Survival and repair durability in patients undergoing concomitant aortic valve reimplantation and mitral valve repair

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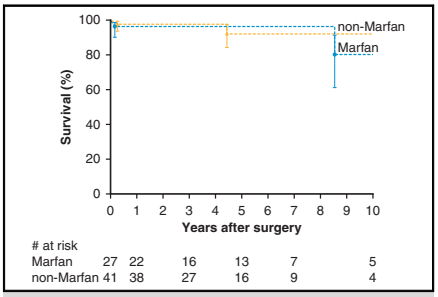
ABSTRACT

Objective: The study objective was to determine repair durability and survival in patients with and without connective tissue disorders undergoing concomitant aortic valve reimplantation and mitral valve repair.

Methods: From 2002 to 2019, 68 patients underwent concomitant aortic valve reimplantation and mitral valve repair, including 27 patients with Marfan syndrome (39.7%). Follow-up echocardiograms were analyzed using nonlinear multiphase mixed-effects cumulative logistic regression. The regurgitation grade over time was estimated by averaging patient-specific profiles. Survival and freedom from reoperation were estimated by the Kaplan–Meier method.

Results: At 7 years, 11% of patients had aortic insufficiency greater than mild (severe in 2 patients). There was no difference in greater than mild aortic insufficiency between patients with or without Marfan syndrome ($P = .37$). Twenty percent of patients had progressed to mitral regurgitation greater than mild (severe in only 1 patient). The prevalence of recurrent mitral regurgitation was higher in those without Marfan syndrome, with greater than mild regurgitation increasing to 24% by 2 years and remaining constant thereafter ($P = .04$). Freedom from reoperation on the aortic valve or mitral valve was 83% at 10 years and did not differ between Marfan syndrome groups. There were no cases of perioperative mortality. Survival at 5 and 10 years was 94% and 87%, respectively, without a difference between those with and without Marfan syndrome.

Conclusions: Patients can undergo a total repair strategy using combined aortic valve reimplantation and mitral valve repair procedures with a low risk of mortality and complications, with favorable freedom from both residual valve regurgitation and reoperation. (JTCVS Techniques 2023;22:159-68)



The 10-year survival for concomitant AV reimplantation and MVr.

CENTRAL MESSAGE

Patients with degenerative MR and aneurysmal aortic root disease can safely undergo concomitant repair of both lesions with favorable survival and repair durability.

PERSPECTIVE

Valve repair is the established treatment strategy for degenerative MV disease. Likewise, for aneurysmal aortic root disease, AV reimplantation is beneficial over composite root replacement using valved conduits. In the subset of patients with both lesions, a total repair strategy can be safely applied, yielding the benefits of each procedure.

Mitral valve repair (MVr) is the gold standard for patients with degenerative disease, conferring benefits over mitral valve (MV) replacement in terms of survival, thromboembolic risk, endocarditis, anticoagulant-related hemorrhage, and reintervention.[1-5] Likewise, in aneurysmal aortic root disease, reimplantation of the

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Abbreviations and Acronyms
AI = aortic insufficiency
AV = aortic valve
MR = mitral regurgitation
MV = mitral valve
MVr = mitral valve repair

aortic valve (AV) has demonstrated beneficial mortality with fewer valve-related adverse events when compared with composite root replacement, along with excellent long-term durability.[6-9] There exists an important minority of patients affected by concomitant aneurysmal aortic root disease and degenerative MV disease. Individually, the goal is repair of the lesion, and both of these procedures can be routinely practiced in isolation with excellent results.[3,10] Less frequent and more technically challenging is the concomitant performance of both procedures, with most reports typically having a significant proportion of prosthetic replacements.[11]

An important subpopulation of this cohort are those people with connective tissue disorders, whose abnormal tissue quality may influence the quality and durability of valve repair. Although possible in subtypes of both Loeys-Dietz and Ehlers-Danlos syndromes, more commonly Marfan syndrome is known to affect both the aortic root and the MV.[12-14] In this population, both MVr and AV reimplantation have demonstrated favorable results, although concomitant AV reimplantation and MVr is performed far less frequently.[15-17]

The objective of this study was to describe a population of patients with and without connective tissue disorders undergoing concomitant AV reimplantation and MVr, and to examine the mortality, repair durability, and incidence of valve reoperation over time.

MATERIAL AND METHODS

Patient Selection, Operative Technique, and Data

The study population includes all patients undergoing combined AV reimplantation and MVr for severe degenerative MR at our institution. All patients met clinical indications for MVr and AV reimplantation alone or as part of a combined procedure.[18] Patients were excluded if they had previous operations or endocarditis. Cases requiring MV or prosthetic aortic root replacement were excluded to limit population heterogeneity. Urgent and emergency procedures were also excluded, as were patients with unidentifiable connective tissue disorders. The study population breakdown can be seen in Figure 1.

All patients underwent AV reimplantation with modification of the technique originally described by David and colleagues with minimal adjunct AV repair techniques used.[19,20] MVr technique included annuloplasty and was tailored to the individual lesion. Posterior leaflet repairs were achieved by triangular resection, quadrangular resection with sliding plasty, or neochord implantation with polytetrafluoroethylene suture. Anterior leaflet repair was achieved by chordal transfer or polytetrafluoroethylene chord implantation. Combinations of techniques were used for bileaflet repair.[21]

The primary baseline, procedural, and morbidity data were abstracted prospectively for quality reporting by independent registry nurses and entered into the Cardiovascular Information Registry. Transthoracic echocardiographic data were measured and entered into the Echocardiography Database by clinical echosonographers. Other Cleveland Clinic electronic medical record databases were also queried. All data used for this study were approved for use in research by the Cleveland Clinic Institutional Review Board, with patient consent waived (Institutional Review Board #4826, approved on December 8, 2021 for the period of December 28, 2021 to December 27, 2022).

End Points

Operative mortality and in-hospital morbidity were defined as for the Society of Thoracic Surgeons National database.[22] For longitudinal

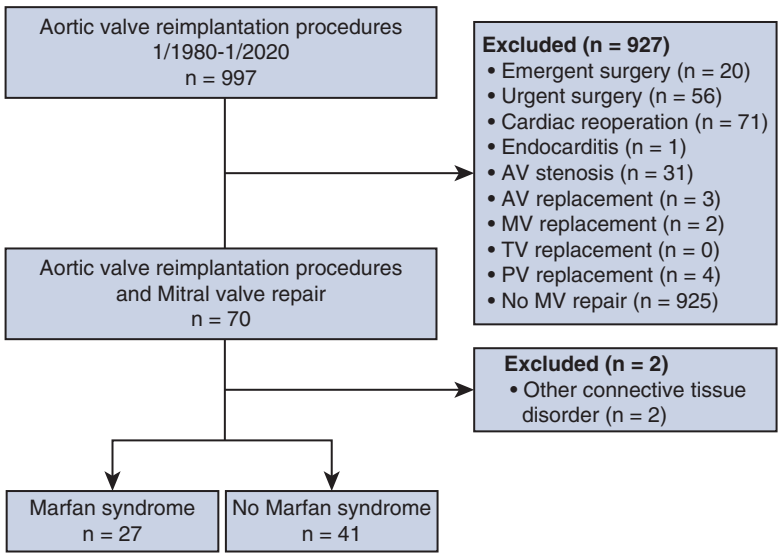


FIGURE 1. CONSORT-style diagram of patients undergoing concomitant AV reimplantation and MVr. *AV*, Aortic valve; *MV*, mitral valve; *TV*, Tricsupid valve; *PV*, pulmonary valve.

estimation of AV and MV regurgitation, all transthoracic echocardiography performed at Cleveland Clinic or provided to the Clinic from outside institutions was reviewed, with the results stored in the Echocardiography Database. Aortic regurgitation and mitral regurgitation (MR) were graded according to a semiquantitative scale as none, trace, mild, moderate, or severe. There were 282 echocardiography records available for 67 of 68 patients (98.5%). Median echocardiography follow-up time was 4.0 months, with 10% of the echocardiography records obtained after 7.6 years. All longitudinal measurements were censored at the time of reoperation.

Patients were followed cross-sectionally for reoperation on the AV or MV and vital status via mailed questionnaire or telephone contact with the patient or a family member. Median follow-up was 2.8 years, with 25% followed more than 6.1 years and 10% more than 11 years. Cross-sectional follow-up for vital status was supplemented with Social Security Death Master File (to 2011) and Ohio State Death Registry data. Median follow-up for vital status was 3.7 years, with 25% followed more than 6.1 years and 10% more than 11 years.

Statistical Analysis

Statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc). Continuous variables are summarized as mean ± SD or as equivalent 15th, 50th (median), and 85th percentiles when the distribution of values was skewed. Categorical data are summarized by frequencies and percentages. The CIs for longitudinal estimates used a bootstrap percentile method to obtain 68% confidence bands (equivalent to ±1 SE). A type I error of 0.05 was used to assess statistical significance.

To assess the temporal trend of individual grades of postoperative aortic and MR (ordinal longitudinal data), follow-up transthoracic echocardiograms were analyzed for the pattern of change across time using a nonlinear multiphase mixed-effects cumulative logistic regression model.[23] The

TABLE 1. Baseline characteristics of patients in the overall group and patients with and without Marfan syndrome groups

Characteristics	Overall (n = 68)		Marfan (n = 27)		Non-Marfan (n = 41)	
	n*	n (%) or Mean ± SD	n*	n (%) or Mean ± SD	n*	n (%) or Mean ± SD
Demographics						
Age (y)	68	49 ± 17	27	36 ± 16	41	57 ± 12
Female	68	14 (21)	27	8 (30)	41	6 (15)
White	67	64 (96)	27	27 (100)	40	37 (93)
Body mass index (kg/m^2)	68	25 ± 5.0	27	22 ± 3.0	41	28 ± 4.6
AI	68	36 (53)	27	10 (37)	41	26 (63)
None	67	31 (46)	26	16 (62)	41	15 (37)
Mild	67	18 (27)	26	8 (31)	41	10 (24)
Moderate	67	14 (21)	26	2 (7.7)	41	12 (29)
Severe	67	4 (6.0)	26	0 (0)	41	4 (9.8)
MR	68	66 (97)	27	25 (93)	41	41 (100)
None	68	2 (2.9)	27	2 (7.4)	41	0 (0)
Mild	68	9 (13)	27	4 (15)	41	5 (12)
Moderate	68	18 (26)	27	7 (26)	41	11 (27)
Severe	68	39 (57)	27	14 (52)	41	25 (61)
Aortic root size (diameter)						
Sinus of Valsalva maximum diameter (cm)	64	4.7 ± 0.45	25	4.6 ± 0.40	39	4.7 ± 0.48
Ascending aorta maximum diameter (cm)	57	4.01 ± 0.68	21	3.8 ± 0.72	36	4.1 ± 0.65
LV function						
LV ejection fraction (%)	67	59 ± 6.5	26	57 ± 6.1	41	61 ± 6.5
Other cardiovascular comorbidities						
Atrial fibrillation/flutter	66	5 (7.6)	26	2 (7.7)	40	3 (7.5)
Previous MI	68	3 (4.4)	27	1 (3.7)	41	2 (4.9)
Noncardiac comorbidities						
Pharmacologically treated diabetes	67	3 (4.5)	27	1 (3.7)	40	2 (5.0)
COPD	68	21 (31)	27	9 (33)	41	3 (7.3)
Peripheral artery disease	68	3 (4.4)	27	0 (0)	41	3 (7.3)
Hypertension	67	42 (63)	27	10 (37)	40	32 (80)
Smoking	68	21 (31)	27	7 (26)	41	14 (34)
Dyslipidemia	68	26 (38)	27	7 (26)	41	19 (46)
Creatinine (mg/dL)	68	0.96 ± 0.19	27	0.87 ± 0.16	41	1.01 ± 0.19
Cerebral vascular accident	68	2 (2.9)	27	0 (0)	41	2 (4.9)
Dialysis	66	0 (0)	26	0 (0)	40	0 (0)

AI, Aortic insufficiency; *MR*, mitral regurgitation; *LV*, left ventricular; *MI*, myocardial infarction; *COPD*, chronic obstructive pulmonary disease. *Patients with data available.

prevalence of each regurgitation grade over time was estimated by averaging the patient-specific profiles. Because of few echocardiogram records in the severe regurgitation category, this category was collapsed together with the moderate category for analysis purposes. Survival and freedom from reoperation were estimated nonparametrically by the Kaplan–Meier method. Comparisons were made using log-rank test.

RESULTS

Patient Characteristics

From 2002 to 2019, 68 patients underwent primary concomitant AV reimplantation and MVr. There were 27 patients with connective tissue disorders, all of which were Marfan syndrome (39.7%). Two patients were excluded because connective tissue diagnosis remained undefined even though they were classed as such. Combined operations slowly increased during this time period, averaging 2.2 combined procedures per year from 2002 to 2014 and increasing to an average of 8.4 combined procedures from 2015 to 2019. Patients were predominantly male and White. Those with Marfan syndrome were typically younger, with fewer comorbidities. Preoperative aortic insufficiency (AI) was present in 53% of patients and more prevalent in those patients without Marfan syndrome. Full demographic information is shown in Table 1.

Perioperative Outcomes

Concomitant procedures were infrequent and comparable between those with and without Marfan syndrome. Cardiopulmonary bypass and aortic crossclamp times were also comparable between groups. There were no cases of postoperative deep sternal wound infection, stroke, reoperation for bleeding, or renal dysfunction (with or without dialysis). A lower incidence of atrial fibrillation was seen in the Marfan syndrome group, although this group did have 1 perioperative reoperation for valvular dysfunction. There were no cases of perioperative mortality. Detailed perioperative information is shown in Table 2. Specific valve pathology and repair techniques used are reported in Table 3.

Recurrent Aortic or Mitral Insufficiency

After the first year of follow-up, there was a gradual decrease in the proportion of patients with no AI, constant after the first year, and a concomitant increase in the

TABLE 2. Operative details and in-hospital morbidities and mortality

Characteristics	Overall (n = 68)		Marfan (n = 27)		Non-Marfan (n = 41)	
	n*	n (%) or median (15th-85th percentile)	n*	n (%) or median (15th-85th percentile)	n*	n (%) or median (15th-85th percentile)
Concomitant procedures						
CABG	68	2 (2.9)	27	1 (3.7)	41	6 (2.4)
Tricuspid valve repair	68	9 (13)	27	4 (15)	41	5 (12)
Surgical ablation for atrial fibrillation	68	5 (7.4)	27	2 (7.4)	41	3 (7.3)
Septal myectomy	56	2 (3.6)	24	1 (4.2)	32	1 (3.1)
ASD/PFO closure	68	3 (4.4)	27	1 (3.7)	41	2 (4.9)
Support						
Circulatory arrest	68	1 (1.5)	27	0 (0)	41	1 (2.1)
Aortic crossclamp time (min)	68	145 (104-201)	27	131 (101-203)	41	151 (106-201)
Cardiopulmonary bypass time (min)	57	170 (124-235)	27	166 (112 - 239)	41	174 (132-221)
Transfusion						
Any blood product transfusion	68	47 (69)	27	18 (67)	41	29 (71)
In-hospital morbidities and mortality						
Deep sternal wound infection	68	0 (0)	-	-	-	-
Stroke	68	0 (0)	-	-	-	-
Renal dysfunction	68	0 (0)	-	-	-	-
Reoperation for bleeding	68	0 (0)	-	-	-	-
Reoperation (valve dysfunction)	68	1 (1.5)	27	1 (3.7)	41	0 (0)
Atrial fibrillation	61	23 (38)	24	5 (21)	37	18 (49)
Operative mortality	68	0 (0)	-	-	-	-
Operative length of stay (d)	68	7 (5-12)	27	7 (5-15)	41	6 (5-11)

CABG, Coronary artery bypass grafting; *ASD*, atrial septal defect; *PFO*, patent foramen ovale. *Patients with data available.

TABLE 3. Valve pathology and repair techniques used

	Overall (n = 68)		Marfan (n = 27)		Non-Marfan (n = 41)	
	N*	n (%)	N*	n (%)	N*	n (%)
AV pathology						
Bicuspid valve	68	8 (11.8)	27	1 (3.7)	41	7 (17.1)
AV repair						
Commissuroplasty	60	8 (13.3)	26	3 (11.5)	34	5 (14.7)
Cusp plication	60	2 (3.3)	26	0 (0)	34	2 (5.9)
Subcommissural closure	60	0 (0)	26	0 (0)	34	0 (0)
Closure of perforation	60	1 (1.7)	26	1 (3.8)	34	0 (0)
Cusp debridement	60	2 (3.3)	26	0 (0)	34	2 (5.9)
Mitral pathology						
Posterior prolapse	48	23 (47.9)	20	15 (75)	28	8 (28.6)
Anterior prolapse	50	9 (18)	21	7 (33.3)	29	2 (6.9)
Bileaflet prolapse	48	18 (37.5)	20	7 (35)	28	11 (39.3)
Chordal rupture	66	7 (10.6)	27	3 (11.1)	39	4 (10.3)
Mitral repair						
Annuloplasty	68	66 (97.1)	27	26 (96.3)	41	40 (97.5)
Chordal transfer	68	2 (2.9)	27	1 (3.7)	41	1 (2.4)
Cleft closure	68	11 (16.2)	27	5 (18.5)	41	6 (14.6)
Commissuroplasty	67	11 (16.4)	26	6 (23.1)	41	5 (12.2)
Edge to edge repair	67	7 (10.4)	26	4 (15.4)	41	3 (7.3)
Leaflet resection	67	31 (46.3)	26	11 (42.3)	41	20 (48.8)
Sliding plasty	68	14 (20.6)	27	5 (18.5)	41	9 (22)
Neochordae	67	10 (14.9)	26	2 (7.7)	41	8 (19.5)

AV, Aortic valve. *Patients with data available.

proportion of patients with mild AI. At 7 years, 22% of patients had mild AI and only 11% had progressed to AI greater than mild (Figure 2, *A*). Two patients had progressed to severe AI. These were due to recurrent cusp prolapse causing an eccentric posterior jet and thickened and retracted AV cusps, respectively. There was no difference in the prevalence of greater than mild AI over time between patients with or without Marfan syndrome ($P = .37$; Figure 2, *B*).

A somewhat different picture was present when examining the MV results. There was a decrease in the proportion of patients with no MR and a concomitant increase in the proportion of patients with mild MR and greater than mild MR. After the first year, the changes were more gradual. At 7 years, 26% of patients had mild MR, and 20% had progressed to MR greater than mild (Figure 3, *A*). Only 1 patient had progressed to severe MR and has yet to undergo reintervention. This was due to progressive posterior leaflet restriction and poor anterior leaflet coaptation. Although there was no early difference ($P = .90$), over time the prevalence of greater than mild MR diverged between patients with and without Marfan syndrome. Although the Marfan syndrome group remained constant at approximately 6.7%, the non-Marfan group increased in prevalence of greater than mild MR to 24% by 2 years and remained constant thereafter ($P = .04$; Figure 3, *B*).

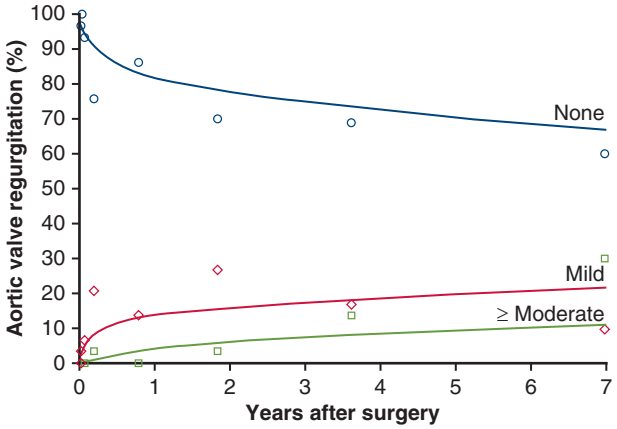
Six patients had moderate MR. Posterior leaflet restriction with poor anterior leaflet coaptation was present in 1 patient. There were 2 cases of recurrent anterior leaflet prolapse and a single case of recurrent posterior leaflet prolapse. Two patients had central functional-appearing MR.

Two patients had both moderate AI and MR. One case of systolic anterior motion with left/noncoronary cusp prolapse was present, and 1 patient had central MR due to a relatively short region of MV coaptation accompanied by noncoronary cusp prolapse.

Reoperation

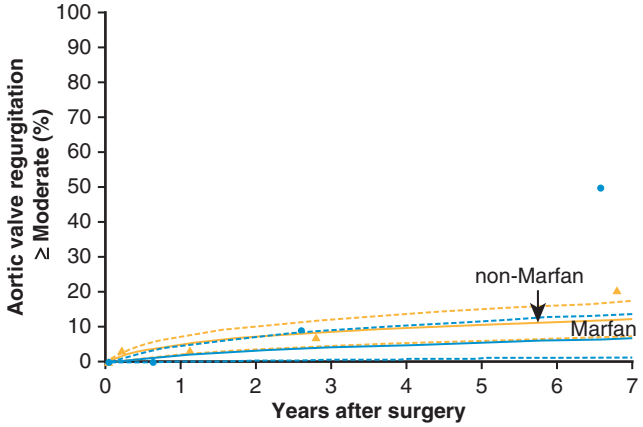
There were 6 reoperations on the AV or MV performed during the follow-up period, divided equally between those with and without Marfan syndrome. Of these 6 reoperations, 3 were reoperations on both the AVs and MVs, 3 were isolated MV reoperations, and 0 were isolated AV reoperations. Freedom from reoperation on the AV or MV was 83% at 10 years (Figure 4, *A*). There was no significant difference in the freedom from reoperation between patients with and without Marfan syndrome; 5- and 10-year freedom from reoperation were 89% versus 93% and 71% versus 93%, respectively (P[log-rank] = .62; Figure 4, *B*).

The 3 operations on both the AVs and MVs were performed in patients without Marfan syndrome. There was 1 case of extensive infective endocarditis requiring AV and MV replacement 2 months from the original surgery. One



Years after surgery	0	1	2	3	4	5	6
Patients	65	25	17	11	10	6	7
Echocardiograms	138	28	19	11	11	6	7

A

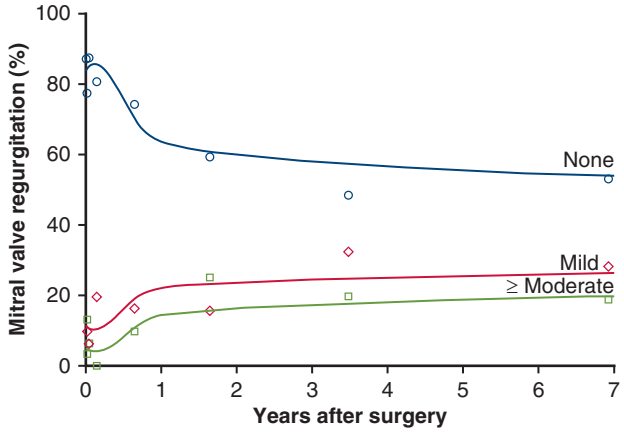


	Years after surgery	0	1	2	3	4	5	6
Non-Marfan	Patients	40	18	14	10	7	3	5
	Echocardiograms	95	21	16	10	7	3	5
Marfan	Patients	25	7	3	1	3	3	2
	Echocardiograms			3	1	4	3	2

B

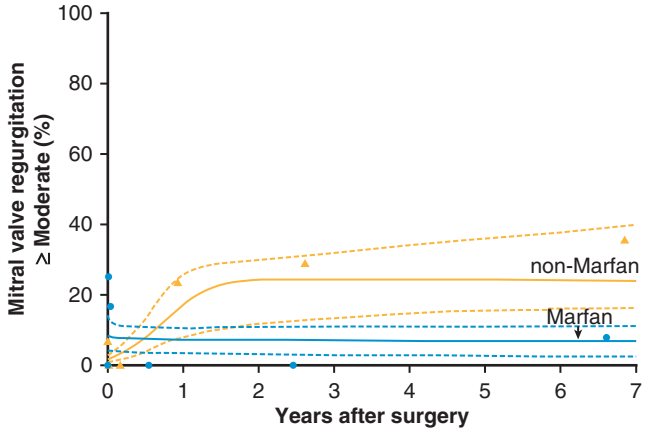
FIGURE 2. Longitudinal aortic regurgitation (*AR*) grades after concomitant AV reimplantation and MVr. Symbols represent data grouped (without regard to repeated measurements) within time frames to provide a crude verification of model fit. A, Postoperative prevalence of AR grades over time. Solid lines represent longitudinal trend in AR grades. Echocardiography follow-up: Shown are the number of patients remaining across follow-up years and number of follow-up echocardiograms within each yearly interval. B, Comparison of AR grades between patients with and without Marfan syndrome. Solid lines represent unadjusted estimates of prevalence of moderate or more AR grade over time, enclosed within a 68% confidence band. Echocardiography follow-up of the 2 cohorts: Shown are the number of patients remaining across follow-up years and number of follow-up echocardiograms within each yearly interval.

reoperation was the result of a failed bicuspid AV repair with less than severe MR requiring reoperation 5 months after the initial operation with severe AI and moderate eccentric MR secondary to a focal region of annuloplasty band dehiscence. The MV was able to be re-repaired, and the AV was replaced. The final reoperation took place 13.5 years after the initial operation: recurrent severe AI due to thickened and retracted cusps without stenosis requiring



Years after surgery	0	1	2	3	4	5	6
Patients	66	25	17	11	10	6	7
Echocardiograms	154	28	19	11	11	6	7

A



	Years after surgery	0	1	2	3	4	5	6
Non-Marfan	Patients	41	18	14	10	7	3	5
	Echocardiograms	107	21	16	10	7	3	5
Marfan	Patients	25	7	3	1	3	3	2
	Echocardiograms	47	7	3	1	4	3	2

B

FIGURE 3. Longitudinal MR grades after concomitant AV reimplantation and MVr. Symbols represent data grouped (without regard to repeated measurements) within time frames to provide a crude verification of model fit. A, Postoperative prevalence of MR grades over time. Solid lines represent longitudinal trend in MR grades. Echocardiography follow-up: Shown are the number of patients remaining across follow-up years and number of follow-up echocardiograms within each yearly interval. B, Comparison of MR grades between patients with and without Marfan syndrome. Solid lines represent unadjusted estimates of prevalence of moderate or more MR grade over time, enclosed within a 68% confidence band. Echocardiography follow-up of the 2 cohorts: Shown are number of patients remaining across follow-up years and number of follow-up echocardiograms within each yearly interval.

replacement, and moderate MR due to progression of mitral disease able to be re-repaired.

All isolated mitral reoperations were in patients with Marfan syndrome and required MV replacements. One case was infective endocarditis 9 years postoperatively secondary to a prostatic abscess. Two cases were early replacements within the first 2 weeks due to recurrent greater than moderate MR secondary to failed surgical edge-to-edge

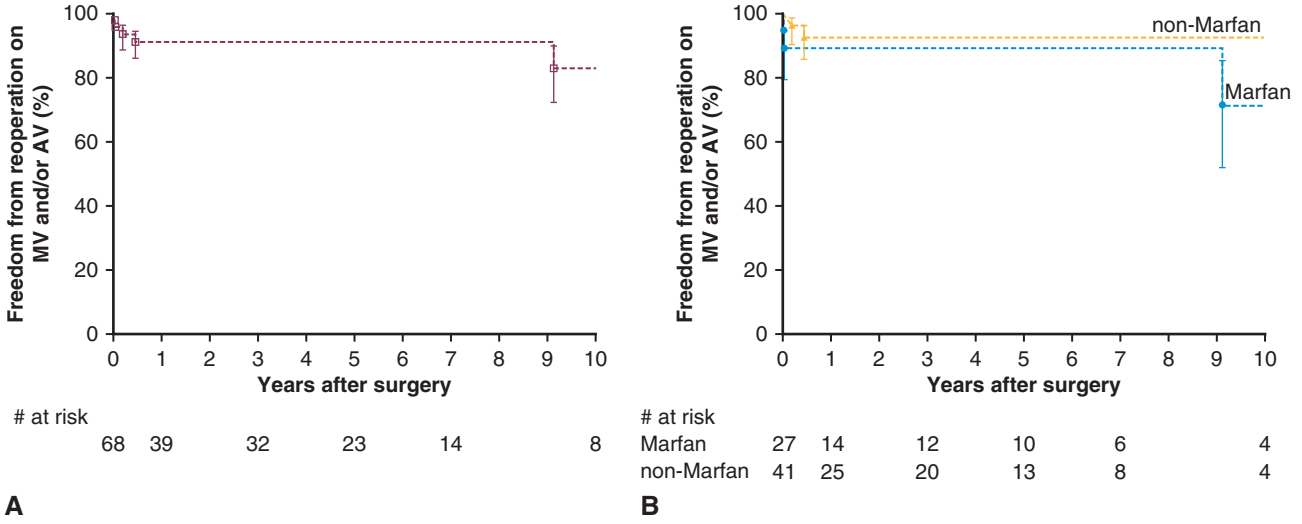


FIGURE 4. Time-related reoperation on AV or MV after concomitant AV reimplantation and MVr. Each symbol represents a Kaplan–Meier estimate of the event, and vertical bars are 68% confidence limits equivalent to ± 1 SE. Numbers below horizontal axis are patients remaining at risk. A, Overall freedom from AV or MV reoperation. B, Comparison of freedom from AV or MV reoperation between patients with and without Marfan syndrome. *MV*, Mitral valve; *AV*, aortic valve.

repair in the context of anterior leaflet disease and annular dilation.

Survival

Five deaths were observed during follow-up: 3 in the Marfan group and 2 in the non-Marfan group. Overall survivals at 5 and 10 years were 94% and 87%, respectively (Figure 5, *A*). There was no significant difference in survival between patients with and without Marfan syndrome; 5- and 10-year survivals were 96% versus 92% and 80% versus 92%, respectively (P[log-rank] = 0.70; Figure 5, *B*).

Two patients who underwent reoperations died. The previously described patient with extensive endocarditis 2 months from the initial operation failed to make a meaningful recovery, with comfort care measures ultimately being instituted 4 weeks from the reoperation. The second previously described patient with isolated MV endocarditis 9 years from the original operation was followed an additional 9 years, after which the patient died of pneumonia secondary to stage IV non–small cell lung cancer.

In patients without reoperations, there were 3 mortality events. One event was secondary to mediastinitis occurring 2 months from the initial operation. One patient was well at

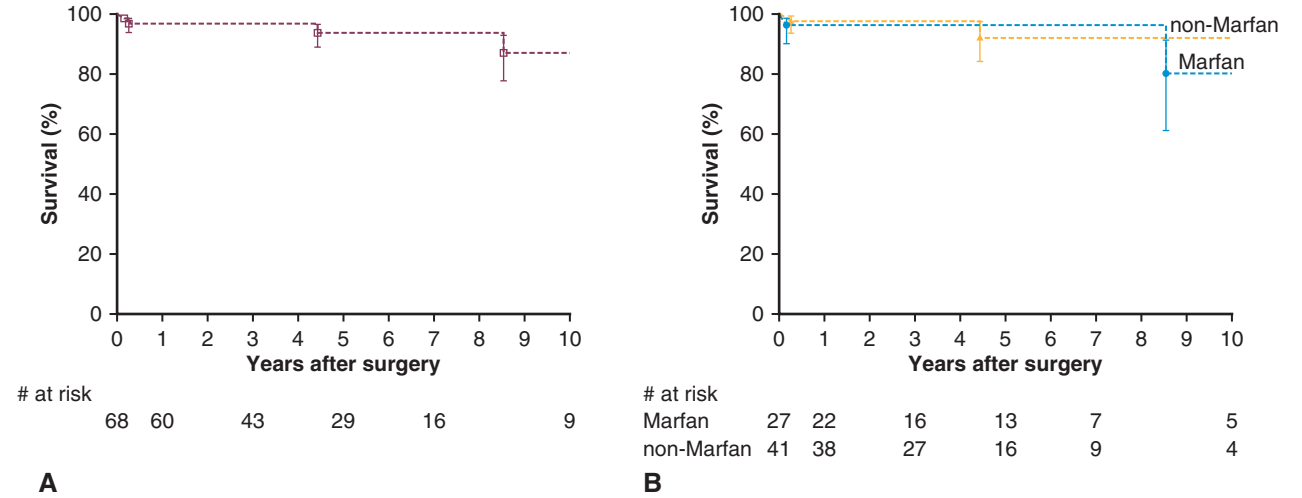


FIGURE 5. Survival after concomitant AV reimplantation and MVr. Format as in Figure 4. A, Overall survival. B, Comparison of survival between patients with and without Marfan syndrome.

the last observed clinical follow-up, 8.5 years from the initial operation, and died 24 days later. Finally, 1 mortality event was recorded in the Ohio Death Record Index 4.5 years from the initial operation, without the record of cause of death available.

DISCUSSION

Our series demonstrates that concomitant AV reimplantation and MVr can be performed successfully without perioperative mortality or significant complication. During the follow-up period, we found a low incidence of mortality, with durability and freedom from reintervention in line with those undergoing isolated procedures. When favorable anatomy is present, it is feasible if not favorable to use a complete valve-preserving strategy.

Previous work focused on a total repair strategy demonstrated favorable mortality and freedom from valve-related complications, while acknowledging that durability remained a concern.[24] This population, however, had abnormal AVs requiring specific AV repair techniques, not otherwise normal AVs with aneurysmal aortic root disease. In a more recent study, we demonstrated that combined aortic root and MVr surgery can be achieved with a low incidence of perioperative mortality and complications, excellent long-term survival, and excellent durability/freedom from reintervention.[11] However, in this study, only a minority of the population underwent a combined AV reimplantation and MVr procedure (41/118, 34.7%), with the remainder receiving composite, homograft, or biologic aortic root replacement procedures. Because of this previously reported population heterogeneity, our current study gives a unique insight. The incidence of valve reoperations was low overall and not clearly different between those with and without Marfan syndrome. Previous work on this topic has shown that in the case of connective tissue disorders, although valve tissue quality and lesion morphology may be different, the repair should not be expected to have inferior durability when compared with a patient without a connective tissue disorder.[25,26]

When comparing our outcomes with those from other reference centers, our results are largely similar. In a series of patients undergoing combined aortic root and MV surgery reported by David and colleagues,[27] the overall operative mortality was 6.5%, with a 79.3% 10-year survival and 85.7% 10-year freedom from reintervention. Although less favorable than our results in terms of perioperative and longer-term survival, this population included a heterogeneous case mix that included reoperations, endocarditis, and multiple other valve pathologies; 38% were considered nondegenerative, and a total repair population was not reported. Additionally, only 17% underwent AV reimplantation and 54% underwent MVr, with the rest being root or valve replacements. The addition of mechanical valves may have favorably influenced the longer-term durability results. Similar findings to this were found in a more recent article by Vohra and colleagues[28] examining combined AV and MVr surgery. This demonstrated 67.3% 10-year survival and 78.4% freedom from valve reintervention. This series was also somewhat heterogeneous, with only 36.9% undergoing a concomitant AV reimplantation and MVr. Survival and durability may have been influenced by the inclusion of both rheumatic and infective valve pathologies.

A series of patients undergoing aortic root replacement with or without MVr for moderate MR was reported by McCarthy and colleagues.[29] In this series, 31 patients (29.8%) underwent MVr in addition to aortic root replacement surgery, although the specific aortic root approach was not specified. Although excellent results were demonstrated, only 32% of the MVr group had myxomatous degeneration and all had only moderate MR at the time of surgery.

Study Limitations

This study must be considered in the context of certain limitations. This is a single institution case series with intermediate follow-up, and as such there is no formal comparator arm. In this observational setting, there was not protocolized follow-up and echocardiographic follow-up was at the discretion of the referring physician. Although we made a distinction between patients with and without Marfan syndrome, the population is too small to allow meaningful between-group comparison, and this should be considered both educational and hypothesis generating. Although adhering to guidelines in recommending AV or MV surgery, there is necessarily a selection bias present when considering who should receive this longer and technically more complex, combined procedure. Both surgeon and institution-specific biases necessarily will exist in this single-center study. We are fortunate to practice in a high-volume specialist center where these procedures are considered routine. Therefore, our findings cannot necessarily be considered widely generalizable. Finally, given the small population, trends regarding reoperation and durability must be interpreted in the context of potential sampling error. Likewise, the absence of certain other connective tissue disorders should be viewed as a result of the small sample population.

CONCLUSIONS

In a high-volume center with dedicated AV and MV specialists, patients with concomitant aneurysmal aortic root disease and degenerative MR can undergo a total repair strategy using combined AV reimplantation and MVr procedures with a low expected risk of mortality and complications. Freedom from both residual valve regurgitation and reoperation over the intermediate term is favorable.

Conflict of Interest Statement

D.J.P.B.: Consultant/speaker: Medtronic, Edwards Lifesciences. M.Y.D.: Consultant: Medtronic, Bristol Myers Squibb, Cytokinetics, Tenaya Therapeutics. A.M.G.: Consultant: Edwards Lifesciences, Abbott, Medtronic, AtriCure, ClearFlow, Artivion. E.E.R.: Consultant: Artivion, Edwards Lifesciences, WL Gore, Medtronic; Speaker: Artivion, Cook, Corcym, Edwards Lifesciences, WL Gore, JenaValve, Terumo Aortic; License: Artivion. P.R.V.: Speaker: Artivion, Edwards Lifesciences. All other authors reported no conflicts of interest.

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

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