

Surgical Management of the Aortic Root in Patients with Marfan Syndrome

Kenton J. Zehr¹, Alireza Matloobi¹, Heidi M. Connolly², Thomas A. Orszulak¹, Francisco J. Puga¹, Hartzell V. Schaff¹

Divisions of ¹Cardiovascular Surgery and ²Cardiology, Mayo Clinic, Rochester, MN, USA

Background and aim of the study: Surgical aortic root reconstruction techniques are standard therapy to avoid catastrophic vascular events in patients with Marfan syndrome with a dilated and/or dissected aortic root. The study aim was to evaluate the long-term results of aortic root reconstruction.

Methods: Eighty-three patients (54 males, 29 females; mean age 37 ± 17 years) fulfilling strict Ghent criteria for Marfan syndrome underwent aortic root surgery between 1971 and 2001. Of these patients, 65 (78%) underwent a composite valve conduit repair and 18 (22%) a valve-sparing aortic root reconstruction. Six patients (7%) suffered from an acute type A dissection, and 16 (19%) a chronic type A dissection.

Results: In-hospital and 30-day mortality was 3.6% (n = 3). Morbidity included stroke (1.2%; n = 1), perioperative myocardial infarction (1.2%; n = 1) and reoperation for bleeding (10%; n = 8). Of 21 late deaths, the cause was cardiac in nine cases. Actuarial survival at 5, 10, 15 and 20 years was 84% (95% CI 76-93%), 73% (CI 61-86%), 59% (CI 45-77%) and 43% (CI

26-72%), respectively. Multivariate predictors for late death were postoperative dysrhythmias and need for inotropes ($p \leq 0.01$). Freedom from reoperation at 5, 10, 15 and 20 years was 86% (CI 78-95%), 69% (CI 56-85%), 53% (CI 38-74%) and 48% (CI 23-71%), respectively. Multivariate predictors for reoperation were preoperative mitral valve prolapse and an initial valve-sparing aortic procedure ($p \leq 0.05$). In the composite valve conduit patients, freedom from thromboembolism was 88% (CI 76-100%), and from endocarditis was 99% (CI 93-100%) at 15 years.

Conclusion: Composite valve conduit replacement of the aortic root in patients with Marfan syndrome offers a durable result, with low mortality and long-term complication rates. Reoperation was most commonly required for cardiac and vascular disease unrelated to the initial operation and in patients undergoing a valve-sparing aortic root procedure.

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Since Bentall introduced the surgical technique of composite valve conduit replacement of a large aortic root aneurysm in 1968 (1), the procedure with minor modification has become standard therapy in Marfan syndrome patients (2-6). Incremental morbidity related to the need for chronic anticoagulation has stimulated interest in valve-preserving procedures. Sarsam and Yacoub (7) and David and Feindel (8) have each described reconstructive techniques to remove or exclude the diseased aneurysmal tissue while preserving the native aortic valve. The decision to preserve the

native valve in a Marfan syndrome patient assumes that the increased benefit of avoiding anticoagulation is not offset by the need for reoperation. The study aim was to evaluate the long-term results of aortic root reconstruction in Marfan syndrome patients and to identify risk factors for late death and the need for further operative intervention.

Clinical material and methods

Patients

A retrospective review of the authors' database identified patients with Marfan syndrome undergoing aortic root reconstruction between January 1971 and December 2000. Patients were included who fulfilled strict Ghent criteria (9) for Marfan syndrome. In all patients, the aneurysm involved the sinuses of Valsalva, the sinotubular junction and the proximal ascending aorta. Patients with a type A dissection,

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Address for correspondence:
Kenton J. Zehr MD, Division of Cardiovascular Surgery, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA
e-mail: zehr.kenton@mayo.edu

either acute or chronic, were included.

Follow up was 100% complete, and data were obtained by chart review and a detailed questionnaire sent to surviving patients. Echocardiographic data were obtained from 57 patients (69%) at follow up.

Eighty-three patients (54 males, 29 females; mean age 37 ± 17 years) underwent aortic root reconstruction. Among these patients, 65 (78%) underwent a composite valve conduit repair (57 mechanical valves, six biological valves, two homografts), and 18 (22%) underwent valve-preserving aortic root reconstruction. The preoperative variables are detailed in Table I. Sixty-seven patients (81%) were operated on electively, 11 (13%) urgently, and five (6%) emergently. The mean maximal aneurysm diameter was 55 ± 19 mm. Six patients (7%) suffered from an acute type A dissection, and 16 (19%) a chronic type A dissection. The mean maximal aneurysm diameter in patients was 61 ± 11 mm without dissection, 52 ± 25 mm in those with acute dissection, and 36 ± 30 mm in those with chronic dissection. Thirty-four (41%) patients had grade III or IV aortic regurgitation.

Statistical analysis

Postoperative survival, and freedom from cardiac death, reoperation, thromboembolism, endocarditis and hemorrhagic complications, were estimated using the Kaplan-Meier method. Overall survival was compared to the expected survival of persons of the same age and sex, as derived from vital statistics for the West North Central region of the United States (Fig. 1). The statistical significance of observed versus expected survival was assessed with a one-sample log-rank test. The associations of potential risk factors to survival were assessed with log-rank tests and the Cox proportional hazards model. The variables identified in Tables I-IV were subjected to analysis. Factors showing significance in the univariate analysis ($p < 0.05$) were analyzed in the multivariate model. Patients undergo-

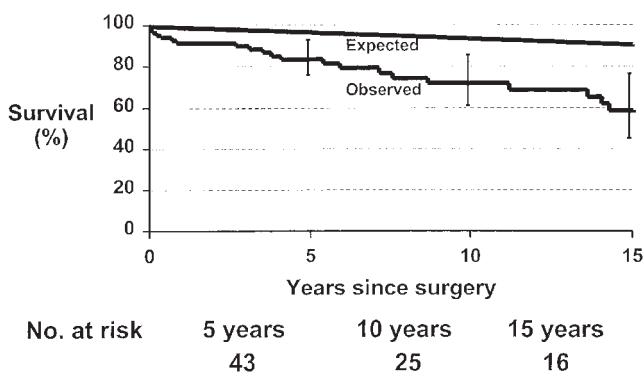


Figure 1: Observed late survival for all surviving patients compared to expected survival curve for the general population. Survival versus event, $p < 0.001$.

Table I: Patient preoperative data.

Parameter	No. of patients
Gender*‡	
Male	54 (65)
Female	29 (35)
Age (years)*‡	$37 \pm 17^+$
Family history of Marfan syndrome*‡	39 (47)
Skeletal abnormalities	65 (78)
Pectus excavatum	17 (20)
Dolichostenomelia	23 (28)
Other skeletal abnormalities	52 (63)
High-arched palate	40 (48)
Ocular abnormalities	49 (59)
Ectopia lentis	27 (33)
Skin stria	13 (16)
Previous surgery	9 (11)
Preoperative symptoms	
Any symptoms	55 (66)
Dyspnea*	22 (27)
Chest pain*	23 (28)
Palpitations	7 (8)
Presyncope/syncope*	1 (1)
Back pain*	8 (10)
Transient ischemic event*	5 (6)
History of cardiac dysrhythmia*‡	9 (11)
NYHA functional class*	
I	61 (73)
II	17 (20)
III	1 (1)
IV	3 (4)
Preoperative beta-blocker*‡	35 (42)
Maximal aortic diameter (mm)*‡	$55 \pm 19^+$
Aortic annulus (mm)	$29 \pm 8^+$
Aortic arch diameter (mm)	$33 \pm 16^+$
Aortic dissection - Type A, acute*‡	6 (7)
Aortic dissection - Type A, chronic*‡	16 (19)
Aortic regurgitation*	
None to trivial	25 (14)
Mild	24 (13.5)
Moderate	54 (30)
Severe	76 (42.5)
Mitral regurgitation*‡	
None to trivial	17 (20)
Mild	13 (16)
Moderate	12 (14)
Severe	22 (27)
Left ventricular hypertrophy (ECG)*‡	37 (45)
Left ventricular size	
End-diastolic diameter (mm)*‡	$63 \pm 24^+$
End-systolic diameter (mm)	$41 \pm 12^+$
Left ventricular ejection fraction (%)*‡	$56 \pm 11^+$
Bicuspid aortic valve*‡	4 (5)
Mitral valve prolapse*‡	23 (28)
Other aneurysms	11 (13)

Values in parentheses are percentages.

*Mean \pm SD.

‡Variable assessed as risk factor for mortality.

‡Variable assessed as risk factor for reoperation.

Table II: Procedures performed and operative data.

Procedure No. of patients	
Elective operation*‡	67 (81)
Urgent operation*‡	11 (13)
Emergent operation*‡	3 (4)
Emergent/salvage*‡	2 (2)
Primary procedure performed	
Composite valve conduit reconstruction*‡	63 (76)
Bentall	24
Modified Bentall	39
Mechanical composites	57
Biological composites	6
Valve-preserving aortic root reconstruction*‡	18 (22)
Aortic root remodeling technique	3
Aortic root reimplantation technique	15
Homograft aortic root reconstruction*‡	2 (2)
Patients requiring associated procedures*‡	
Mitral valve replacement	4 (5)
Mitral valve repair	1 (1)
Hypothermic circulatory arrest used	4 (5)
Aortic cross-clamp time (min)*	100 ± 32*

Values in parentheses are percentages.

*Mean ± SD.

*Variable assessed as risk factor for mortality.

‡Variable assessed as risk factor for reoperation.

Table III: Perioperative variables and complications.

Parameter	No. of patients
<i>Variable</i>	
Intra-aortic balloon pump	2 (2)
Inotropes*	15 (18)
Postoperative arrhythmias*	15 (18)
Atrial fibrillation	13 (15)
Ventricular tachycardia	3 (4)
Transfusion requirement*	59 (71)
<i>Complication</i>	
Reoperation for bleeding	8 (10)
Perioperative myocardial infarction*	1 (1)
Low cardiac output syndrome*	5 (6)
Tracheostomy	2 (2)
Permanent pacemaker insertion	1 (1)
Perioperative stroke	1 (1)

Values in parentheses are percentages.

*Variable assessed as risk factor for mortality.

ing composite valve conduit aortic root replacement and those undergoing valve-preserving aortic root reconstruction were compared with chi-square tests for the categorical variables and Rank sum tests for continuous variables. Data were expressed as mean ± SD, and a p-value <0.05 was considered to be statistically significant.

Results

Operative procedures performed, together with intraoperative data, are detailed in Table II. Pathology was available in 53 patients (64%), and confirmed cystic medial necrosis in all cases. Tissue was not obtained for pathological analysis in the remaining 30 patients (36%). Morbidity included stroke (1%; n = 1), perioperative myocardial infarction (1%; n = 1) and reoperation for bleeding (10%; n = 8). Perioperative variables and complications are detailed in Table III. In-hospital and 30-day mortality was 3.6% (n = 3). The cause of the two in-hospital deaths was cardiac failure, whilst the single 30-day mortality occurred at home two weeks after surgery and was of unknown cause. Among 21 late deaths, the cause was cardiac in only nine cases. Of the nine known late cardiac deaths, three patients died from congestive heart failure, two died secondary to coronary artery disease, one patient died from a ruptured descending thoracic aneurysm, one from a descending thoracic aortic dissection, one from a ruptured right coronary artery pseudoaneurysm, and one died during attempted repair of a descending thoracic aortic aneurysm. Follow up data are detailed in Table IV. The mean follow up was 7.6 ± 6.6 years. Actuarial survival at five, 10, 15 and 20 years was 84% (95% CI 76-93%), 73% (CI 61-86%), 59% (CI 45-77%) and 43% (CI 26-72%), respectively (Fig. 1). There was a significant difference between the survival curve of this patient series compared to the general population

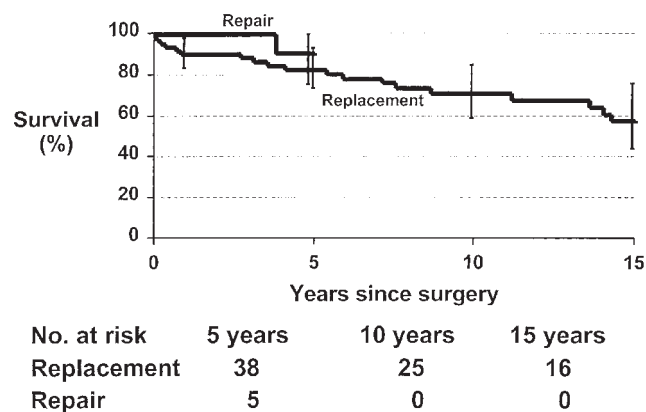


Figure 2: Late survival for surviving patients comparing patients undergoing a composite graft reconstruction to those undergoing a valve-preservation procedure. p = 0.30.

Table IV: Follow up data.

Parameter	Data
Mean follow up (years)	7.9 ± 6.9 ⁺
NYHA functional class	
I	43 (52)
II	34 (41)
III	3 (4)
Left ventricular size	
End-diastolic diameter (mm)	56 ± 10 ⁺
End-systolic diameter (mm)	37 ± 10 ⁺
Left ventricular ejection fraction (%)	56 ± 11 ⁺
Mean aortic valve gradient (mmHg)	12 ± 7 ⁺
Proximal ascending aorta diameter (mm)	31 ± 6 ⁺
Aortic arch diameter (mm)	29 ± 6 ⁺
Late deaths	24 (29)
Cardiac	11 (13)
Non-cardiac	8 (10)
Unknown	5 (6)
Warfarin complication	16 (22)
Life-threatening hemorrhage	4 (5)
Minor hemorrhage	14 (17)
Thromboembolism	5 (6)
Permanent	2 (2)
Transient	3 (4)
Mean time to thromboembolism (years)	7.7 ± 6.6 ⁺
Late endocarditis	1 (1)
Mean time to endocarditis event (years)	1.9
Reoperation [*]	
Aortic valve replacement	7 (9)
Other aortic aneurysm or dissection	9 (11)
Mitral valve replacement	2 (2.5)
Coronary artery bypass grafting	2 (2.5)
Pseudoaneurysm repair	2 (2.5)

Values in parentheses are percentages.

⁺Mean ± SD.

^{*}Total 22 procedures in 20 patients.

curve of expected mortality. There was no difference in late survival between those patients having a composite valve conduit reconstruction versus those undergoing valve-preserving surgery (Fig. 2).

Freedom from reoperation was 86% (CI 78-95%), 69% (CI 56-85%), 53% (CI 38-74%) and 48% (CI 23-71%) at five, 10, 15 and 20 years, respectively. There was a significantly higher freedom from reoperation in patients undergoing composite valve conduit reconstruction compared to those undergoing valve-preserving surgery (92% (CI 85-100%) versus 58% (CI 32-100%) at five-year follow up ($p < 0.007$) (Fig. 3). Among 22 reoperations conducted in 20 patients

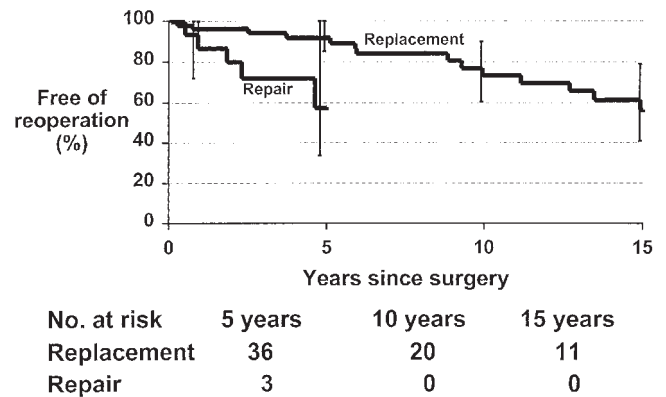


Figure 3: Freedom from reoperation among late survivors comparing patients undergoing a composite graft reconstruction to those undergoing a valve-preserving procedure. $p = 0.007$.

(Table IV), only two were required secondary to complications of the initial operation. One patient required repair of a coronary anastomotic pseudoaneurysm at 15.2 years postoperatively, and one of a distal suture line anastomotic pseudoaneurysm at three months postoperatively. Five patients required aortic valve replacement after a valve-sparing procedure for progressive severe aortic regurgitation at a mean time to reoperation of 2.0 ± 2.6 years (three for prolapse of all three cusps, and two for a torn, macerated right coronary cusp). All five patients had undergone an initial reimplantation valve-preserving aortic root reconstruction. Nine operations were for aortic disease elsewhere, the patients undergoing reoperation at a mean interval of 8.2 ± 1.6 years. Two patients required re-replacement of a composite valve conduit after having received a tissue valve conduit initially, at nine and 15 years postoperatively, this being due to structural valve degeneration. Four reoperations were for other cardiac problems.

Hemorrhagic complications occurred in 12 patients who had received a mechanical valve composite graft procedure (two with life-threatening hemorrhage, 10 with minor bleeding). One patient died from a cerebral hemorrhage. Freedom from a minor and major hemorrhagic complication was 75% (CI 61-90%) at 15 years. Overall, freedom from thromboembolism was 97% (CI 93-100%), 97% (CI 91-100%), 88% (CI 76-100%) and 81% (CI 58-100%) at five, 10, 15 and 20 years, respectively. Five strokes occurred during the follow up period (two permanent, three transient), and one of these was fatal. All events occurred in patients receiving a composite mechanical valve conduit.

Freedom from endocarditis was 99% (CI 93-100%) at 15 years follow up. Only one event occurred in a patient with a mechanical valve, and this was successfully medically treated.

Table V: Predictors of late death.

Condition	Univariate p-value	Multivariate p-value	Odds ratio
Preoperative dysrhythmia	0.005	-	-
Preoperative ejection fraction <50%	0.02	-	-
Mitral regurgitation, +3-4 at presentation	0.0002	-	-
Need for concomitant procedures	0.03	-	-
Postoperative dysrhythmia	0.0005	0.003	4.9
Inotropes required postoperatively	0.0004	0.001	5.2

Univariate significant predictors for late death and need for reoperation are detailed in Tables V and VI, respectively. Multivariate analysis revealed postoperative dysrhythmia, and the need for postoperative inotropes to be significant predictors for late death ($p \leq 0.01$) (Table V). Mitral valve prolapse, and an initial valve-preserving aortic root reconstruction, were significant multivariate predictors of the need for reoperation ($p \leq 0.02$) (Table VI).

Discussion

The results of the present study underscore the success and durability of composite graft reconstruction for aortic root aneurysms and/or dissection in patients with Marfan syndrome. Only four patients required reoperation related to the initial operation, two for structural failure of a tissue valve and two for anastomotic pseudoaneurysm. The incidence of endocarditis was very low, with only one event occurring in a patient with a mechanical valve conduit at 1.9 years after surgery. This patient was successfully treated medically. Because of the young age at presentation, composite mechanical valve conduit reconstruction exposes these patients to a lengthy period of risk of thromboembolism and hemorrhage related to warfarin therapy. Despite this difficulty, relatively few long-term problems were observed in the present series that were related to the placement of mechanical valve conduits and from long-term anti-coagulation. Although there were 12 hemorrhagic events, only two were life-threatening. Five (6%) thromboembolic events occurred during the follow up period, but only two of

these were permanent. Actuarial freedom from thromboembolism at 15 years was 88%, this event rate being in line with that reported in other series. For example, Kouchoukos et al. (10) reported freedom from thromboembolism to be 82% at 12 years among 168 patients who underwent composite valve conduit replacement (30 patients with Marfan syndrome). Later, Gott et al. (5) reported a freedom from thromboembolic events of 93% at 20 years in 271 Marfan syndrome patients. In a multi-institutional study of 675 Marfan syndrome patients, the freedom from thromboembolism was 90% at 20 years for a linearized rate of 0.62 events per 100 patient-years (4). Previously, the present authors reported a 91% actuarial freedom of thromboembolic events at 20 years in 195 late survivors after aortic root reconstruction (11). One of the best arguments for performing a valve-preserving procedure is to avoid the deleterious effects of warfarin therapy and the risk of stroke and endocarditis associated with a mechanical valve. The results of the present study suggest that the complications associated with a mechanical valve conduit in this patient group are acceptable.

In the present series, the survival curve was significantly lower than the expected survival among the general population in the authors' region (see Fig. 1). This was not related to the type of surgical procedure performed. The present authors reported previously on a series of 203 patients (including 50 Marfan syndrome cases), with a mean age of 53 ± 16 years, who underwent non-emergent aortic root reconstruction for annuloaortic ectasia (11). In that series, the survival curve of operated patients was not significantly different to the expected survival among the regional popu-

Table VI: Predictors of need for reoperation.

Condition	Univariate p-value	Multivariate p-value	Odds ratio
Mitral valve prolapse	0.01	0.02	2.9
Preoperative mitral regurgitation +3-4	0.02	-	-
Aortic valve-preserving operation performed	0.007	0.02	4.2
Concomitant procedure performed	0.02	-	-

lation. To reconcile these data, it could be surmised that patients with Marfan syndrome have a decreased life expectancy secondary to the predisposition to form aneurysms elsewhere, potential for arrhythmias, the presence of mitral disease, other cardiac disease, and non-cardiac comorbidities from multisystem involvement. Among the considerable number of reoperations required in this series, the indications for most were related to manifestations of aneurysmal disease elsewhere.

One of the objectives of therapy in Marfan patients is to avoid the inevitable vascular catastrophe of aortic dissection and/or aortic rupture. In the present series, despite intervention occurring at a mean aneurysm diameter of 55 ± 19 mm, 26% of patients presented with either acute or chronic dissections, with mean aortic diameters less than the dimensions usually considered to be an indication for surgery. The maximal aortic diameter in patients with chronic dissections in the present series was <4 cm. Gott et al. (5) found that one-third of the dissections occurred in Marfan syndrome patients with aortic diameters <6.5 cm, while Roman et al. (12) documented aortic complications occurring in 21 of 112 Marfan syndrome patients at a mean aortic diameter of 5.1 ± 0.8 cm. Experience from 11 patients reported by Treasure recorded the predissection aortic diameter as 5.1 cm (13). Others have suggested intervening at smaller aneurysm diameters, especially in patients with a family history of dissection (mean 4.3 cm) (14). In a large heterogeneous group of patients being followed by the Yale database, Coady et al. (15) determined that the hinge point for the occurrence of vascular complications occurs at 6 cm for ascending aortic aneurysms, though this hinge point is clearly smaller for patients with Marfan syndrome.

Whether valve-preserving techniques should be applied universally to patients with Marfan syndrome is debatable. While the aortic valve cusps often appear relatively normal, this is not true in structural terms. It has been shown that abnormal fibrillin metabolism affects the valve tissue. Fleischer et al. (16) showed that the aortic valve cusps and mitral valve leaflets in Marfan syndrome patients were equally affected by fibrillin-1 fragmentation compared to the aortic wall, with the changes being most severe in patients aged over 20 years. Missirlis et al. (17) showed that compliance of the aortic cusp in a Marfan syndrome patient was an order of magnitude greater than that of the normal aortic valve cusp. Due to this increased compliance, as the sinotubular junction diameter increases initially the valve cusps become thinner and the free margin lengthens, but the cusps continue to coapt. It is not uncommon to find a moderately to severely dilated aortic root with only mild to moderate aortic regurgitation. Invariably, the patient develops central aortic

insufficiency as the sinotubular junction diameter exceeds 5.5 mm. Among patients with Marfan syndrome, the Toronto group (6) observed that there was a correlation between aneurysm size and the ability for the valve to be preserved. Most aortic valve cusps appeared normal if the aneurysm was <5 cm, but only 50% appeared normal if the aneurysm diameter was 5–6 cm. In patients with aneurysms >6 cm, most aortic cusps were abnormal and a composite graft reconstruction was more likely performed. Yacoub et al. (18) found that reoperation was more common in patients with a longer duration of symptoms. These authors concluded that early operation, before the chronic valve changes caused by regurgitation, could reduce the incidence of reoperation. Whereas, these observations are an important consideration for all patients with aortic root aneurysms, they are particularly pertinent for patients with known structurally abnormal valves.

In the present series, the most significant predictor of a need for reoperation was having undergone a valve-preserving procedure (odds ratio 4.2). Three patients represented with severe central regurgitation secondary to prolapse of all three cusps. All three had undergone a reimplantation technique and had the root base fixed below the level of the annulus. Marfan syndrome patients have a larger than normal annular size, and thus a longer cusp free margin. In the present series, the mean annulus diameter was 29 ± 8 mm. A previous investigation conducted by the present authors showed that an annulus size >25 mm prior to valve-preserving reconstruction was a significant predictor of a need for reoperation in patients undergoing valve-preserving aortic root reconstruction (19). Casselman et al. (20) reported an annulus size of 27 mm to be predictive of failure in the routine repair of bicuspid aortic valve. Again, failure in this subset of patients may occur because of higher stress on the cusp edges associated with a longer free edge. The larger cusps are more difficult to suspend in a normal position above the annulus. Pethig et al. (21) observed that if the coaptation point of the valve cusps were >2 mm below the level of the annulus after reconstruction, then the need for reoperation was increased. The second mechanism of valve failure was a torn single cusp in two patients. This failure was likely due to trauma when the cusps opened, hitting the tube graft. One of these two patients who presented 1.5 years after a reimplantation procedure with a macerated, torn cusp has been reported previously (22). These cases emphasize the importance of correct sizing of the Dacron tube graft. Several modifications have been carried out of both the remodeling and reimplantation techniques to create neo-sinuses and reduce cusp trauma. This evolution has been detailed in a review by Miller of the valve-

preserving operation in relation to Marfan syndrome patients (23). The importance of these efforts has yet to be proven, however.

In the present series, a composite valve conduit aortic root reconstruction offered a more durable result. Several reports have been made specifically analyzing the valve-preserving procedure in patients with Marfan syndrome, but with varying results. Birks et al. (24) evaluated 82 patients reconstructed with a remodeling procedure. The chance of needing a reoperation was 17% at 10 years, but this was increased compared to the 11% risk reported in an earlier series with a majority of non-Marfan patients (18). Moderate aortic regurgitation was present in 21% of the patients at follow up. Carias de Oliveira et al. (6) reported on 61 patients undergoing valve-preserving reconstruction. Freedom from reoperation was 100% at 10 years, though freedom from grade >2+ aortic regurgitation was 75% at 10 years. Karck et al. (25) evaluated 45 patients who were reconstructed with a reimplantation technique, and showed freedom from reoperation to be 84% at 5 years. Further follow up is required to determine if patients with moderate aortic regurgitation will go on to require reoperation.

The results of the present study emphasize the success of composite valve conduit aortic root replacement in patients with Marfan syndrome. The valve-preserving procedure should be reserved for patients with normal valve cusps who wish to avoid anticoagulation for quality of life issues or other contraindications. This surgery should be used with caution in patients with valve characteristics that have been shown to be at risk for decreased durability.

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Meeting discussion

DR. ALICE OLIVESI (France): Could you tell us more about the causes of late mortality, because there were quite a few late deaths?

DR. KENTON J. ZEHR (Rochester, MN, USA): There were nine cardiac deaths - three were due to congestive heart failure, three were related to descending aortic disease, two were due to coronary artery disease, and one patient died from a ruptured right coronary artery anastomosis pseudoaneurysm. Cause of death is discussed in more detail in the discussion in the manuscript.

DR. HANI K. NAJM (Saudi Arabia): Can you elaborate on the patients who failed the valve-preserving operation? You have used two types of surgery - the David I and II. We know that the David II/Yacoub technique is contraindicated in patients with Marfan syndrome, because the annulus is not fixed and that is a progressive process, unless you add an annuloplasty. In the patients who failed, did you use type II David, Yacoub, or David I?

DR. ZEHR: We published details of our valve-sparing procedures in the *Journal of Heart Valve Disease*. These are a small subset of valve-preserving procedures performed at the Mayo Clinic. We evaluated the whole group by univariate analysis - we didn't have sufficient failures to do a multivariate analysis. We found that patients with an annulus diameter >25 cm, male gender, and those requiring manipulation of an individual aortic cusp were associated with failure. The type of valve-sparing procedure was not associated with failure by univariate analysis. With regard to cusp

manipulation, in a larger series of patients with annuloaortic ectasia presented at the Western Thoracic we had several failures related to cusp manipulation. Three of these patients had a Trussler stitch placed near the commissure and re-presented with a torn cusp. I believe that cusp manipulation might not be durable in Marfan patients because the cusps are so diaphanous and don't hold a suture well. Dr. Miller has suggested that if the node of Arantius is bunched up slightly, the tissue is slightly tougher and can take a stitch better, and this shortens the free margin. The most common reason for failure in our patients was progressive prolapse of all three cusps in three cases. This resulted in progressive regurgitation. As reported previously by the Hanover, Germany group, if the procedure is finished with coaptation >2 mm below the plane of the annulus, the patients are more likely to fail.

DR. NAJM: I am still not clear - did you use the David procedure?

DR. ZEHR: All of those failures were in the reimplantation technique group - they all had David procedures.

DR. NAJM: The first type, or the second? Have you remodeled only the sinuses, or have you put the entire root inside the graft?

DR. ZEHR: Fifteen of the operations were done with the entire root inside the graft, using a standard reimplantation technique. The Yacoub technique was used in three patients - but as you know there is debate as to whether the Yacoub technique works in Marfan patients, or not. Does the annulus dilate over time and result in progressive central regurgitation? The Harefield results published by Birks et al. showed fairly good results in Marfan patient using the remodeling technique. I wouldn't say categorically that the jury is in. As in Dr. Miller's recent editorial in the *Journal of Thoracic and Cardiovascular Surgery*, it becomes very convincing that perhaps we should fix these annuli fairly tightly. But all of the failures in our series did have fixed annuli.

DR. ROBERT DION (Netherlands): How did your results change your indications for operating in Marfan patients with regard to aorta diameter? You showed that a not very dilated aorta was present with the dissection.

DR. ZEHR: This series was spread over 30 years, so this finding came as a statistical surprise to us.

DR. DION: Did it change your daily routine?

DR. ZEHR: Not yet, but referral patterns take time to change. There is no doubt that we have a heightened awareness as to the need to intervene earlier in patients with a familial predisposition to dissection. We were surprised to see such low aortic aneurysm diameters in those patients who dissected. We need to

look at our Marfan patients specifically to see if they have a history of family dissection or of hypertension, or if they have disproportionate aortic sizes to body surface areas, and intervene in higher risk patients at an earlier stage. My most recent Marfan patient was operated at an aortic diameter of 45 mm because her son had dissected.

DR. F. W. MOHR (Germany): Looking at your data, you might have changed your policy. I am surprised that you had only four patients with circulatory arrest, and that several patients returned for aneurysm surgery or died late due to aneurysms elsewhere. Our policy is always to use an open technique, and to attempt a hemiarch operation at the first operation of the ascending aorta. Do you have any comments on that point?

DR. ZEHR: Our initial arch size was 33 mm, and when patients were followed up with echocardiography we didn't find an arch increase. Most of the echo follow up is complete, and none of our patients has returned with arch aneurysms. All of the remaining aneurysms were in the descending thoracic aorta, and not in the arch.

DR. MOHR: But echo control of the arch is not really reliable, and if reoperation of the descending aorta is attempted, the repair of the arch makes the operation much easier and more controllable. I think that many surgeons use this approach at present.

DR. ZEHR: I take your point - this is a debatable issue, and until now we have been relatively conservative about hemiarch replacement. Most have been replaced

to the base of the innominate artery, as high as one can get without an open technique. But I do understand the debate about this.

DR. R. DION (Netherlands): Do you think we should be more aggressive with regard to the mitral valve status in Marfan disease? I noted that some of your reoperations were due to mitral valve problems. At our center we consider carefully the height of coaptation of the mitral valve in Marfan disease - if it is minimal, and even if no great leakage, it may be better to place a ring prophylactically. Have you any thoughts about that?

DR. ZEHR: It is interesting that 28% of our patients had mitral valve prolapse, but only four needed reoperation for mitral valve problems. So the majority of the patients with prolapse did not come to a mitral valve problem. I do believe that the reason it was significant in a multivariate analysis was that it is a type of indicator of the significant overall connective tissue disorder that the patient has. If both their aortic valve and mitral valve show evidence of weakness, they are more likely going to have more problems with other aortic diseases. But it does not necessarily follow that all patients with mitral valve problems will present later with mitral valve regurgitation.

DR. DION: Are you referring to prolapse or ballooning or billowing?

DR. ZEHR: This is prolapse without eccentric regurgitation. If the patient has a significant eccentric regurgitation such as moderate mitral regurgitation, we would carry out a posterior repair on them.