variables were tested for normal distribution with the Shapiro-Wilk test, and are expressed as medians with interquartile ranges. Categorical variables are presented as percentages. Comparisons between the 2 groups were performed using Student *t* test or Mann-Whitney *U* test for continuous variables and by χ^2 test or Fisher exact test (when any of the expected cell frequencies was <5) for categorical variables. Survival analysis was conducted using the Kaplan-Meier estimator. Statistical analysis was performed with BlueSky Statistics version 7.40 (BlueSky).

RESULTS

Patient Characteristics

A total of 41 patients (median age, 77 years; 14 women) had mitral valve surgery after TEER during the study period. Baseline characteristics are displayed in Table 1. Twenty-one patients had previous cardiac surgery (9 had coronary artery bypass grafting [CABG], 4 had aortic valve replacement, four had combined aortic valve replacement and CABG, and 4 had other procedures). The median STS-PROM for mitral valve replacement was 9.4%. Surgical consultation before TEER was documented for 31 patients, not done in 1, and unknown for 8 outside referrals. Surgeons who evaluated these patients before TEER reported the high-risk nature of a potential surgical intervention in all cases due to multiple comorbidities (n = 18), difficult chest re-entry (n = 6), advance age/frailty (n = 5), and severe mitral annular calcification (n = 2).

TEER

TEER was performed at Mayo Clinic in 29 patients and at other institutions in 12 patients between October 2014 and April 2021. Indications for the index TEER included severe primary mitral regurgitation in 19 patients, secondary in 17 patients, and mixed etiology in 5 patients (Table 1). All patients had a MitraClip (Abbott) implanted. One MitraClip was implanted in 24 patients, 2 clips in 16 patients, and 3 in 1 patient. Clips were implanted in the A2-P2 mitral valve regions in 36 patients, in the A3-P3 in 5 patients, and multiple regions in 7 patients. A repeat clipping procedure was attempted in 3 patients after the initial TEER. The median time from TEER to mitral valve surgery was 8 months (interquartile range, 4-6 months; range, 21 days to 4.5 years) (Figure 1, *A*). There were no differences in surgical timing post-TEER between primary operations and reoperations (Figure 1, *B*).

TABLE 1. Characteristics of patients who underwent mitral valve surgery after transcatheter edge-to-edge repair (*TEER*)

Variable	All patients (N = 41)	Primary surgery (n = 20)	Reoperation (n = 21)	*P* value
Age (y)	77 (70-82)	77 (68-82)	77 (71-80)	.98
Female sex	14 (34)	8 (40)	6 (29)	.44
STS predicted risk of operative mortality (%)	9.4 (5.6-12.6)	7.6 (5.3-10.6)	11.6 (6.7-14.5)	.08
BMI	27.8 (25.0-33.5)	26.5 (23.5-33.6)	29.2 (26.5-33.1)	.33
Diabetes mellitus	12 (29)	2 (10)	10 (48)	.008
History of atrial fibrillation	23 (56)	7 (35)	16 (76)	.008
Hypertension	35 (85)	16 (46)	18 (54)	.41
Hypercholesterolemia	38 (93)	18 (90)	20 (95)	.52
Peripheral vascular disease	7 (17)	1 (5)	6 (29)	.09
History of myocardial infarction	11 (27)	5 (25)	6 (29)	.80
History of PCI	15 (37)	8 (40)	7 (47)	.66
History of stroke	10 (24)	3 (15)	7 (33)	.28
Chronic lung disease	12 (29)	4 (20)	8 (38)	.20
Smoking history	29 (71)	14 (70)	15 (71)	.92
End stage renal disease	4 (10)	4 (20)	0 (0)	.05
Liver disease	6 (14)	3 (15)	3 (14)	1.00
Permanent pacemaker	7 (17)	4 (20)	3 (14)	.70
Congestive heart failure	22 (54)	10 (50)	12 (57)	.65
NYHA functional class				.41
II	4 (10)	2 (10)	2 (10)	
III	27 (66)	14 (70)	13 (62)	
IV	10 (24)	4 (20)	6 (29)	
Previous cardiac surgeries				
Any previous cardiac surgery	21 (51)	–	21 (100)	–
CABG	9 (22)	–	9 (43)	–
AVR	4 (10)	–	4 (19)	–
CABG + AVR	4 (10)	–	4 (19)	–
Other	4 (10)	–	4 (19)	–
TEER details				
Etiology of mitral regurgitation before TEER				.35
Primary	19 (46)	11 (55)	8 (38)	
Secondary	17 (42)	6 (30)	11 (52)	
Mixed primary/secondary	5 (12)	3 (15)	2 (10)	
No. of implanted clips	1 (1-2)	1 (1-2)	2 (1-2)	.21
>1 clip implanted	17 (41)	6 (30)	11 (52)	.15
A2-P2 clip location	36 (88)	19 (95)	17 (81)	.34
Involvement of multiple scallops	7 (17)	1 (5)	6 (29)	.09
Time from MitraClip* to surgery (mo)	8 (4-16)	14 (5-18)	8 (4-11)	.13
Primary surgical indications for mitral valve replacement after failed TEER				
Persistent/recurrent mitral regurgitation	33 (80)	15 (75)	18 (86)	.45
Mitral stenosis	1 (2)	0 (0)	1 (5)	1.00
Combined regurgitation and stenosis	7 (17)	5 (25)	2 (10)	.24
Urgent operation	4 (10)	0 (0)	4 (19)	.11

(Continued)

TABLE 1. Continued

Variable	All patients (N = 41)	Primary surgery (n = 20)	Reoperation (n = 21)	*P* value
Preoperative (post-TEER) echocardiographic parameters				
Left ventricular ejection fraction (%)	57 (55-63)	57 (55-61)	59 (55-65)	.57
Severity of mitral regurgitation				.51
Mild	1 (2)	0 (0)	1 (5)	
Moderate	3 (7)	1 (5)	2 (10)	
Severe	37 (90)	19 (95)	18 (86)	
LVESD (mm)	36 (31-42)	38 (34-43)	34 (31-39)	.22
LVEDD (mm)	54 (50-58)	55 (52-58)	51 (49-57)	.34
RV systolic pressure (mm Hg)	57 (44-63)	57 (50-63)	54 (41-65)	.82
Mitral stenosis	13 (32)	7 (35)	6 (29)	.66
Degree of tricuspid regurgitation				.97
Trivial	2 (5)	1 (5)	1 (5)	
Mild	7 (17)	4 (20)	3 (14)	
Moderate	11 (27)	5 (25)	6 (29)	
Severe	21 (51)	10 (50)	11 (52)	

Values are presented as n (%) or median (range). *STS*, Society of Thoracic Surgeons; *BMI*, body mass index; *PCI*, percutaneous coronary intervention; *NYHA*, New York Heart Association; *CABG*, coronary artery bypass grafting; *AVR*, aortic valve replacement; *LVESD*, left ventricular end-systolic diameter; *LVEDD*, left ventricular end-diastolic diameter; *RV*, right ventricle. *Abbott, Abbot Park, Ill.

Indications for Mitral Valve Surgery

Indications for mitral surgery and preoperative echocardiographic findings are displayed in Table 1. All patients presented with heart failure symptoms, and 37 were in New York Heart Association functional class III or IV. Mitral valve regurgitation was the primary indication for operation in 33 patients (persistent, n = 27; recurrent, n = 6), combined mitral regurgitation and stenosis in 7, and mitral stenosis alone in 1. Echocardiography before mitral valve surgery demonstrated severe mitral regurgitation in 37 patients. Some degree of mitral stenosis was identified in 13 patients and was severe in 5, moderate in 7, and mild in 1 patient. Among patients with mitral stenosis, the median transmitral gradient was 10 mm Hg (8-11 mm Hg), and the median mitral valve area was 1.2 cm^2 (0.9-1.8 cm^2). Mitral annular calcification was reported in 15 patients and was severe in 4. Median left ventricular ejection fraction was 57%, the median left ventricular end-systolic diameter was 36 mm, and end-diastolic diameter was 54 mm. More than mild tricuspid regurgitation was present in 32 patients, and median right ventricular systolic pressure was 57 mm Hg. Additional cardiac pathology included aortic valve stenosis in 7 patients (gradient >40 mm Hg was present in 2 patients) and coronary disease requiring revascularization in 6 patients. There were no cases of active endocarditis.

Operative Techniques

Operations were performed through a median sternotomy in 37 patients or a right thoracotomy in 4 patients (Table 2). Surgery was considered urgent due to advanced heart failure in 4 patients, and 3 required inotropic support preoperatively. All patients underwent mitral valve replacement, and a bioprosthesis was used in 35 patients, including 1 transatrial implantation of modified Sapien 3 transcatheter aortic valve (Edwards Lifesciences) due to extensive calcification of the mitral annulus. In 6 patients, single leaflet detachment of the clip was reported (4 detached from the anterior leaflet and 2 from the posterior leaflet); in the remaining cases, clips remained attached. The median size of the implanted prosthetic valve was 29 mm (interquartile range, 29-31 mm; range, 25-33 mm). MitraClips were resected with surrounding tissue in 36 cases, whereas atraumatic removal was possible in 5 patients. The subvalvular apparatus was preserved in 33 patients.

Associated Procedures

The atrial septostomy was closed in all patients, and in 30 cases, at least 1 additional procedure was required (Table 2). Tricuspid valve procedures were performed in 25 patients (20 repairs and 5 replacements), aortic valve procedures in 4; 1 patient required aortic root replacement. Six patients underwent coronary revascularization, and a maze procedure was done in 2 patients (cryoablation in 1 and radiofrequency in the other). Four patients underwent isolated left atrial appendage occlusion.

Aortic cross-clamp times and by-pass times were similar in primary operations compared with reoperations, and there were no differences in intraoperative blood product transfusions (Table 2). The cross-clamp times and by-pass times for isolated mitral procedures compared with mitral operations with concomitant procedures were 66 minutes (range, 56-96 minutes) and 91 minutes (range, 68-115 minutes) ($P = .14$) and 118 minutes (range, 75-145 minutes) versus 137 minutes (range, 101-162 minutes) ($P = .22$), respectively.

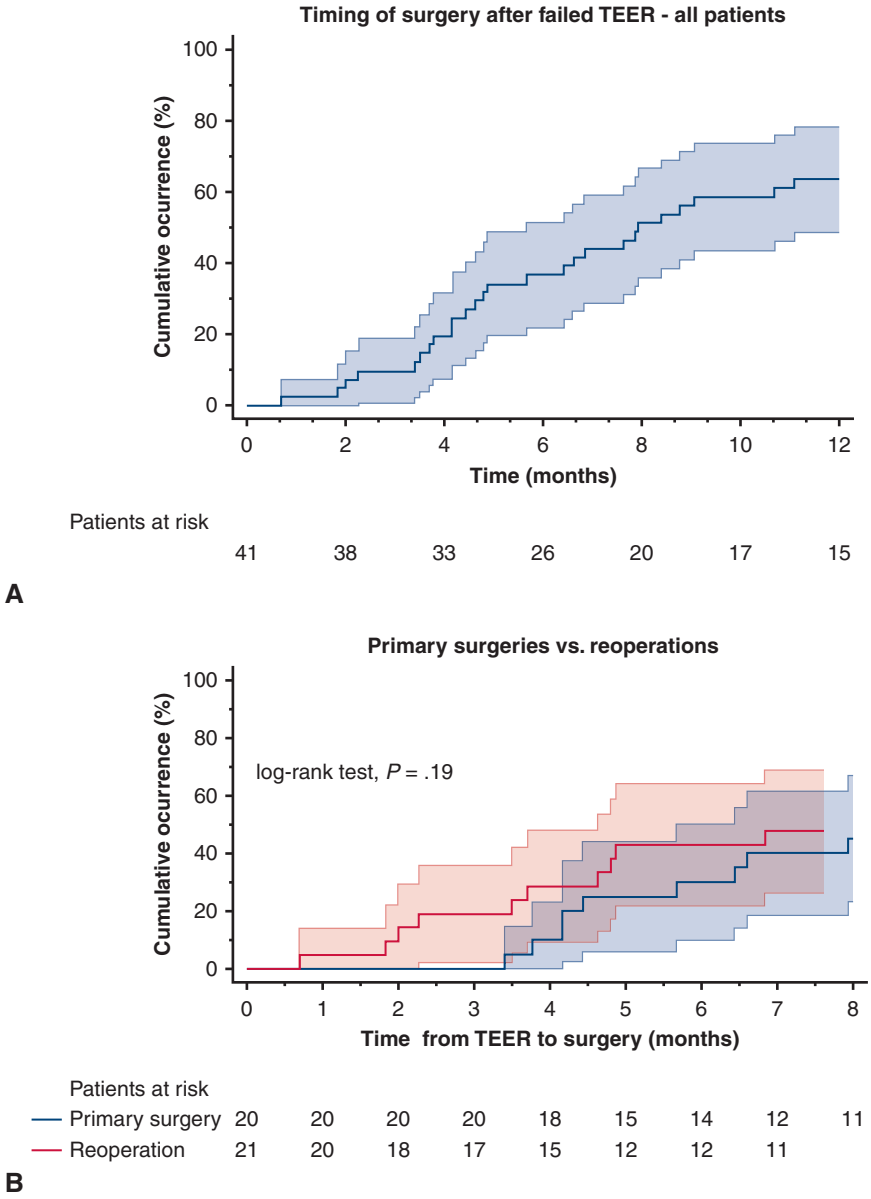

FIGURE 1. Timing of the surgery following failed transcatheter edge-to-edge mitral valve repair (*TEER*). A, In all patients. B, In subgroups undergoing primary surgery (*blue*) versus reoperation (*red*). The *shaded areas* represent 95% CI.

Operative Outcomes

There were 2 operative mortalities (5%). Causes of death were bleeding in a Jehovah's Witness who refused homologous blood transfusion and intestinal ischemia in the second patient. The O/E mortality ratio was 0.52. Operative complications are summarized in Table 3. Six patients required delayed sternal closure due to hemodynamic instability, and an intra-aortic balloon pump was needed postoperatively in 5 individuals. Two patients required postoperative extracorporeal membrane oxygenation for circulatory support. The median length of intensive care unit stay, and hospital stay were 2.9 and 11 days, respectively. There were no differences in operative outcomes and complications between primary surgery and reoperation groups (Table 3).

Overall Survival

Median follow-up was 1.5 years (interquartile range, 4.7 months-2.7 years). The 1- and 3-year actuarial survival were 79% (95% CI, 66%-94%) and 61% (95% CI, 43%-86%) (Figure 2, *A*). Survivorship was similar when patients were stratified by primary versus reoperative procedures (Figure 2, *B*) and degenerative versus functional mitral regurgitation (not shown).

TABLE 2. Operative and postoperative characteristics

Variable	Total (N = 41)	Primary surgery (n = 20)	Reoperation (n = 21)	*P* value
Surgical procedures				
Median sternotomy	37 (90)	19 (95)	18 (86)	.61
Right thoracotomy approach	4 (10)	1 (5)	3 (14)	.61
Mitral valve surgery				
Mitral valve replacement	41 (100)	20 (100)	21 (100)	–
Mechanical	6 (15)	1 (5)	5 (14)	.18
Tissue	35 (85)	19 (95)	16 (76)	.18
Associated cardiac procedures				
Atrial septostomy closure	41 (100)	20 (100)	21 (100)	–
CABG	6 (15)	3 (15)	3 (14)	1.00
Other valve surgery	27 (66)	13 (65)	14 (67)	.91
Tricuspid valve surgery	25 (61)	13 (65)	12 (57)	.61
Exclusion of left atrial appendage	4 (10)	2 (10)	2 (10)	1.00
Maze procedure	2 (5)	1 (5)	1 (5)	1.00
Aortic surgery	1 (2)	1 (5)	0 (0)	.49
Aortic cross-clamp time (min)	86 (58-102)	84 (60-103)	86 (46-102)	.63
CPB time (min)	132 (99-158)	117 (81-152)	151 (114-165)	.07
Intraoperative transfusions				
RBC transfusion	23 (56)	12 (60)	11 (52)	.62
Platelets transfusion	25 (61)	11 (55)	14 (67)	.44
FFP transfusion	21 (51)	10 (50)	11 (52)	.88
Cryoprecipitate transfusion	3 (7)	3 (15)	0 (0)	.11

Values are presented as n (%) or median (range). *CABG*, Coronary artery bypass grafting; *CPB*, cardiopulmonary bypass; *RBC*, red blood cells; *FFP*, fresh frozen plasma.

Follow-up Echocardiography

Follow-up transthoracic echocardiograms were available in 40 patients after a median of 2.5 months (interquartile range, 8 days-1 year). Mitral regurgitation was absent in 10 patients, trivial in 24 patients, mild in 5, and moderate in 1. Periprosthetic mitral regurgitation was not seen on post-by-pass transesophageal echocardiography in any of the cases but was described in 4 patients in the follow-up (mild in 3 patients and moderate in 1 patient with severe mitral annular calcification). Median left ventricular ejection fraction was 54%, mean mitral gradient was 6 mm Hg, and mitral valve area (n = 31) was 1.9 cm^2. There were no differences in any follow-up echocardiographic parameters between primary and redo operations.

TABLE 3. Operative outcomes after mitral valve surgery following failed transcatheter edge-to-edge repair

Variable	Total (N = 41)	Primary surgery (n = 20)	Reoperation (n = 21)	*P* value
Operative mortality	2 (5)	1 (5)	1 (5)	1.00
Length of mechanical ventilation (h)	12 (5-64)	8 (4-70)	15 (6-58)	.44
ICU length of stay (h)	69 (43-261)	70 (29-174)	68 (47-267)	.62
Hospital length of stay (d)	11 (8-19)	11 (8-25)	13 (8-18)	.92
Postoperative atrial fibrillation	17 (43)	9 (47)	8 (38)	.55
Pneumonia	9 (22)	4 (20)	5 (24)	1.00
Renal failure	11 (17)	5 (25)	6 (29)	.80
Delayed sternal closure	6 (15)	4 (20)	2 (10)	.41
GI bleeding	6 (15)	3 (15)	3 (14)	1.00
IABP use	5 (12)	1 (5)	4 (19)	.34
Sepsis	4 (10)	3 (15)	1 (5)	.34
ECMO use	2 (5)	0 (0)	2 (10)	.49
Re-exploration for surgical bleeding	1 (2)	0 (0)	1 (5)	1.00
Stroke	1 (2)	0 (0)	1 (5)	1.00
Hospital readmission	8 (20)	4 (20)	4 (19)	.94

Values are presented as median (interquartile range) or number (%). *ICU*, Intensive care unit; *GI*, gastrointestinal; *IABP*, intra-aortic balloon pump; *ECMO*, extracorporeal membrane oxygenation.

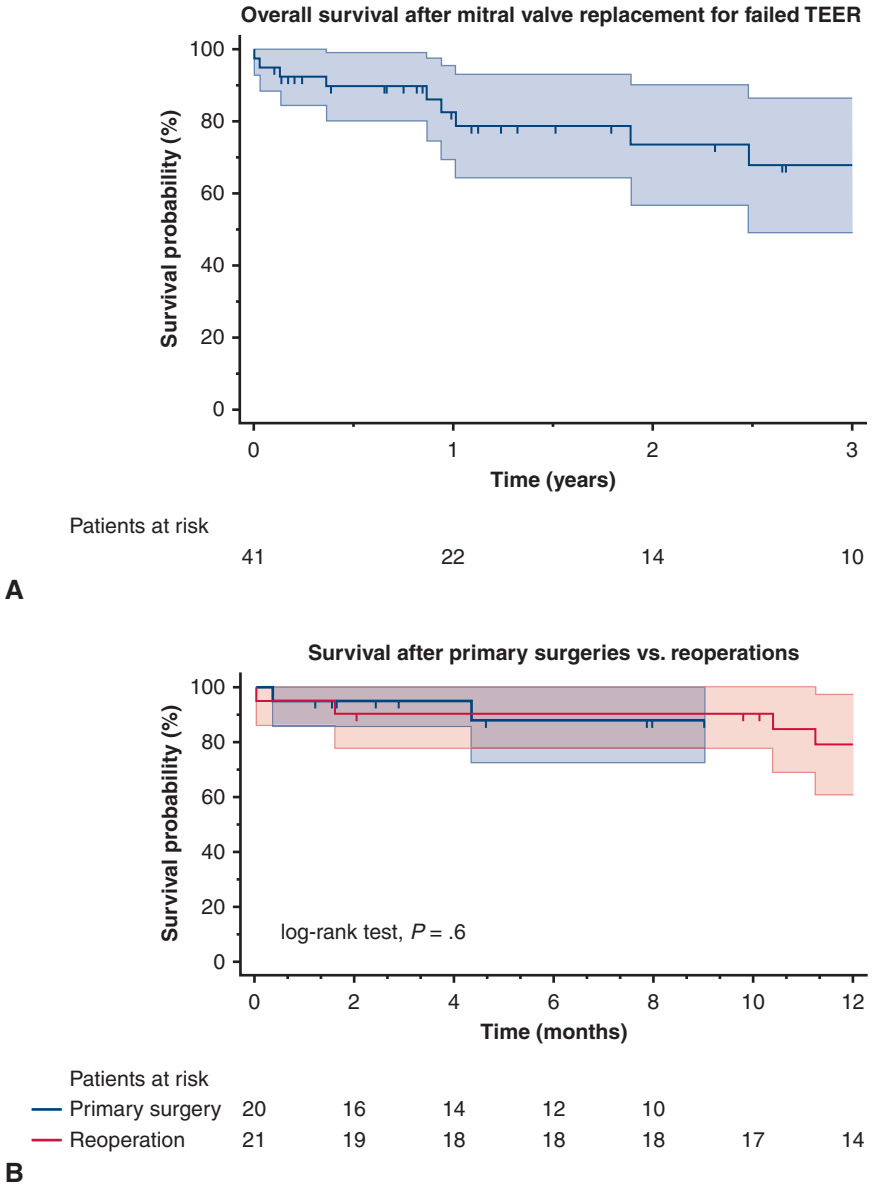

FIGURE 2. Overall survival after mitral valve replacement following failed transcatheter edge-to-edge mitral valve repair (*TEER*). A, in all patients. B, In subgroups undergoing primary surgery (*blue*) versus reoperation (*red*). The *shaded areas* represent 95% CI.

DISCUSSION

This study describes the clinical and operative characteristics of 41 high-risk surgical patients who had mitral valve surgery after failed TEER. We found that mitral valve surgery is usually required after failed TEER within a year. All patients had symptoms of congestive heart failure secondary to mitral regurgitation or combined regurgitation and stenosis, and mitral valve replacement was necessary for all patients. Despite the elevated risk in this cohort, surgery after TEER can be performed with satisfactory operative outcomes, as evidenced by operative mortality approaching half of the predicted risk.

Incidence and Indications for Surgery After TEER

The number of surgical referrals due to failure of TEER is increasing. A 5-year analysis of the Endovascular Valve Edge-to-Edge Repair Study (EVEREST II) trial showed that as many as 28% of patients treated with MitraClip insertion eventually require surgical intervention.[8] A recent analysis of the STS database by Chikwe and colleagues[7] demonstrated that the number of surgical interventions following TEER is steadily increasing, in line with findings from the European CUTTING-EDGE registry.[9] Although our study is too small to identify solid trends, 41% of our patients underwent operation within the past 2 years. The

true incidence in our center is difficult to calculate because almost one-third of referrals came from other institutions, and some patients who underwent TEER at Mayo Clinic may have been operated on elsewhere.

All patients had heart failure symptoms, and 90% were in New York Heart Association functional class III or IV secondary to persistent or recurrent mitral regurgitation, followed by combined regurgitation and stenosis. The mechanism of mitral regurgitation was due to its persistence or progression in the 34 patients, in whom the TEER device remained attached to the leaflets, or recurrence, in 6 patients, in whom the clip partially detached. In previous studies, severe mitral regurgitation was the main indication in 62% to 79% of patients requiring surgery, whereas device detachment was observed in 25%.[7,9]

Risk Characteristics

The surgical risk of patients referred for TEER is high at baseline. The median STS-PROM before TEER reported in 2017 was 9.2% for mitral valve replacement and 6.1% for repair in the STS/ACC TVT registry.[10] In a more recent analysis of more than 30,000 patients from the STS/ACC TVT registry, the overall reported risk for mitral valve repair was 5.4% before TEER. More than 40% of patients had a predicted risk of $\geq$8% for mitral valve replacement.[3] In our study, the preoperative STS-PROM for mitral valve replacement (9.4%) was higher than that reported in other surgical reports on patients operated on for failed TEER, including the STS database analysis (7.6%)[7] and the CUTTING-EDGE registry (4.8%).[9] It is conceivable that the surgical post-TEER cohorts do not include the extreme risk patients, who were deemed truly inoperable by surgeons.

It is interesting to note that TEER outcomes differ depending on the underlying valve pathology.[10] Patients with primary mitral regurgitation tend to have better overall survival and fewer rehospitalizations for heart failure than subjects with secondary mitral regurgitation.[10] Primary mitral regurgitation as the underlying mitral pathology is present in 38% to 59% of surgical patients treated for failed TEER[7,9] and constituted approximately one-half of the patients in this report. In the STS/ACC TVT registry, primary mitral regurgitation was present in 72% of TEER patients, secondary was seen in 11% and 11% had mixed etiology.[3] The number of patients reported here is too small to draw definitive conclusions.

Surgical Procedures: Timing and Valve Repairability

Despite extensive experience with mitral valve repair at our institution, all patients in this report required mitral valve replacement. The rate of successful mitral valve repairs after TEER failure reported in the literature is only 5% to 7%.[7,8] The chance of valve repair may be the highest in patients with aborted TEER and in those in whom surgery was performed early after TEER because the degree of leaflet inflammation and fibrosis generated by the TEER device increases over time (Figure 3).[11,12] In this report, surgery was performed at a median of 8 months from TEER, more than 2-fold longer than reported by the CUTTING-EDGE registry,[9] likely contributing to the low repair rate. That notwithstanding, a in a recent report of 26 cases from Germany, the rate of valve replacements was 100% despite the median time from TEER being just 34.5 days.[13] The timing at which the rate of repairability starts to decrease remains unknown.

One-third of patients requiring surgery after TEER have a previous history of cardiac surgery, most commonly CABG.[7,14-16] Half of our patients had a prior sternotomy. Whereas reoperations are more demanding and increase the overall risk, our outcomes are equivalent to primary operations following TEER failure. Furthermore, previous heart surgery does not influence the care pathway after TEER failure, as evidenced by similar time to intervention.

Associated Procedures

Almost 75% of the patients in this report required associated cardiac procedures during surgery for failed TEER. Associated valve procedures were the most common, followed by coronary revascularization. The rate of tricuspid valve repair was higher than in previous studies.[7,9,15,17] There is considerable controversy on the influence and benefit of tricuspid valve surgery at the time of mitral valve surgery. In the CUTTING-EDGE registry, severe tricuspid regurgitation was associated with increased 1-year mortality after mitral valve surgery for failed TEER,[9] but a recent Cardiothoracic Surgery Network trial showed no survival

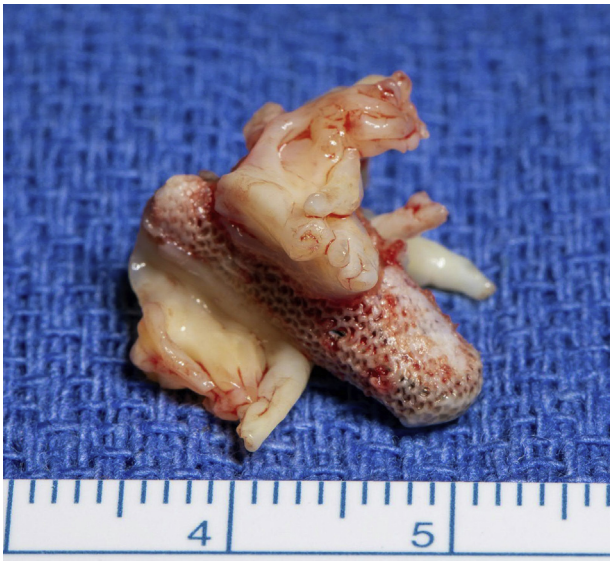

FIGURE 3. An example of a clip with adjacent fragments of fibrosed anterior and posterior mitral valve leaflets 3 months postimplantation.

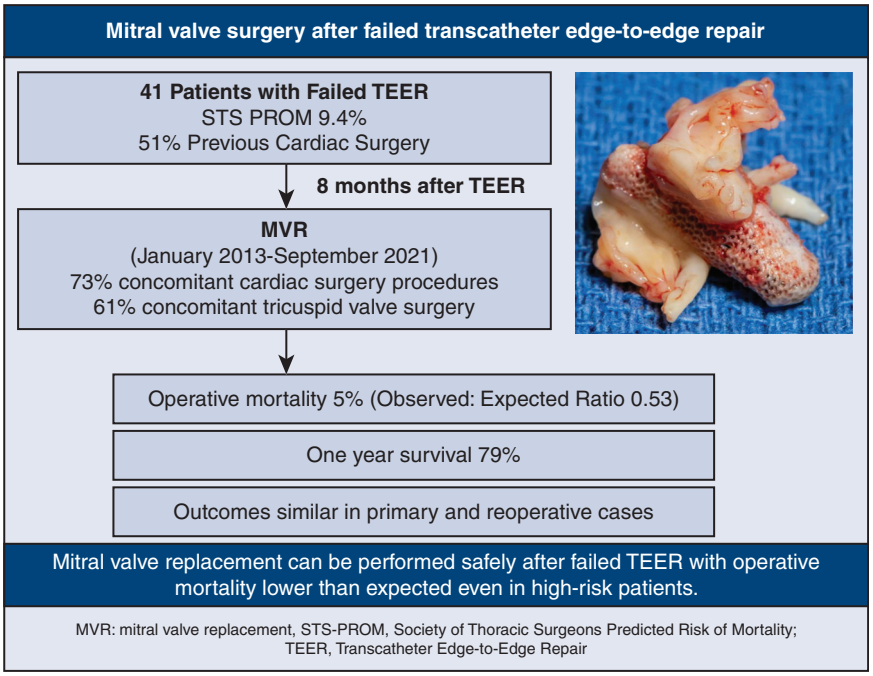

FIGURE 4. Operative mortality after mitral valve replacement due to transcatheter edge-to-edge repair failure was lower than predicted despite the high incidence of reoperations and concomitant procedures.

benefit when tricuspid repair was done during mitral repair surgery, with an increased rate of pacemaker implantation.[18] Addressing associated cardiac pathologies during surgery for failed TEER might have a favorable influence on long-term outcomes, but the role of tricuspid surgery and other associated procedures remains to be established.

Outcomes

The operative mortality rate in this study is lower than that reported from the national STS database (5% vs 10.6%),[7] lower than expected based on the predicted by risk models (O/E ratio 0.53), and similar to the 30-day mortality after TEER reported in the STS/ACC TVT registry (4.5%).[3] A history of previous cardiac surgery did not influence the operative mortality and rates of postoperative complications. Despite the higher STS-PROM and frequency of prior cardiac operations, the 1-year mortality rate was 21%, which compares favorably with other reports in the literature, where 1-year mortality ranges from 26.5% to 41%.[9,15,17] The 1-year mortality observed in the current study is comparable to the 1-year mortality of 23.1% after isolated TEER.[3] These results suggest that mitral valve surgery following failed TEER is a viable option even in patients with previous cardiac surgery. The findings of this study are summarized in Figure 4 and in Video Abstract.

Limitations

This retrospective study is relatively small and reflects a single-center experience. We do not know the number of patients evaluated for surgery after failed TEER who were considered unsuitable for surgery after failed TEER. As such, this study effectively excluded the inoperable and most extreme-risk patients, arguably improving the outcomes. Nonetheless, the STS-PROM score higher than reported in the literature for surgical patients after failed TEER and for primary TEER suggests that these patients were high-risk. The follow-up was short, and given the small cohort, we could not determine the effect of mitral regurgitation etiology on outcomes. The reasons for undergoing TEER instead of surgery during the index procedure were not analyzed. Long-term data on functional status and quality of life were not available, and echocardiographic follow-up data were limited. Finally, patients in whom a TEER was aborted were excluded from the analysis.

CONCLUSIONS

Mitral valve surgery after failed TEER can be performed with good early outcomes in high-risk surgical patients with heart failure symptoms often secondary to mitral regurgitation. Most patients require mitral valve replacement within a year of the failed TEER procedure. It is unknown whether or not the timing of the surgery affects the rate of valve repairs. Although more than half of these patients required reoperations, and the majority underwent at least 1 additional procedure, operative mortality was lower than predicted. One-year survival was comparable to that after TEER alone.

Conflict of Interest Statement

The 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 have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP III, Gentile F, et al. 2020 ACC/AHA guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on clinical practice guidelines. *Circulation*. 2021;143:e35-71.
2. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, et al. 2021 ESC/EACTS guidelines for the management of valvular heart disease. *Eur Heart J*. 2022;43:561-632.
3. Mack M, Carroll JD, Thourani V, Vemulapalli S, Squiers J, Manandhar P, et al. Transcatheter mitral valve therapy in the United States: a report from the STS/ACC TVT Registry. *Ann Thorac Surg*. 2022;113:337-65.
4. Ailawadi G, Lim DS, Mack MJ, Trento A, Kar S, Grayburn PA, et al. One-year outcomes after MitraClip for functional mitral regurgitation. *Circulation*. 2019;139:37-47.
5. Neuss M, Schau T, Isotani A, Pilz M, Schopp M, Butter C. Elevated mitral valve pressure gradient after MitraClip implantation deteriorates long-term outcome in patients with severe mitral regurgitation and severe heart failure. *JACC Cardiovasc Interv*. 2017;10:931-9.
6. Schnitzler K, Hell M, Geyer M, Kreidel F, Munzel T, von Bardeleben RS. Complications following MitraClip implantation. *Curr Cardiol Rep*. 2021;23:131.
7. Chikwe J, O'Gara P, Fremes S, Sundt TM III, Habib RH, Gammie J, et al. Mitral surgery after transcatheter edge-to-edge repair: Society of Thoracic Surgeons database analysis. *J Am Coll Cardiol*. 2021;78:1-9.
8. Feldman T, Kar S, Elmariah S, Smart SC, Trento A, Siegel RJ, et al. Randomized comparison of percutaneous repair and surgery for mitral regurgitation: 5-year results of EVEREST II. *J Am Coll Cardiol*. 2015;66:2844-54.
9. Kaneko T, Hirji S, Zaid S, Lange R, Kempfert J, Conradi L, et al. Mitral valve surgery after transcatheter edge-to-edge repair: mid-term outcomes from the CUTTING-EDGE International Registry. *JACC Cardiovasc Interv*. 2021;14:2010-21.
10. Sorajja P, Vemulapalli S, Feldman T, Mack M, Holmes DR Jr, Stebbins A, et al. Outcomes with transcatheter mitral valve repair in the United States: an STS/ACC TVT Registry report. *J Am Coll Cardiol*. 2017;70:2315-27.
11. Schmiady MO, Taramasso M, Maisano F, Sigler M. Mitral valve surgery after MitraClip implantation: what histopathology can tell us? *Eur Heart J*. 2020;41:3767.
12. Ladich E, Michaels MB, Jones RM, McDermott E, Coleman L, Komtebedde J, et al. Pathological healing response of explanted MitraClip devices. *Circulation*. 2011;123:1418-27.
13. Pingpoh C, Kreibich M, Berger T, Thoma M, Beyersdorf F, Comberg T, et al. Clinical outcomes after mitral valve surgery in failed MitraClip procedures. *Thorac Cardiovasc Surg*. February 25, 2022 [Epub ahead of print].
14. Takayuki G, Soren S, Kristin R, Harnath A, Grimmig O, Soren J, et al. Surgical revision of failed percutaneous edge-to-edge mitral valve repair: lessons learned. *Interact Cardiovasc Thorac Surg*. 2019;28:900-7.
15. Ostovar R, Erb M, Schroeter F, Zytowski M, Kuehnel RU, Hartrumpf M, et al. MitraClip: a word of caution regarding an all too liberal indication and delayed referral to surgery in case of failure. *Eur J Cardiothorac Surg*. 2021;59:887-93.
16. Geidel S, Schmoeckel M. Impact of failed mitral clipping on subsequent mitral valve operations. *Ann Thorac Surg*. 2014;97:56-63.
17. Melillo F, Baldetti L, Beneduce A, Agricola E, Margonato A, Godino C. Mitral valve surgery after a failed MitraClip procedure. *Interact Cardiovasc Thorac Surg*. 2021;32:380-5.
18. Gammie JS, Chu MWA, Falk V, Overbey JR, Moskowitz AJ, Gillinov M, et al. Concomitant tricuspid repair in patients with degenerative mitral regurgitation. *N Engl J Med*. 2022;386:327-39.

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