

What Is the Best Surgical Treatment for Obstructive Hypertrophic Cardiomyopathy and Degenerative Mitral Regurgitation?

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Background. Many prefer mitral valve replacement (MVR) for patients with obstructive hypertrophic cardiomyopathy (HCM) and concomitant degenerative mitral regurgitation (MR). We reviewed our results of septal myectomy combined with mitral valve repair (MVrep) and MVR when these problems coexist.

Methods. Between 1990 and 2006, 32 patients (56% men; mean age, 60.7 ± 16.7 years) underwent extended septal myectomy for HCM with concomitant MVrep or MVR for degenerative MR (4% of myectomies and 3% of isolated MVrep during the same period). Preoperatively, 63% were in New York Heart Association (NYHA) functional class III/IV. Preoperative peak left ventricular outflow tract (LVOT) gradient was 63.7 ± 37.6 mm Hg. Systolic anterior motion (SAM) was present in 94%, with severe MR in 88%.

Results. Extended septal myectomy included concomitant MVrep in 28 (88%) or mechanical MVR in 4 (12%). MVrep included leaflet resection in 10 (36%), edge-to-edge stitch in 6 (21%), and leaflet plication in 8 (29%). An

annuloplasty ring/band was used in 19 (68%) and commissural annuloplasty in 2 (7%). There was one early death (3%). At discharge, resting LVOT gradient was reduced to 10.2 ± 19.0 mm Hg ($p < 0.005$). Dismissal echocardiography in MVrep patients demonstrated chordal SAM in 6 (21%, $p < 0.005$). MR was absent or mild in 21 (75%) and moderate in 6 (21%; $p < 0.005$ vs preoperatively). At late follow-up, LVOT gradient was 2.5 ± 5.8 mm Hg, SAM resolved in all patients, and 2 had moderate MR; 24 (83%) were in NYHA class I/II ($p < 0.005$).

Conclusions. Concomitant MVrep with myectomy for HCM and degenerative MR can be performed with low early mortality with satisfactory relief of LVOT obstruction and MR. Most patients have significant relief of symptoms. MVR can be avoided in most patients with degenerative MR and HCM.

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The gold standard for surgical treatment for obstructive hypertrophic cardiomyopathy (HCM) is left ventricular (LV) septal myectomy, although mitral valve replacement (MVR) remains an alternative [1–3] approach. Mitral regurgitation (MR) associated with HCM is functional in most patients and due to systolic anterior motion (SAM). Despite minor structural abnormalities in the mitral apparatus associated with HCM, intervention on the MV is not necessary after complete relief of LV outflow tract obstruction (LVOTO) with septal myectomy when MR is due to SAM.

When MV repair is performed for degenerative MR, an annuloplasty band is generally used and can result in SAM of the MV [4], resulting in LVOTO. The combination of MV disease that requires repair is thus particularly challenging when it occurs in the setting of obstructive HCM. The risk of SAM is particularly high in these

instances because of myxomatous, redundant mitral leaflet tissue, the short distance from the leading edge of the anterior leaflet to the basal septum, the hyperdynamic nature of the ventricle, and reduced ventricular size [4–7]. Therefore, some surgeons believe that MVR with or without septal myectomy is the preferred surgical treatment in this setting.

We hypothesize that in patients with obstructive HCM and degenerative MR, the combination of an extended septal myectomy and modified MV repair techniques is possible, thus avoiding the need for MVR [8, 9].

Patients and Methods

Patient Selection

Between January 1990 and January 2006, 791 patients underwent extended septal myectomy for obstructive HCM. From this group we identified for study patients with obstructive HCM who underwent concomitant MVR or MV repair at the time of extended septal myectomy. Institutional review board approval was obtained. Requirement for patient consent was waived.

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Table 1. Patient Characteristics

Variable	Mean \pm SD, or No. (%)
All patients	32 (100)
Age, y	60.7 \pm 16.7
Male	18 (56)
NYHA class	
I/II	12 (37)
III/IV	20 (63)
Atrial fibrillation/flutter	6 (19)
LVEF	0.734 \pm 0.063
LVOT peak gradient, mm Hg	65.9 \pm 37.6
Basal septal thickness, mm	21.5 \pm 5.1
SAM at rest	30 (94)
Pre-op MR grade	
2	4 (12.5)
3	4 (12.5)
4	24 (75)
MR pathology	
Anterior leaflet	2 (6.3)
Posterior leaflet	22 (68.8)
Bileaflet	4 (12.5)
Dilated annulus	4 (12.5)
LVEDD, mm	48.7 \pm 8.8
LVESD, mm	26.1 \pm 6.8
RVSP, mm Hg	59.0 \pm 27.4
MPAP under anesthesia, mm Hg	33.0 \pm 17.0

LVEDD = left ventricular end-diastolic dimension; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic dimension; LVOT = left ventricular outflow tract; MPAP = mean pulmonary arterial pressure; MR = mitral regurgitation; NYHA = New York Heart Association; RVSP = right ventricular systolic pressure on preoperative echocardiography; SAM = systolic anterior motion; SD = standard deviation.

Patient Characteristics

During the study period, 32 patients (56% men) had extended septal myectomy for obstructive HCM with concomitant MV repair or replacement for degenerative MR (4% of all myectomies, Table 1). Mean age was 60.7 \pm 16.7 years (range, 8 to 83 years). New York Heart Association (NYHA) class III/IV heart failure symptoms were present in 63%. The preoperative mean ejection fraction was 0.734 \pm 0.063, and peak left ventricular outflow tract (LVOT) gradient was 65.9 \pm 37.6 mm Hg. SAM at rest was present in 30 patients (94%), and MR was moderately severe or severe MR in 28 patients (88%). The color flow jet of MR was observed to be both posteriorly directed and central, indicating that some MR was due to SAM and some was due to a structural problem with the MV. Of note, at least a mild to moderate degree of pulmonary hypertension was present in these patients, as demonstrated by elevated right ventricular systolic pressure on echocardiography preoperatively and elevated mean pulmonary arterial pressure under anesthesia (Table 1).

Surgical Data

Techniques of extended myectomy have been described elsewhere in detail [10]. In general, an oblique proximal

aortotomy directed towards the noncoronary sinus was made, and the aortic valve was exposed with the proximal aorta suspended. Our method of extended septal myectomy was performed starting slightly rightward to the nadir of the right aortic cusp and extending this incision leftward, terminating short of the attachment of the anterior mitral leaflet. This muscular excision was lengthened towards the apex of the left ventricle, typically reaching the level of the bases of the papillary muscles. Additional midventricular muscular resection was done on the apical third of the septum to the right of the coronary cusp incision to avoid injury to the conduction tissue. This resulted in a trough that was much wider in the midventricle compared with the base of the heart.

Standard techniques of our MV repair in the setting of HCM include leaflet resection for an unsupported scallop of the posterior leaflet and artificial chordae (Gore-Tex, W. L. Gore and Associates, Flagstaff, AZ) or plication for an unsupported scallop of the anterior leaflet. An adequately sized posterior flexible annuloplasty band is used selectively to avoid the potential development of SAM postoperatively. Eccentric annuloplasty or an edge-to-edge stitch is used when mitral annular dilatation is minimal, leaflet tissue is redundant, and the mitral regurgitation is central.

Data Collection and Statistical Analysis

Survival data, obtained through medical record review, Social Security database, and HCM clinic database, were available in all patients (100%) for a mean duration of 5.6 \pm 3.5 years (maximum follow-up, 15 years). Follow-up functional status was obtained from medical records of clinic visits and the HCM clinic database for a mean duration of 6.2 \pm 2.8 years in 27 early survivors (87%). Late echocardiographic data were obtained at a mean duration of 3.9 \pm 2.7 years in 22 of the 29 late survivors (76%). Comparisons for continuous data in the two groups were made using the paired *t* test, and discontinuous data were compared using the Fisher exact test. A value of *p* < 0.05 was considered statistically significant.

Results

All procedures were performed with cardiopulmonary bypass (CPB; 2.4 L/min/m²) at normothermia or mild (32° to 34°C) hypothermia. Mean CPB time was 89 \pm 43 minutes; for the 12 patients who required a second bypass run, the mean CPB time was 94 \pm 41 minutes. Antegrade cold blood cardioplegia (800 to 1000 mL induction) was used for myocardial protection; additional antegrade cold blood cardioplegia (400 to 500 mL) was given at 20-minute intervals during the cross-clamp period. Mean cross-clamp time was 66 \pm 33 minutes; for 12 patients who required a second CPB run, the mean cross-clamp time was 70 \pm 28 minutes.

Intraoperative transesophageal echocardiography and direct simultaneous measurements of LV and aortic pressures before and after myectomy were obtained routinely. While the patient was under anesthesia, but before myectomy, the measured peak-to-peak LV outflow

gradient in the absence of any provocation was 47.5 ± 28.9 mm Hg. The pathology examination of the resected mitral leaflet(s) showed changes characteristic of myxomatous valve degeneration.

Extended Septal Myectomy With Concomitant MV Repair

In 28 patients (88%), MV repair was concomitant with extended septal myectomy. MV repair was performed with leaflet resection in 10 (36%), edge-to-edge stitch in 6 (21%), and leaflet plication in 8 (29%). An annuloplasty ring or band was used in 19 (68%) and commissural (eccentric) annuloplasty in 2 (7%).

Extended Septal Myectomy With Concomitant MVR

Four patients underwent MVR with a mechanical prosthesis. The first patient had diffuse, extensive myxomatous changes of both mitral leaflets and was considered to be not amenable to MV repair. The second patient underwent two unsuccessful attempts at repair, so MVR was performed. The third patient continued to have significant SAM and LVOTO after septal myectomy, but due to minimal septal hypertrophy (<16 mm), it was determined that further myectomy would result in potential ventricular septal defect, so MVR was performed. The fourth patient underwent a complex MV repair involving triangular resection of P2, closure of a cleft in the posterior leaflet, and plication of the posteromedial commissure. However, dehiscence of the repair resulted in reoperation on postoperative day 4, leading to MVR.

Early Mortality

There was one early death (3%) in this series. This occurred in an 80-year-old man who underwent extended septal myectomy, MV repair involving plication of the medial and lateral scallops of the posterior leaflet, application of a posterior annuloplasty band, aortic valve repair with commissural plication, and double coronary artery bypass grafting (CABG) with reverse saphenous vein grafts. His intraoperative course was complicated by bleeding due to rupture of the posterolateral free wall of the left ventricle. This was repaired, but the patient required two subsequent reoperations for bleeding. The patient died 5 days after the operation of sepsis and low cardiac output syndrome.

Late Death

Two late deaths occurred; both patients had initially undergone successful myectomy and MV repair. The first death occurred 5 years postoperatively in a 69-year-old woman who had long-standing severe chronic obstructive pulmonary disease requiring supplemental oxygen preoperatively. Her forced expiratory volume at 1 second was less than 1 L. The cause of death was end-stage lung disease. The other patient was an 87-year-old woman who had undergone myectomy with MV repair 14 years earlier. At 10 years after the initial operation, she underwent mitral and aortic valve replacement for degenerative severe mitral and moderate aortic regurgitation. She

Table 2. Concomitant Procedures

Procedure	No. (%)
Coronary artery bypass grafting	6 (19)
Patent foramen ovale closure	5 (16)
AVR for bicuspid aortic valve	2 (6)
Biatial Maze procedure	2 (6)
Tricuspid valve annuloplasty	3 (9)
Aortic valve repair	2 (6)
Resection fibroelastoma	1 (3)
Resection subaortic membrane	1 (3)

AVR = aortic valve replacement.

remained in NYHA class II 2 years thereafter. The cause of her death was not ascertained.

Concomitant Procedures

A total of 35 operations were performed in 32 patients. Concomitant procedures were performed in 20 patients (Table 2).

Repeated CPB and Reoperations

More than one period of CPB and aortic cross-clamping was required in 12 patients. In 8 patients, the septal myectomy was performed first and MR was reassessed after separation from CPB. These patients had floppy, redundant MVs with no unsupported scallops of either leaflet. TEE documented central and posteriorly directed MR before CPB. Since we have noted most MR to improve or resolve after adequate myectomy, we determined that a postmyectomy TEE interrogation of the MV was necessary before intervening. All of these patients had MR of at least a moderate degree after the myectomy, so CPB was resumed and MV repair was performed in 6 patients successfully and MVR was necessary in the other 2.

In the other 4 patients, obvious structural MV disease was present preoperatively with an unsupported segment (P2) in each patient. MV repair in addition to the myectomy was planned from the beginning. Significant residual MR was observed after myectomy and MV repair and separation from CPB; thus, CPB was resumed a second time and additional maneuvers were required for satisfactory MV repair in all 4 patients. However, a dehiscence of the MV repair in 1 patient necessitated MVR 4 days after the initial operation.

Echocardiographic Follow-Up and Functional Status

In the MV repair group at time of dismissal, the resting LVOT gradient was reduced to 10.5 ± 19.7 mm Hg ($p < 0.005$ vs preoperatively). In 6 patients (21%), mild SAM was observed ($p < 0.005$ vs preoperatively). In the MV repair group, 21 (75%) had none or mild residual MR and 6 (21%) had moderate MR ($p < 0.005$ vs preoperatively). At midterm follow-up (mean 3.9 years), the peak LVOT gradient was 2.5 ± 5.8 mm Hg, SAM had resolved in all who had it at hospital discharge, and 2 patients had persistent moderate MR.

In the MVR group, normally functioning mitral prostheses were confirmed on dismissal echocardiography; 3 patients had complete relief of LVOTO. One had a residual LVOT gradient of 22 mm Hg; however, repeat echocardiography at follow-up revealed the LVOT gradient had resolved. Of the 29 late survivors, 24 (83%) were in NYHA I/II ($p < 0.005$).

Heart Block and Permanent Pacemaker Requirement

Postoperative complete heart block requiring permanent pacemaker implantation before dismissal was necessary in 1 patient (3%), a 70-year-old man who underwent extended septal myectomy, MV repair with P2 resection, placement of a posterior annuloplasty band, and single CABG.

Comment

The advantages of MV repair compared with prosthetic replacement are well established [11–15]. Repair results in greater regression of LV dimensions and normalization of LV function compared with MVR. There is also a long-term survival benefit of valve repair compared with replacement, and durability of repair is similar to prosthetic replacement [11]. In most patients with obstructive HCM, associated MR is caused by SAM of the valve leaflets, and leakage is relieved or greatly improved after adequate myectomy for relief of LVOT obstruction. However, structural abnormalities, primarily leaflet prolapse, contribute to MR in some patients with HCM, and this combination of problems presents special problems in surgical management.

First, exposure of the MV through a standard left atriotomy may be compromised by the anterior displacement of the hypertrophied LV. Second, use of an annuloplasty band to reinforce leaflet repair may predispose to SAM and residual LVOTO. Finally, combining septal myectomy and MV repair increases ischemic time and duration of CPB.

Because of these concerns, some surgeons may choose to replace the MV in patients with obstructive HCM and structural MV disease. As first reported by Cooley and associates [2], removal of the anterior MV leaflet with prosthetic replacement relieves LVOTO and MR in patients with obstructive HCM. This approach, however, leaves patients with the liabilities of a prosthetic heart valve, which may be particularly problematic in patients with HCM, who often present for operation at a relatively young age.

In patients with obstructive HCM who have associated degenerative (structural) MV disease, we have preferred to perform extended septal myectomy and MV repair whenever possible. The diagnosis of associated structural valve disease in patients with obstructive HCM is suggested when echocardiographic color flow imaging shows an anteriorly directed MR jet in addition to the typical posterolateral-lateral jet caused by systolic anterior mitral motion [16]. In patients with an obvious flail segment of the MV, we proceed with transaortic extended septal myectomy and transatrial MV repair during a single period of aortic occlusion. For patients with

less severe degrees of leaflet prolapse, preoperative MR may be caused primarily by SAM of the MV and will be relieved after adequate myectomy.

If MR persists after SAM of the valve leaflets is corrected by myectomy, then direct valve repair is undertaken. The present study demonstrates that such an approach is safe, and when direct intervention on the valve is necessary, repair is possible in more than 85% of patients. The need to proceed with a second CPB run to address residual MV abnormalities should not be viewed as a failure, because it is frequently not possible to understand the relative contributions of MR from SAM vs structural disease preoperatively, especially when there are no unsupported segments. Leaving important, unaddressed mitral pathology behind may result in a stormy postoperative course and poor late outcome.

For patients with HCM, MV repair techniques should be individualized and modified to minimize the risk of recurrence of LVOTO and MR associated with SAM. When an annuloplasty band or ring is used, it is important to select an adequate sized prosthesis to avoid aggravating SAM of the MV. If leaflet repair corrects prolapse and the annulus is nearly normal in size, an annuloplasty band may not be necessary. Plication of leaflet segments and edge-to-edge repairs were used selectively in these patients. With adequate myectomy and these repair techniques, almost 80% of patients were free of SAM of the MV on the pre-discharge echocardiography. In the remaining patients, SAM was minor, often involving just the chordal apparatus, and did not contribute importantly to LVOTO. Also, these early postoperative studies may be a “worst case” assessment because of postoperative anemia and the hyperdynamic state that may follow the operation. Importantly, at subsequent follow-up, the SAM had resolved in all patients, as often occurs when SAM develops after valve repair for degenerative MV disease [17].

MVR was required in 4 patients in this series; repair was attempted in 2 but was not successful, and MVR was necessary. In a third patient, the MV considered to be abnormal enough that MVR was performed simultaneously with myectomy. In the fourth patient, LVOTO from SAM persisted after the initial extended septal myectomy, and because of the relative thinness of the septum (15 mm), MVR was performed to minimize the risk of iatrogenic ventricular septal defect from additional septal myectomy. A minimally hypertrophied septum (< 16 mm) may be a relative contraindication to myectomy, and MVR should be considered in such patients, particularly if the surgeon is not experienced with the myectomy procedure [18]. Patients aged older than 70 years with obstructive HCM and degenerative MV disease are another subgroup where initial MVR may be preferred rather than septal myectomy and MV repair.

Severe LVOTO may also lead to acute chordal rupture and rapid hemodynamic deterioration. Recognition of this clinical presentation is especially important because afterload reduction, the standard treatment for acute, severe MR, will aggravate obstructive HCM and worsen MR and low cardiac output [19, 20]. These acutely ill

patients also can be managed with extended septal myectomy and MV repair [18].

Limitations of this study include individual surgeon's preference and variability in the threshold for MVR. Owing to the relatively small number of patients in this series, it is not possible to compare the outcome of obstructive HCM with concomitant degenerative MR with myectomy and MV repair vs myectomy and MVR.

In conclusion, patients with obstructive HCM with degenerative MR are a subgroup in which surgical treatment is challenging. However, with modifications of MV repair techniques, we believe MVR can be avoided in most patients, and MV repair may offer superior outcome compared with MVR, with or without septal myectomy. MVR is a safe alternative when myectomy and MV repair cannot be performed.

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DISCUSSION

DR TOMISLAV MIHALJEVIC (Cleveland, OH): This is obviously an excellent presentation, and results from the Mayo Clinic have always been excellent. I have just two practical questions. The first one is how do you choose the appropriate technique for a mitral valve repair? You have used very many different techniques, some of them with rings, some of them without a ring, Alfieri's resections. What do you do today based on your current experience?

And secondly, 21% of patients at dismissal had SAM [systolic anterior motion] and some degree of left ventricular outflow tract obstruction. In the OR [operating room], when you do the echo at the end of the procedure, when do you draw the line in terms of what is an acceptable degree of SAM, an acceptable degree of obstruction vs something that cannot be tolerated and should be addressed during the operation?

DR WAN: First of all, to answer the question of what techniques to use for mitral repair, as you can see, this is a small proportion

of patients in the entire pool of patients with HCM [hypertrophic cardiomyopathy] who required myectomy. The choice of technique was somewhat surgeon-dependent, with individualization and modification of mitral valve repair technique. In general, repair techniques were similar to that performed for myxomatous mitral valves. It is difficult to conclude, based on this series, what is one single, effective method in repairing these mitral valves. Since one of the risks of mitral valve repair is recurrent SAM, when an annuloplasty ring or band is used, it should not be undersized, and consideration to not using a ring should be given.

To answer your second question, which was how much MR [mitral regurgitation] we would tolerate, at the end of the procedure, we routinely assess the following variables: the presence or absence of SAM, the presence or absence of LV [left ventricular] outflow tract obstruction, the residual gradient, and lastly, how much mitral regurgitation there is and the mechanism of it.

The methods of assessing these parameters are through intraoperative transesophageal echocardiography and also with direct pressure measurements with needles in the left ventricle and the aorta simultaneously. TEE [transesophageal echocardiography] provides reliable information about residual outflow tract obstruction, residual MR, and the mechanism of MR.

The treatment of residual MR is different depending on the mechanism. For example, SAM and LV outflow tract obstruction suggest incomplete myectomy. In general, we resume bypass and perform additional myectomy for a residual gradient of more than 20 mm Hg or SAM-related MR. Mild or moderate central mitral regurgitation is left alone. Chordal SAM is also left alone and rarely contributes to recurrent left ventricular outflow tract obstruction.

DR WALAA A. SABER (Cairo, Egypt): Can you give us, please, a little bit more details about this technique of leaflet plication.

DR WAN: Leaflet plication in these cases?

DR SABER: Yes. In 7 cases you used this leaflet plication technique.

DR WAN: Yes. Leaflet plication was used for flail, prolapsing, or redundant segments of the mitral leaflets, with or without extra maneuvers in the mitral repair technique.

DR DEARANI: The anterior mitral leaflet plication was used very infrequently in this series. When it was utilized, it was performed with the technique very similar to what has been described in New York. The anterior leaflet can be elongated with obstructive hypertrophic cardiomyopathy, so the plication occurs by bringing the leading edge of the anterior mitral leaflet closer to the annulus (ie, the height of the anterior leaflet is shortened).

DR Y. JOSEPH WOO (Philadelphia, PA): In the other 759 patients who underwent myectomies, do you have a sense of the degree of mitral regurgitation in those patients that did not need repair? And if so, do you know how much reduction in mitral regurgitation you had just from relief of LV outflow tract obstruction?

DR WAN: Results of our myectomy for HCM have been summarized and published elsewhere. Patients with HCM can present with mild to severe mitral regurgitation due to SAM. In the vast majority of the patients, no maneuver is needed on the mitral valve for mitral regurgitation, provided an aggressive, extended myectomy is performed. Most patients leave the operating room with none to mild mitral regurgitation and a residual gradient of less than 5 mm Hg.

Online Discussion Forum

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Once the article selected for discussion is published in the online version of *The Annals*, we will post a notice on the CTSNet home page (<http://www.ctsnet.org>) with a **FREE LINK** to the full-text article. Readers wishing to comment can post their own commentary in the discussion forum for that article, which will be informally moderated by *The Annals* Internet Editor. We encourage all surgeons to participate in this interesting exchange and to avail themselves of the other valuable features of the CTSNet Discussion Forum and Web site.

For September, the article chosen for discussion under the Pediatric Cardiac Surgery Dilemma Section of the Discussion forum is:

Dissecting Multidisciplinary Cardiac Surgery Rounds

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