Mitral valve surgery in patients with extensive calcification of the mitral annulus

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Objectives: The objective of this work was to examine the clinical outcomes of mitral valve surgery in patients with extensive mitral annular calcification.

Methods: Mitral valve surgery was performed in 54 patients (28 men and 26 women, mean age 63 ± 14 years) with mitral regurgitation and extensive mitral annular calcification. Most patients (78%) were in New York Heart Association classes III and IV, 14 had coronary artery disease, and 9 had prior mitral valve replacement in which the calcium bar was not removed. The calcium bar was excised and a new mitral annulus was created by suturing a strip of pericardium onto the endocardium of the left ventricle from lateral to medial fibrous trigones and to the endocardium of the left atrium. The mitral valve was repaired in 12 patients and replaced in 42. In 23 patients the intervalvular fibrous body was reconstructed and the aortic valve was also replaced. Mean follow-up was 4.1 ± 3.7 years and was complete.

Results: There were 5 operative deaths and 11 late deaths. Five-year survival was $73 \pm 7\%$. Four patients needed reoperation and each survived. Freedom from reoperation at 5 years was $89 \pm 6\%$. Three patients had a stroke and 4 had anticoagulation-related hemorrhage, one of which was fatal. Five-year freedom from valve-related mortality or morbidity was $75 \pm 8\%$. Most survivors were in New York Heart Association functional classes II and III.

Conclusions: Resection of the calcium bar and creation of a new annulus with pericardium provided good clinical results in patients with extensive calcification of the mitral valve.

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Calcification of the mitral annulus is a degenerative process in which there is dystrophic deposition of calcium in the mitral annulus. The calcification usually extends from the lateral to the medial fibrous trigones along the posterior mitral annulus, giving a radiographic appearance of a horseshoe-like structure in the base of the heart. The calcification may also extend into the ventricular muscle and, in cases of advanced myxomatous disease of the mitral valve, may involve the papillary muscles and the intervalvular fibrous body. When severe mitral insufficiency is present, surgery may be necessary. However, patients with extensive calcification of the mitral annulus who require mitral valve surgery present a major

TABLE 1. Clinical profile of patients undergoing mitral valve surgery with extensive calcification of the mitral annulus

No. of patients	54
Age (y)	
Mean $\pm$ SD	63 $\pm$ 14
Range	24-88
Sex	
Male	29 (54)
Female	25 (46)
Electrocardiogram	
Sinus rhythm	31 (57)
Atrial fibrillation	21 (39)
Heart block	2 (4)
Timing of surgery	
Elective	39 (72)
Urgent	15 (28)
New York Heart Association	
Class I	1 (2)
Class II	12 (22)
Class III	24 (44)
Class IV	17 (32)
Left ventricular ejection fraction	
$\geq 60\%$	20 (38)
41%–59%	27 (51)
$\leq 40\%$	6 (11)
Coronary artery disease	13 (24)
Previous mitral valve replacement	9 (17)
Aortic valve disease	18 (33)
Tricuspid insufficiency	2 (4)

challenge to the surgeon and are at risk for increased operative mortality and morbidity.¹

This study reviews our experience with mitral valve surgery in patients with extensive calcification of the mitral annulus in whom the calcium bar was removed and the annulus reconstructed with either fresh autologous or glutaraldehyde-fixed bovine pericardium.

Patients and Methods

A retrospective review of our heart valve surgery database identified 54 patients with extensive calcification of the mitral annulus who underwent mitral valve surgery and reconstruction of the mitral annulus between July 1985 and November 2000. There were 29 men and 25 women, aged 63 $\pm$ 14 years (range, 24 to 88 years). Table 1 outlines the clinical profile of these patients. Seven patients had mitral valve replacement elsewhere and were reoperated on because of prosthetic valve dehiscence from the calcium bar. One patient had 4 previous mitral valve replacements and 3 patients had 2 previous replacements. The indication for surgery in the remaining patients was mitral regurgitation due to degenerative disease. All 54 patients had extensive calcification of the mitral annulus, which involved at least one third of its circumference. In contrast to patients with predominantly mitral stenosis, the leaflets tended to be relatively spared from the calcification process. Dur-

ing this same time period 3585 mitral valve operations were performed in our institution.

Operative Procedures

Patients underwent mitral valve surgery via a standard median sternotomy and pericardiotomy. The left atrium was entered through the interatrial groove in patients who only required isolated mitral valve surgery. In those patients who also needed aortic valve replacement, exposure was achieved by opening the aortic root and dome of the left atrium.

In 31 patients the calcium bar was limited to the posterior part of the mitral annulus. If the mitral valve was thought to be nonrepairable, it was excised and the calcium bar removed by sharp en bloc dissection. The atrioventricular junction was then reconstructed with a strip of untreated autologous or glutaraldehyde-preserved bovine pericardium by suturing it to the endocardium of the left ventricle with a continuous 3-0 polypropylene suture. The valve sutures were passed through this patch at a level that corresponded to the mitral annulus posteriorly and to the intervalvular fibrous body superiorly. Before a prosthetic valve was implanted, the proximal part of the patch was secured to the left atrium.

For the 12 patients in whom the mitral valve was thought to be repairable, the posterior leaflet was completely detached from the calcium bar from commissure to commissure. The calcium bar was excised by en bloc dissection and the atrioventricular groove was reconstructed with fresh untreated autologous pericardium. The prolapsed section of the posterior leaflet was resected, repaired, and then sutured to the pericardial patch that was used to reconstruct the posterior mitral annulus. Prolapse of anterior leaflet, when present, was corrected by chordal replacement with expanded polytetrafluoroethylene sutures. A flexible annuloplasty ring or a posterior band was used in all patients and was secured to the pericardial patch and leaflets.

Twenty-three patients required circumferential reconstruction of the mitral annulus because of intervalvular fibrous body calcification. The aortic valve was diseased or had been previously replaced in 17 of these patients and was normal in 6. The operation was performed through the aortic root and dome of the left atrium. The aortotomy was extended into the anterior leaflet of the mitral valve and the dome of the left atrium, exposing both the left ventricular inflow and outflow tracts. After complete excision of the calcium bar and the calcified intervalvular fibrous body, a large strip of glutaraldehyde bovine pericardium patch was sutured to the endocardium of the left ventricle from the medial to the lateral fibrous trigones as well as to the left atrium. Approximately two thirds of the circumference of a prosthetic mitral valve was secured to the patch. Then a triangular patch of Dacron or bovine pericardium was sutured to the lateral and medial fibrous trigones, to the remaining superior aspect of the prosthetic mitral valve, and then to the aortic root with a continuous 3-0 polypropylene suture. A separate patch was used to close the dome of the left atrium. An aortic prosthetic valve was implanted in the aortic position by securing it to the native aortic annulus and to an additional patch on the right side of the aortic root. Further technical details including illustrations of these operative procedures have been previously published.^{2,3}

Table 2 summarizes the operative data.

TABLE 2. Operative data of patients undergoing mitral valve surgery with extensive calcification of the mitral annulus

Mitral valve surgery	
Replacement	32
Repair	12
Aortic valve replacement	17
Aortic valve repair	2
Replacement of the ascending aorta	1
Tricuspid valve repair	3
Cardiopulmonary bypass time (mean min $\pm$ SD)	146 $\pm$ 60
Aortic clamping time (mean min $\pm$ SD)	122 $\pm$ 49

Follow-up

Long-term follow-up was obtained through questionnaires, telephone interviews, and outpatient chart review. Follow-up extended from 3 to 181 months (mean, 54 $\pm$ 47 months), and no patient was lost to follow-up. Most patients had multiple echocardiographic studies over the years and every patient had at least 1 echocardiographic study after hospital discharge.

Statistical Analysis

SAS 8.1 (SAS Institute, Cary, NC) was used for all statistical analyses. Descriptive data are reported as the mean $\pm$ SD for continuous variables and as proportions for categorical variables. As this is an observational, descriptive study of a complex operative procedure with relatively few patients, multivariable Cox regression analyses to determine the independent predictors of operative and late mortality were not performed. The Kaplan-Meier method was used to estimate long-term survival and freedom from morbid events.

Results

There were 5 operative deaths for an operative mortality of 9.3%: 2 due to severe coagulopathy, 1 due to low cardiac output, 1 due to sepsis and multiorgan failure, and 1 due to myocardial infarction complicated by rupture of the posterior interventricular septum that was related to an occlusion of a diseased right coronary artery. Operative mortality for the other 3585 mitral valve procedures done over the same period in our institution was 1.5%. Postoperative complications included reexploration for bleeding in 5 patients, renal failure in 1 patient, and permanent heart block requiring pacemaker insertion in 11 patients.

There were 10 late deaths: 6 cardiac (congestive heart failure in 2, sudden death in 2, myocardial infarction in 1, and arrhythmia in 1), 1 valve-related (anticoagulation-related hemorrhage), and 3 noncardiac and nonvalvular causes. Survival was 65% $\pm$ 8% at 8 years as shown in Figure 1.

Four patients required reoperation: 1 for hemolysis due to patch dehiscence 4 months after surgery, 1 for prosthetic valve endocarditis 20 months after surgery, 1 for pannus ingrowth and valve dysfunction at 62 months after surgery, and 1 for valve dehiscence at 132 months after surgery. All

Figure 1. Long-term actuarial survival of patients undergoing mitral valve surgery with extensive calcification of the mitral annulus.

patients requiring reoperation survived. Freedom from reoperation was 91% $\pm$ 5% at 8 years in the patients at risk as shown in Figure 2. Five patients had thromboembolic events: 3 had a stroke (2 with complete and 12 with partial recovery) and 2 had transient ischemic attacks. Three patients had major hemorrhagic complications, 1 of whom died. Freedom from thromboembolic events was 85% $\pm$ 7% at 8 years in the patients at risk as shown in Figure 3.

Overall a total of 12 patients had valve-related complications. Freedom from valve-related mortality or morbidity was 74% $\pm$ 8% at 8 years in the patients at risk as shown in Figure 4.

At the most recent follow-up contact, 18 patients were in New York Heart Association functional class I, 10 were in class II, 6 were in class III, and 1 was in class IV.

Discussion

Mitral valve annular calcification is a process that is related to aging^{1,4} and to stress of the mitral valve apparatus.^{5,6} The overall incidence of mitral valve annular calcification, based on echocardiographic screening of 5694 patients in the Framingham study, is 2.8%.⁷ The incidence was found to be higher at 8.5% in an autopsy study of an older patient population.⁸ It is more common in women, in whom it also tends to be more extensive than in men.^{1,4,7}

In its most characteristic form, mitral annular calcification manifests itself as a semilunar bar or ring of calcium within the fibrous annulus of the mitral valve. Although the base of the valve leaflet and the adjacent myocardium are affected, there is minimal involvement of the actual leaflet and chordae.^{1,6} Progressive calcification of the base of the posterior leaflet eventually restricts its mobility and also prevents contraction of the atrioventricular annulus. The submitral calcification pushes the posterior leaflet up toward the atria, often simulating a degree of prolapse, and causes

Figure 2. Freedom from reoperation of patients undergoing mitral valve surgery with extensive calcification of the mitral annulus.

Figure 3. Freedom from thromboembolic events (TE) of patients undergoing mitral valve surgery with extensive calcification of the mitral annulus.

Figure 4. Freedom from valve-related mortality and morbidity (VRMM) of patients undergoing mitral valve surgery with extensive calcification of the mitral annulus.

paravalvular leak and possible dehiscence. Securing the prosthetic mitral valve sewing ring directly to a calcium bar is almost certain to fail as it likely lead to paravalvular leak and/or dehiscence.

Another approach that may avoid an extensive annular dissection is the technique of intra-atrial insertion of a mitral prosthesis as described by Natafet and coworkers.¹¹ The prosthesis in these patients is modified by enlarging the circumference of the sewing ring with a Dacron collar, which in turn is sutured to the left atrial wall. A limitation of this procedure is the transfer of high left ventricular pressure into the left atrium, which may in turn lead to severe hemorrhage or valve dehiscence. In Natafet's series of 36 patients in whom the mitral annulus was destroyed due to endocarditis or calcification, the operative mortality was 36%. Furthermore, valve dehiscence subsequently developed in 4 of the 23 survivors.

Some authors have favored limiting the decalcification to the area of repair and reconstructing the fibrous annulus with nonpledget-supported vertical figure-of-8 sutures.¹² However, this technique is limited to those cases in which the valve is repairable and the calcification is not extensive.

Annular reconstruction after complete decalcification has been described by different techniques. Carpentier and colleagues⁶ described reconstruction of atrioventricular junction by a series of figure-of-8 nonpledget-supported sutures placed into the atrial and ventricular edges and tied on the atrial wall. The posterior leaflet is sutured to this edge after valve repair.

In our series, we used a patch repair in all patients as described previously by us and by others.^{2-4,12,13} The patch technique has the advantage that it can be used when extensive repairs involving the posterior aspect as well the superior aspect of the annulus are necessary. Using this technique we have not seen any long-term failures such as

increased traction on the chordae. This may in turn lead to insufficient coaptation of the mitral leaflets and result in further chordal elongation and possible rupture.^{1,4,9,10}

Extensive calcification of the mitral annulus may present a formidable surgical challenge during mitral valve surgery. The patient is at risk from such potentially fatal complications as intractable hemorrhage, atrioventricular disruption, and ventricular rupture. Therefore, it is not surprising that a variety of different surgical techniques have been used to approach this difficult problem with varying results.

In those cases in which the mitral annulus is sufficiently dilated it may be possible to simply removed part of the valve and sew a prosthetic valve of adequate size into position without having to dissect the calcium away from the annulus. Although this may appear to be a safe approach, it is important to ensure that the new valve is sewn into relatively pliable tissues to avoid the development of a

aneurysm formation or dehiscence. Although any patch material can be used, because of their strength we have preferred the use of gluteraldehyde-fixed bovine pericardium or Dacron for reconstruction of superior annulus and intervalvular fibrous body. Repairs of the posterior annulus alone can usually be achieved using the patient's own untreated pericardium.

As calcification spares the leaflets in most of the myxomatous valves, repair of the mitral valve should be attempted and is the preferred operation.^{6,12,14} However, severely fibrotic, calcified, and immobile leaflets, heavily deformed subvalvular apparatus, calcification of the entire annulus, and/or extremely fragile tissues remain contraindications for valve repair. In our series of 54 patients, repair was possible in only 12 cases and 2 of these patients required reoperation (16.7%) due to pannus formation and hemolysis. This is in contrast to the normally excellent long-term results with mitral valve repair without annular reconstruction.^{6,12} At the time of reoperation, the reconstructed annulus was found to be intact and no further decalcification or annular reconstruction was needed before valve replacement.

Patients with extensive mitral annular calcification who require mitral valve surgery may present significant challenges to the surgeon. Although we recommend removal of the calcium bar, this is a major undertaking and should not be considered lightly. In our own institution, patients noted to have extensive mitral annular calcification on angiography are usually referred to the more experienced valve surgeons. If a surgeon is not comfortable with the reconstruction of the mitral annulus, then it might be safer to simply partially excise the valve leaflets and leave enough rim intact to which an adequate-sized prosthesis can be inserted. However, if the annulus is too small for an adequate-sized valve or if there is no remaining tissue to which a valve can be sewn, then patch reconstruction of the annulus will have to be considered. Patch reconstruction of the mitral annulus is an extremely useful adjunct to help avoid dreaded complications of atrioventricular disruption or valve dehiscence. On the basis of our experience we believe that a prosthetic mitral valve can be safely secured into a newly created annulus with very acceptable operative mortality and morbidity as well as good long-term results.

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Discussion

Dr Robert B. Karp (*Snowmass, Colo*). I would like to congratulate Dr Feindel on his presentation and indeed in particular the Toronto group for an outstanding record of accomplishment in a very difficult group of patients. The mortality was 9%, reflecting I think the complexity of the problem and the procedure. Reentry for bleeding was 8%, and we shall get back to that in a moment.

Older approaches using small prostheses without decalcification have been the conventional way. Large sutures passed through the calcium seemed to have worked fine but I think none of us knows the reoperation rate and the prevalence of paravalvular leakage. Historically, as Dr Feindel indicated there was an explicit prohibition against decalcification of the posterior mitral annulus. In Dr David's group those methods, taken from treatment of annular abscesses and treatment of infective endocarditis, are used here to replace the annulus and cushion it.

The extent of the disease is indicated by the involvement of the aortic valve in at least 28 patients. Some of these may have had intrinsic aortic disease but at least 6 had normal aortic valves, yet aortic valve replacement was necessary and is a disadvantage of the procedure.

I have several questions: First, considering the extensive nature of this procedure, how does one make the decision to offer operation to such a patient? In the operating room, how does one make the decision to do this extensive decalcification rather than trying to put in a smaller valve with a bulky ring?

Second, there was a rather high incidence of bleeding. Does this reflect in particular disruption in any of the areas where the calcium was debrided, and were there any ventricular disruption patients who did not die but were treated successfully? Also, what is the prevailing attitude toward how to avoid coronary artery disturbance?