

Midterm results after seamless patch mitral reconstruction



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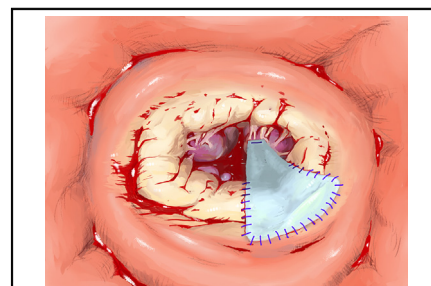
ABSTRACT

Objectives: Some pathologies, including infective endocarditis or sclerotic changes of the mitral leaflet, make the conventional mitral valve repair challenging. Our previously described technique for reconstruction with a seamless pericardial patch makes the repair feasible in some of such difficult pathologies. However, the extent of mitral leaflet segments that could be safely repaired using this technique remains unknown. We investigated the association between the midterm outcome and the extent of mitral leaflet segments replaced by a pericardial patch.

Methods: From January 2009 to January 2022, patients who underwent mitral valve repair with the seamless 1-patch reconstruction technique were included. The glutaraldehyde-treated pericardium was trimmed and anchored at the papillary muscle. The edge was sewn to the leaflet and the annulus.

Results: A total of 49 patients (aged 60 ± 15 years) underwent mitral valve repair with this technique. The totally endoscopic approach was used in 27 patients (55%). No patient's repair was converted to valve replacement. No operative mortality or disabling stroke was observed during the early postoperative period. In the midterm follow-up, redo surgery was required in 9 patients (18%). Freedom from mitral valve reintervention rates at 1, 5, and 10 years were 84%, 82%, and 82% for all patients, respectively. Freedom from reoperation at 5 years was 100%, 92%, and 46% for commissural lesion, 1- to 2-segment involvement, and 3-segment involvement, respectively. There was a significant difference among the 3 groups with regard to mitral valve reoperation rate ($P = .002$).

Conclusions: Mitral valve seamless patch reconstruction provides excellent midterm results if applied to commissural lesions or lesions involving up to 2 segments. (JTCVS Techniques 2022;16:35-42)



Mitral valve reconstruction with seamless patch technique.

CENTRAL MESSAGE

Mitral valve reconstruction with the seamless patch technique provides an excellent long-term result when applied to the pathologies involving the commissure or up to 2 segments.

PERSPECTIVE

Durable repair of mitral valves with active endocarditis, small leaflet, or restrictive leaflet remains challenging. This approach is easily accessible technically and augments the surgeon's armamentarium, especially in young patients to avoid valve replacement.

▶ Video clip is available online.

Mitral valve repair is the standard of care for degenerative mitral regurgitation (MR) meeting operative indications.^{1,2} Numerous techniques for mitral repair have been reported

with good long-term outcomes.³⁻⁵ However, durable repair of mitral valves with active endocarditis, small leaflet, or restrictive leaflet remains challenging. The difficulties are often related to the lack of sufficient leaflet tissue to provide adequate coaptation. To repair such pathologies, we reported our technique of "seamless" patch reconstruction using a glutaraldehyde-treated autologous pericardium.^{6,7} This technique uses a single

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Abbreviations and Acronyms

MR = mitral regurgitation

MS = mitral stenosis

SRT = seamless patch reconstruction technique

piece of pericardium patch to cover the defective or diseased mitral leaflet with a good early outcome. As we have broadened the application of our technique to more extensive valve pathologies, we aimed to characterize the association between the long-term outcome and the extent of segments repaired.

MATERIALS AND METHODS**Patient Selection**

This report was approved by the Institutional Review Board of the Japanese Red Cross Nagoya First Hospital (2021-429) April 1, 2021. The individual informed consent was waived. We retrospectively reviewed our

database and included all the patients who underwent the seamless patch reconstruction technique (SRT). All of the patients who were planned pre-operatively to undergo SRT successfully underwent SRT and were included in this series. Patients were considered as a candidate for SRT when the defect or sclerotic mitral leaflet was limited to 1 leaflet (regardless of the number of involved segments). We excluded patients who received leaflet repair by means other than autologous pericardium. We did not attempt SRT when the lesions were in both anterior and posterior leaflets. We investigated our perioperative and long-term outcomes stratified by the extent of leaflet replaced with SRT. Patients were divided into 3 groups: commissure leaflets replaced, 1 to 2 segments replaced, and 3 segments replaced. We analyzed the long-term outcomes in terms of the valve function.

Surgical Technique

A median sternotomy or an endoscopic approach was chosen on the basis of the patient's anatomy. All patients underwent cardiopulmonary bypass. Totally endoscopic procedures were performed through a right minithoracotomy without rib spreading.⁸ The autologous pericardium was harvested at the time of pericardiectomy. The harvested pericardium was soaked in 0.6% glutaraldehyde solution for 10 minutes and rinsed twice with normal saline for 10 minutes.

The left atrium was opened at the Waterson groove. The mitral valve was repaired using the harvested pericardium. The edge of the prepared

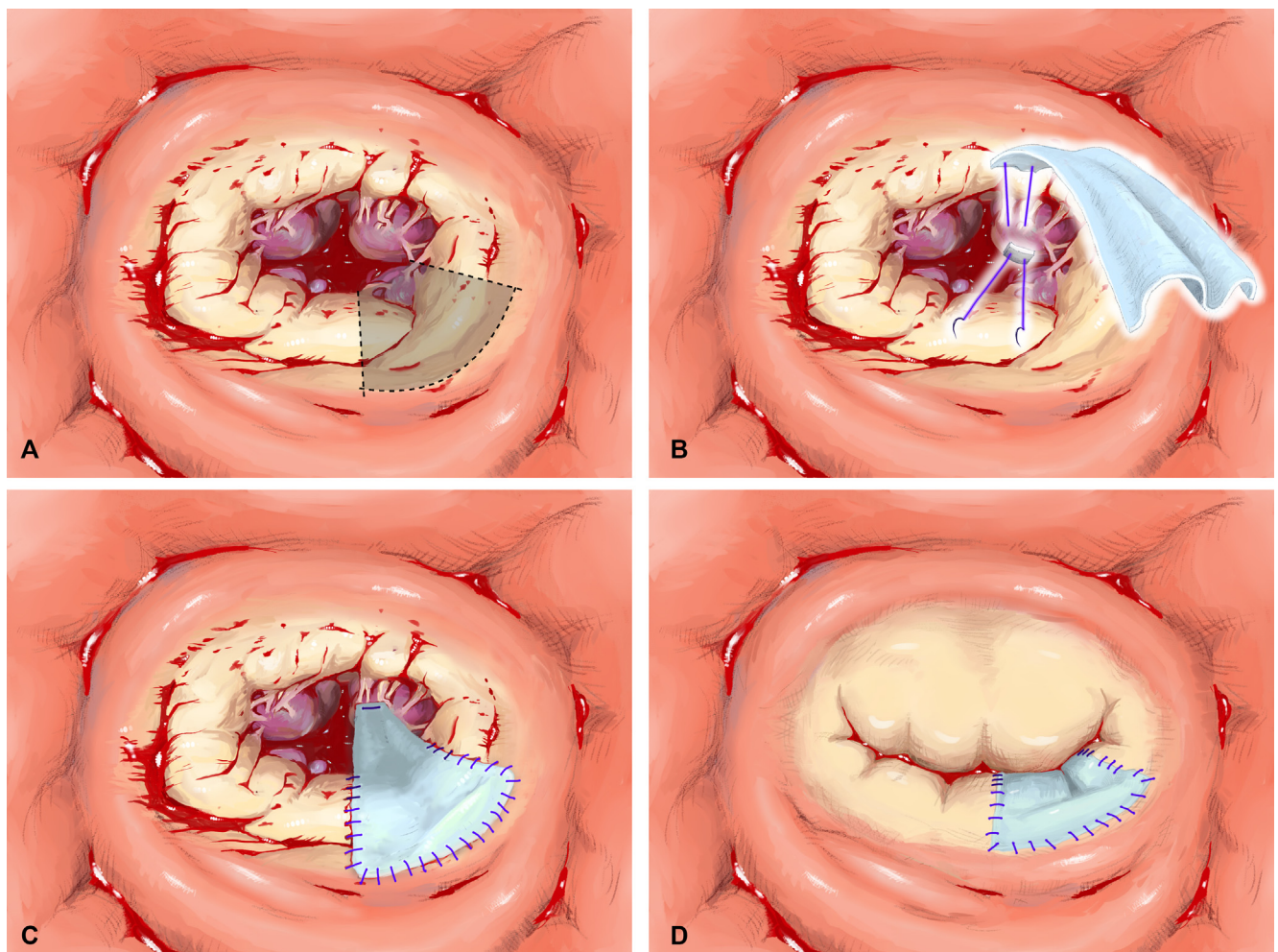
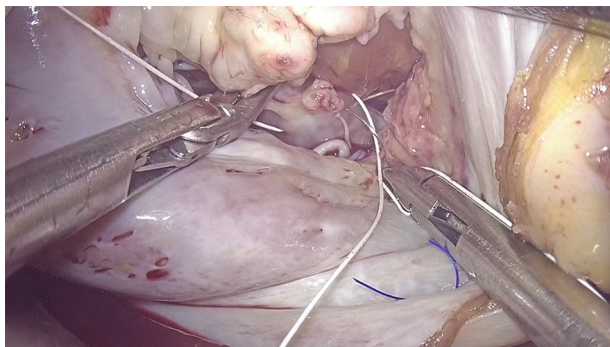


FIGURE 1. A-D, Schema of SRT applied to 1- or 2-segment involvement.



VIDEO 1. Totally 3-dimensional endoscopic mitral valve repair using SRT after converting the 2-dimensional view. A mitral valve repair for active endocarditis is shown. A 32-year-old man, previously diagnosed with moderate mitral valve regurgitation with anterior leaflet prolapse, presented with intractable fever after treatment for pyogenic spondylitis. Urgent surgery was carried out for the large vegetation after 1 week of antibiotic treatment. The infective tissue was found at the P3 to posterior commissure. After the debridement, a triangular-shaped autologous pericardium was prepared to cover the whole P3 to PC area. Myxomatous change in the anterior mitral leaflet was found and corrected with a loop technique. Video available at: [https://www.jtcvs.org/article/S2666-2507\(22\)00529-6/fulltext](https://www.jtcvs.org/article/S2666-2507(22)00529-6/fulltext).

pericardium is attached to the base of the papillary muscle with a pledgetted 4-0 Gore-Tex (WL Gore & Associates Inc) suture. We refer the length or width of the leaflet to the adjacent leaflets and try not to shorten the leaflet or the length to the annulus. The pericardium was sewn to the native leaflet with a single interrupted 5-0 polypropylene suture (Figure 1, A-D, and Video 1) according to the valve anatomy. The annuloplasty was made if there is an annular dilatation. The details of the technique are also described in our previous reports.^{6,7}

After confirming the valve competency with saline injection to the left ventricle, the left atrium was closed with single-layer polypropylene sutures. The cardiopulmonary bypass was weaned after the resumption of the heart rhythm.

Patient Follow-up

Transthoracic echocardiography was performed preoperatively and before the hospital discharge. All the studies were reviewed by a cardiologist specialized in cardiac imaging (Y.M.). The degree of MR was according to the American Society of Echocardiography guideline. Each measured parameter was recorded at preoperative and at the time of long-term follow-up. The patients are followed at our clinic with an annual echocardiography. All patients received warfarin and aspirin for the first 3 months after the procedure, and aspirin was continued thereafter.

Statistical Analysis

Data were summarized as means \pm standard deviation for continuous variables and number (%) for categorical variables. Echocardiographic characteristics of the mitral valve were compared preoperatively and postoperatively in echocardiographic measurements using the 2-tailed paired *t* test for ejection fraction, MR degree, and mean gradient across the mitral valve. Overall survival, freedom from redo surgery, and freedom from significant MR (more than mild) were displayed in Kaplan–Meier plots, and statistical significances were tested using the log-rank test. We also performed competing-risk analysis for freedom from significant MR and freedom from redo surgery to account for the competing mortality risk. The analysis was performed using SPSS 21 (IBM Corp) and cmprsk package for R Studio 4.2.1 (R Foundation).

TABLE 1. Preoperative characteristics

Age (y \pm SD)	60 \pm 15
Male, n (%)	23 (47)
BMI (mean \pm SD)	21 \pm 3.7
Hypertension, n (%)	16 (33)
Diabetes, n (%)	15 (31)
Dyslipidemia, n (%)	10 (20)
History of CVD, n (%)	5 (10)
Smoking, n (%)	16 (33)
Chronic kidney disease, n (%)	8 (16)
Hemodialysis, n (%)	3 (6)
History of atrial fibrillation, n (%)	22 (45)
Ejection fraction (mean \pm SD)	59 \pm 14
Low EF, n (%)	2 (4.1)
NYHA (mean \pm SD)	2.7 \pm 0.6
Previous cardiac surgery, n (%)	3 (6)
Endocarditis, n (%)	14 (29)
Active endocarditis, n (%)	8 (16)
Posterior leaflet lesion, n (%)	28 (57)
Anterior leaflet lesion, n (%)	9 (18)
Commissure lesion, n (%)	12 (24)
Degenerative MR, n (%)	26 (53)
Functional MR, n (%)	23 (47)
Atrial functional MR, n (%)	6 (12)
Ventricular functional MR, n (%)	9 (18)
Carpentier classification	
Type I, n (%)	0
Type II, n (%)	26 (53)
Type IIIa, n (%)	8 (16)
Type IIIb, n (%)	15 (31)

SD, Standard deviation; BMI, body mass index; CVD, cerebrovascular disease; EF, ejection fraction; MR, mitral regurgitation; NYHA, New York Heart Association.

RESULTS

Preoperative Variables

From January 2009 to January 2022, 49 patients underwent SRT in our institution using the described technique. During the same time period, 831 mitral valve procedures (surgical repair or replacement) were performed in our institutions. Patients' mean age was 60 \pm 15 years at the index surgery. All patients had moderate or severe MR, and 1 patient (2.0%) had moderate mitral stenosis (MS). Preoperative variables are summarized in Table 1.

Mitral Valve Pathologies and Type of Patch

Details of the mitral valve pathologies and the Carpentier classification are shown in Table 1. The most common pathology was type II disease (26 patients, 53%). Posterior leaflet

TABLE 2. Perioperative variables

Totally endoscopic surgery, n (%)	27 (55)
Mitral annuloplasty, n (%)	41 (84)
Concomitant aortic valve replacement, n (%)	6 (12)
Concomitant root replacement, n (%)	1 (2.0)
CABG, n (%)	2 (4.1)
Left ventricular restoration, n (%)	2 (4.1)
Tricuspid valve repair, n (%)	18 (37)
Maze procedure, n (%)	13 (27)
Left atrial appendage closure, n (%)	24 (49)
Cardiopulmonary bypass time, min (mean \pm SD)	198 \pm 61
Aortic crossclamp time, min (mean \pm SD)	143 \pm 46
30-d mortality, n (%)	0
Disabling stroke, n (%)	0
Reexploration for bleeding, n (%)	2 (4.1)
Prolonged ventilation >72 h, n (%)	1 (2.0)
ICU stay, d, median (IQR)	2 (1-3)
Hospital stay, d, median (IQR)	11 (9-16)

CABG, Coronary artery bypass grafting; ICU, intensive care unit; IQR, interquartile range.

involvement was the majority in the group (28 patients, 57%). A total of 38 patients (78%) had a triangle- or pentagon-shaped patch, and 11 patients (22%) received a double pentagon attached to both anterolateral and posteromedial papillary muscle. A total of 12 patients (24%) received the patch around the commissure. A total of 26 patients (53%) had 1 or 2 segments replaced with a triangle- or pentagon-shaped patch (Figure 1). A total of 11 patients (22%) had 3 segments covered with the double pentagon-shaped patch. Four patients (8.2%) were treated with a loop technique for the coexisting type II lesion in addition to SRT. All of the patients received glutaraldehyde-treated autologous pericardium described above in terms of the patch used.

Perioperative Variables

Intraoperative and early postoperative characteristics are shown in Table 2. Seven patients (14%) underwent concomitant aortic valve replacement with a standard stented bioprosthesis. One patient (2.0%) had a concomitant root replacement, and 2 patients (4.1%) had coronary artery bypass grafting simultaneously. Tricuspid repair, maze procedure, and left atrial appendage closure were performed in 18 patients (37%), 13 patients (27%), and 24 patients (49%), respectively. Annuloplasty was performed in 41 patients (84%), including 3 patients with an annuloplasty ring from the previous surgery.

Mean aortic crossclamp time and cardiopulmonary bypass time were 143 \pm 46 minutes and 198 \pm 61 minutes,

TABLE 3. Last follow-up transthoracic echocardiographic findings

Variables	Predischarge	Follow-up	P value
Ejection fraction, % (mean \pm SD)	52 \pm 15	57 \pm 15	.03
Mean pressure gradient, mm Hg (mean \pm SD)	3.8 \pm 2.7	3.9 \pm 3.1	.87
Mean pressure gradient >5mm Hg, n (%)	5 (10)	7 (14)	.76

SD, Standard deviation.

respectively. All patients underwent mitral valve repair without the need for replacement. There was no 30-day mortality. Ischemic stroke occurred in 1 patient (2.0%). There was no conversion to sternotomy in patients planned for totally endoscopic approach (27 patients, 55%).

Midterm Result

The mean duration of the follow-up from the index surgery was 69 \pm 41 months (range, 1-159). Follow-up was completed in 100% of the patients. Postoperative transthoracic echocardiographic results at latest follow-up are shown in Table 3. The mean duration of the transthoracic echocardiography was 55 \pm 40 months (range, 1-159, 96% completeness in the midterm follow-up).

In the midterm follow-up, redo surgery was required in 9 patients (18%). Of those, a double pentagon patch for 3-segment lesion was used in 6 patients (67%) at the initial operation. The reasons for redo surgery were a tear in the patch in 2 patients (4.1%), sclerotic change in remnant leaflet tissue in 2 patients (4.1%), and hemolysis in 2 patients (4.1%). One patient had redo for MS 8 years after the repair. The details of the redo surgery are shown in Table E1. No recurrence of MR was found in the cases of commissural involvement. Three patients required reoperations (12%) among those who had 1 or 2 segments replaced, and 6 patients required reoperations (55%) among those who had 3 segments replaced.

The 1-, 5-, and 10-year survivals were 96%, 80%, and 80% for all patients, respectively, and freedom from cardiac mortality was 96%, 90%, and 90% for all patients, respectively. Long-term survival was not significantly different in the 3 subgroups of commissural lesion, 1- to 2-segment involvement, and 3-segment involvement ($P = .35$, Figure 2).

Freedom from mitral valve reintervention rates at 1, 5, and 10 years were 84%, 82%, and 82% for all patients, respectively. There was a significant difference among the 3 groups with regard to mitral valve reoperation in competing risk of death and reoperation by the extent of leaflet involvement ($P = .005$, Figure E1). Freedom from reoperation rates at 5 years were 100%, 92%, and 46% for commissural lesion, 1- to 2-segment involvement, and 3-segment involvement, respectively. In terms of freedom from more than mild mitral valve regurgitation, there was

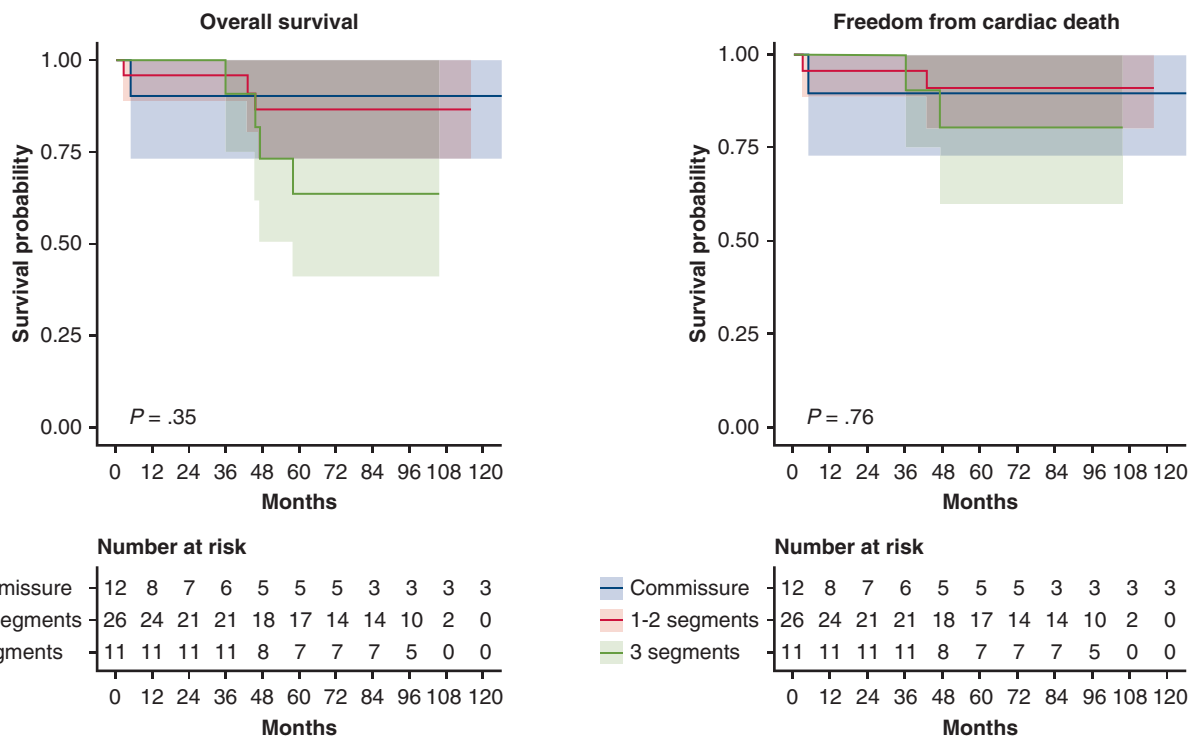


FIGURE 2. Actuarial overall survival and cardiac death after seamless patch mitral reconstruction in the commissural, up to 2-segment, and 3-segment involvement groups.

a significant difference among the 3 groups in competing risk of death and reoperation by the extent of leaflet involvement ($P = .019$, Figure E2). Freedom from more than mild MR rates at 5 years were 100%, 84%, and 58% for commissural lesion, 1- to 2-segment involvement, and 3-segment involvement, respectively.

DISCUSSION

We previously described our technique and early outcome of this seamless patch reconstruction.^{6,7} Our previous study demonstrated its effectiveness and reproducibility in the short-term. The results of our current study are consistent with previous reports of the fresh autologous pericardium.⁹⁻¹¹ The rate of freedom from reoperation in patients who underwent SRT was 82% at 5 years, comparable to those previous studies ranging from 82% to 89% at 5 years. Our study represents one of the largest series of mitral repair using autologous pericardium.

Our data demonstrated that the anatomic location of the SRT application was associated with midterm durability of the repair. The SRT patch implanted at the commissure had no recurrence in the midterm. The SRT patch covering 1 to 2 segments also had excellent midterm outcomes. On the other hand, if applied to more than 2 segments, SRT had a higher incidence of recurrence compared with the less-extensive repair. We applied this technique for patients who otherwise would have received a valve replacement, such as infective endocarditis or type III lesion. We consider the midterm result acceptable

when applied to the limited lesion to salvage the native valve. A limitation of our study is that the included population is heterogenous and the variation in outcomes may partly be due to the variation in pathology. On the basis of the repair durability data presented, the extent of segments involved may be a unifying variable that could guide the patient selection for appropriate SRT candidates, regardless of the valve pathologies or etiologies. The study investigates a small number of patients retrospectively, and a larger number of patients are necessary to corroborate our findings. In addition, a learning curve effect may play a relevant role in this setting.

Study Limitations

A possible drawback of this technique is the potential inflow obstruction by the pericardial patch, as described in previous reports.⁶ In our series, 3 patients had more than moderate MS in the midterm, including a patient with rheumatic mitral morphologies. In most of the patients (94%), the MS was negligible with a mean pressure gradient of 3.9 mm Hg. The use of fresh autologous pericardium in mitral repair has been reported to rarely incur calcification in the long-term.^{10,11} Our series corroborates this observation with no patients showing signs of calcification in the leaflet.

CONCLUSIONS

This approach is easily accessible technically and augments the surgeon’s armamentarium, especially in young

patients to avoid valve replacement. We have performed SRT in a totally endoscopic manner in the majority of the patients (55%) using a 3-port technique⁸ (Video 1) without any mortalities or major complications. We now routinely perform SRT with an endoscopic platform. Mitral valve reconstruction with the seamless patch technique provides an excellent midterm result when applied to the pathologies involving the commissure or up to 2 segments.

Conflict of Interest Statement

T.I. received a proctor fee from Edwards Lifescience, Inc, and a lecture fee from Medtronic, Inc, and Abbott, Inc (no direct conflict with this manuscript). 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: autologous pericardium, mitral valve, mitral valve reconstruction, mitral valve repair

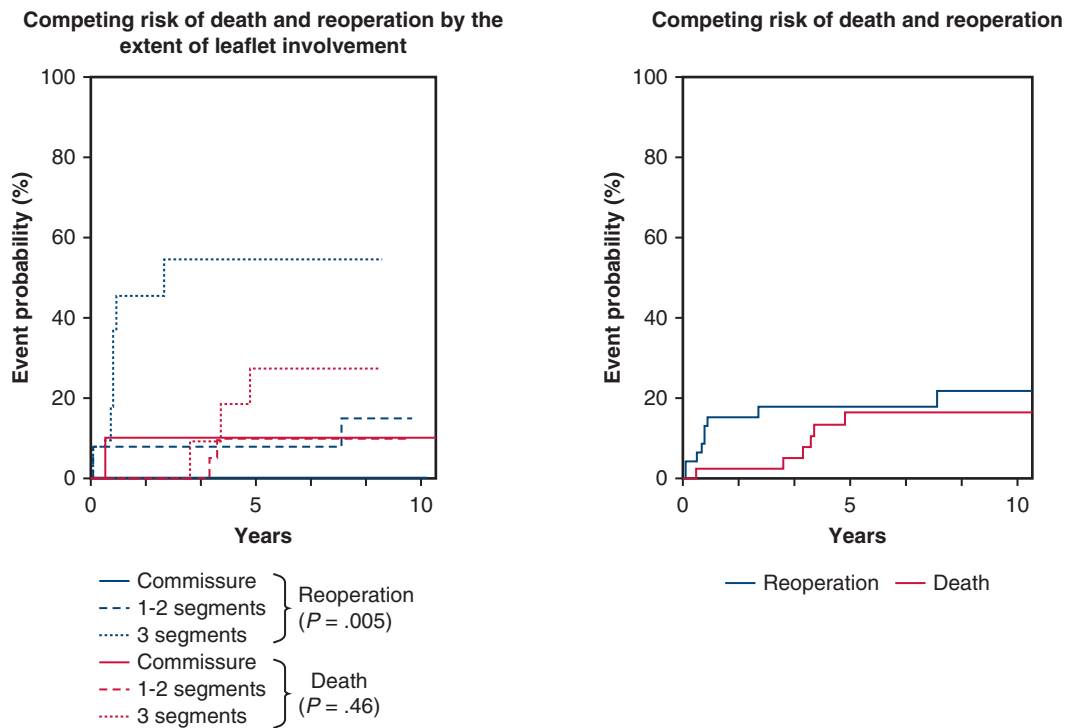


FIGURE E1. Freedom from reoperation after seamless patch mitral reconstruction in the commissural, up to 2-segment, and 3-segment involvement groups with competing risk of death and reoperation by the extent of leaflet involvement.

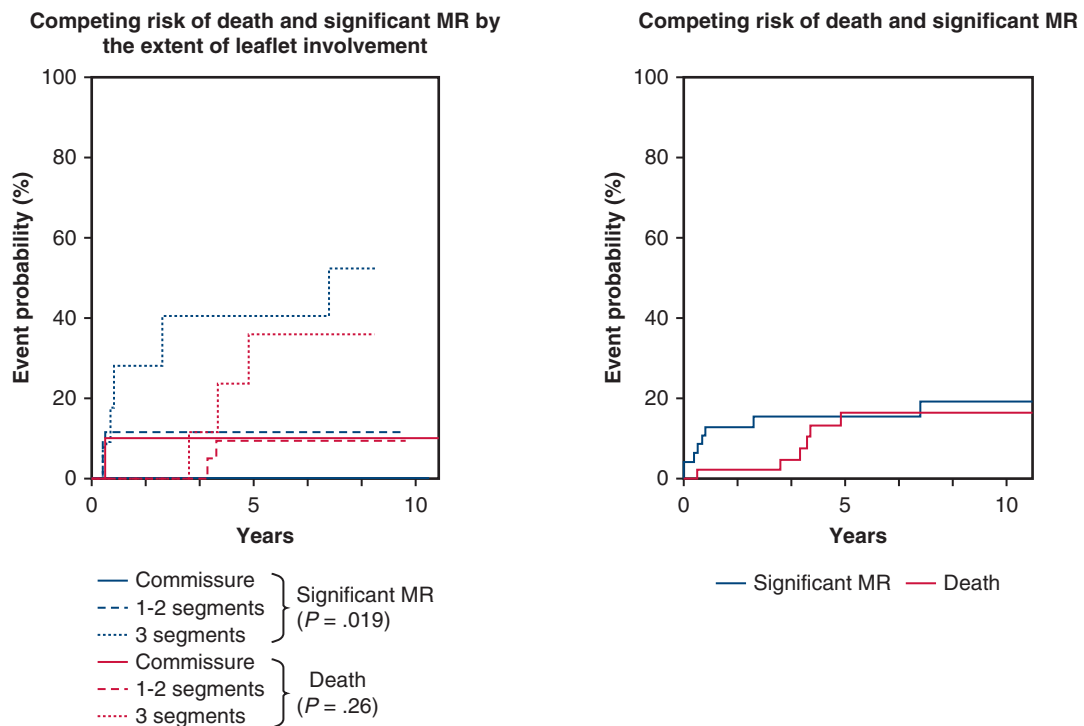


FIGURE E2. Freedom from significant MR after seamless patch mitral reconstruction in the commissural, up to 2-segment, and 3-segment involvement groups with competing risk of death and reoperation by the extent of leaflet involvement. MR, Mitral regurgitation.

TABLE E1. Details of the mitral reinterventions

	Age, y, gender/reason for redo surgery	Findings in redo surgery	Months from the index surgery	Index procedure	Reoperation
1	63 F/MR	Torn patch	9	Double pentagon P1-2	Replacement
2	57 F/MR	Torn patch	5	Double pentagon P1-3, A1-3	Replacement
3	66 F/MR	Torn patch	8	Double triangle A1-3	Replacement
4	70 M/MR	Torn patch/ring detachment	27	Double pentagon P1-3	Replacement
5	88 F/MR	Hemolysis	7	Pentagon, P1-3	Re-repair
6	83 F/MR	Systolic anterior motion/hemolysis	1	Pentagon, P2-3	Replacement
7	67 F/MR	Unknown	8	Double pentagon, A1-3	Replacement
8	69 F/MR	Remnant leaflet sclerosis	1	Double pentagon, A1-3	Replacement
9	76 F/MS	Remnant leaflet sclerosis	91	Pentagon, A2-3	Replacement

MR, Mitral regurgitation; MS, mitral stenosis.