Mitral valve repair for extreme billowing and prolapsing valve

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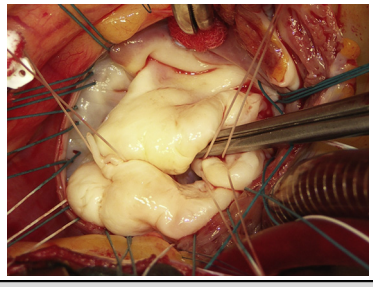
ABSTRACT

Objectives: We describe our method and results of mitral valve repair up to 20 years in a defined group of patients with mitral regurgitation caused by an extreme billowing and prolapsing valve.

Methods: An extreme billowing and prolapsing valve was defined by the presence of excess tissue on both leaflets and prolapse of 2 or more of the 3 segments of each leaflet. Among 1344 consecutive patients who underwent mitral valve repair for degenerative mitral regurgitation between 1991 and 2012 at the Sakakibara Heart Institute, 73 patients met our definition of an extreme billowing and prolapsing valve. From these 73 patients, 67 patients who underwent mitral valve repair based on the surgical strategy we developed in July 1996 were enrolled in this study. Our strategy of mitral valve repair for extreme billowing and prolapsing valves consists of (1) volume reduction of the leaflets, (2) physiologic remodeling annuloplasty for long anterior leaflet, and (3) wide usage of artificial chordae.

Results: Mean age of the patients was 46.6 ± 12.9 years. There were no hospital deaths and 6 late deaths in this series. Kaplan–Meier survival at 10 years was 96.8 ± 2.2%. There were 2 reoperations. Cumulative incidence rate of mitral valve reoperation and moderate or severe mitral regurgitation at 10 years was 1.8 ± 1.8% and 11.2 ± 4.0%. Number of artificial chordal replacement was associated with decreased risk of recurrent moderate mitral regurgitation (hazard ratio, 0.60; $P = .03$).

Conclusions: Long-term echo follow-up demonstrates good results of mitral valve repair for extreme billowing and prolapsing valves using our strategy. (JTCVS Open 2022;10:169-75)



The extreme billowing and prolapsing valve is a generalized prolapse of both leaflets.

CENTRAL MESSAGE

We defined the extreme billowing and prolapsing (EBP) valve to be a valve with prolapse of 2 or more of the 3 segments of each leaflet and excess tissue present on both leaflets.

PERSPECTIVE

Long-term echo follow-up demonstrates good results of mitral valve repair for extreme billowing and prolapsing valves using our strategy, which consists of volume reduction, proper annuloplasty, and a wide use of artificial chordae. We believe a further investigation using this definition of EBP valve in many centers will contribute to the development of surgical treatment in this field.

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Video clip is available online.

We sometimes encounter the so-called Barlow type valve, and mitral valve (MV) repair for such Barlow valves is quite different from MV repair for fibroelastic deficiencies.[1] However, what is a Barlow valve really? Even though there is no clear definition of a Barlow valve in the literature, most surgeons will probably imagine an aneurysmal valve with excess tissue on both leaflets when presented with the term "Barlow." Carpentier used the term "Barlow" to

Abbreviations and Acronyms

AL = anterior leaflet
BL = bileaflet
EBP = extreme billowing and prolapsing
ePTFE = expanded polytetrafluoroethylene
MR = mitral regurgitation
MV = mitral valve
PL = posterior leaflet
SAM = systolic anterior motion
TEE = transesophageal echocardiography
TTE = transthoracic echocardiography

mean the same thing as billowing in his manuscript and clearly separates billowing from prolapsing valves.[2]

The correction of the prolapse of both voluminous and deformed leaflets caused by advanced degeneration is technically demanding, and echo assessment reveals that late recurrent mitral regurgitation (MR) is quite common.[3] In this manuscript, we define the extreme billowing and prolapsing (EBP) valve to be where there is prolapse of more than 2 of the 3 segments of each leaflet with excess tissue present on both leaflet, and describe our concept, methods, and results of MV repair for this subgroup of patients with MR.

METHODS

Patients

The EBP valve is bileaflet (BL) prolapse. Each leaflet consists of 3 segments. We define the EBP valve to be a valve with prolapse of 2 or more of the 3 segments of each leaflet and excess tissue present on both leaflets. From December 1991 to December 2012, among 1344 consecutive patients who underwent MV repair for MR associated with degenerative disease at the Sakakibara Heart Institute, 405 patients received MV repair for BL prolapse. Of these 405 patients, 73 patients (18.0%) met our definition of a EBP valve. From these 73 patients, 67 patients who received MV repair based on the strategy that was developed in July 1996 were enrolled in this study. The Ethics Committee of the Sakakibara Heart Institute approved this manuscript, waived the need for consent of the patient, and provided approval before publication of the data.

Our strategy of MV repair for EBP valves consists of (1) volume reduction of the leaflets (Figure 1, *A*), (2) proper annuloplasty (Figure 1, *C*), and (3) wide use of artificial chordae for anterior leaflet (AL) repair (Figure 1, *B*). The median follow-up was 11.1 years and 100% complete (maximum, 20.2 years). Preoperative and perioperative characteristics of all patients with a EBP valve are shown in Table 1.

Operative Technique

Operative techniques used are shown in Table 2. The primary techniques used for MV repair included chordal replacement with extra polytetrafluoroethylene (ePTFE) sutures for AL prolapse (67/67; 100%)[4,5] and leaflet resection for posterior leaflet (PL) prolapse (67/67; 100%).[6] In 56 patients (56/67; 83.6%) with a high PL, the sliding leaflet technique[7] was performed to reduce the height and volume of the PL.

Leaflet resection of the redundant portion of the AL was performed in 5 patients. Wherever possible, excess leaflet tissue was removed to achieve a near-normal configuration of the MV.

Chordal replacement for the PL was performed in 36 cases. The mean number of ePTFE sutures used for AL repair of the 67 EBP valve patients treated with this strategy was 3.7 pairs. For the last 30 cases, this figure increased to 4.2 pairs.

A prosthetic ring or band was used for annuloplasty in 52 patients and autologous pericardium band in 15 patents. Remodeling annuloplasty using a rigid ring that has a 3:4 anteroposterior-transverse dimension for redundant AL in EBP sometimes causes systolic anterior motion (SAM) or dysfunction of the AL.[8] The basic concept of our annuloplasty technique for EBP valves is to retain the shape of the patient's own redundant AL[9] to ensure normal functioning of the AL (physiologic remodeling annuloplasty) (Figure 1, *C*). Although the selection of the material was influenced to some extent by a preference or intraoperative judgment of the operators, when using a semirigid ring, a larger size was selected. Band annuloplasty was mainly used for valves considered to have high risk of SAM.

Follow-up

All patients underwent preoperative transthoracic echocardiography (TTE) and transesophageal Doppler echocardiography (TEE). The left ventricular ejection fraction was calculated using the biplane Simpson method, and left ventricular end-diastolic dimension and left ventricular end-systolic dimension were determined on a 2-dimensional parasternal long-axis view. An effective regurgitant orifice area was calculated as the ratio of regurgitant flow to regurgitant velocity by use of the proximal isovelocity surface area method. The grade of MR was determined quantitatively according to the American College of Cardiology/American Heart Association 2006 Guidelines.[10] When the quantitative assessment of MR was not applicable, the severity of MR was determined semiquantitatively using other parameters such as a vena contracta and MR jet area.[11] The pulmonary artery systolic pressure was estimated by Doppler echocardiography, using the simplified Bernoulli equation. Intraoperative TEE was performed to assess the postrepair MV after the patient was weaned from cardiopulmonary bypass. TTE was performed before discharge and at follow-up visits. TTE was performed at least once after discharge for all 67 patients during follow-up (the median echocardiography follow-up period was 9.6 years postoperatively).

Statistical Analysis

Descriptive statistics are presented as count (%) for categorical data and median (interquartile range), where appropriate. Logistic regression analysis was used to assess variable effect on procedure-related outcomes. Reversed Kaplan–Meier estimates were used to determine follow-up event, and Kaplan–Meier estimates were used to calculate estimates of freedom from mortality. Cox proportional hazards models were created to assess variable effect on time-dependent outcomes. Hazard ratios and 95% confidence intervals were calculated. All statistical analyses were performed using JMP 11.2 software (SAS Institute, Inc).

RESULTS

There were no hospital deaths and 6 late deaths in this series. The cause of late death in 3 cases were cardiac reason (heart failure 1, cerebral infarction 1, and sudden death 1), and the others were attributed to noncardiac reasons. Kaplan–Meier survival at 10 years was 96.8 ± 2.2%. There were 2 reoperations performed at 8.0 and 15.3 years, respectively. In both cases, the reason for reoperation was recurrent severe MR. Both patients underwent MV replacement. The probability of MV reoperation at 10 years was 1.8 ± 1.8% (Figure 2). Six incidences of SAM were detected by intraoperative TEE. In 3 of these 6 patients without significant MR, SAM disappeared after discontinuation of inotropic agents or volume challenge. In the other 3

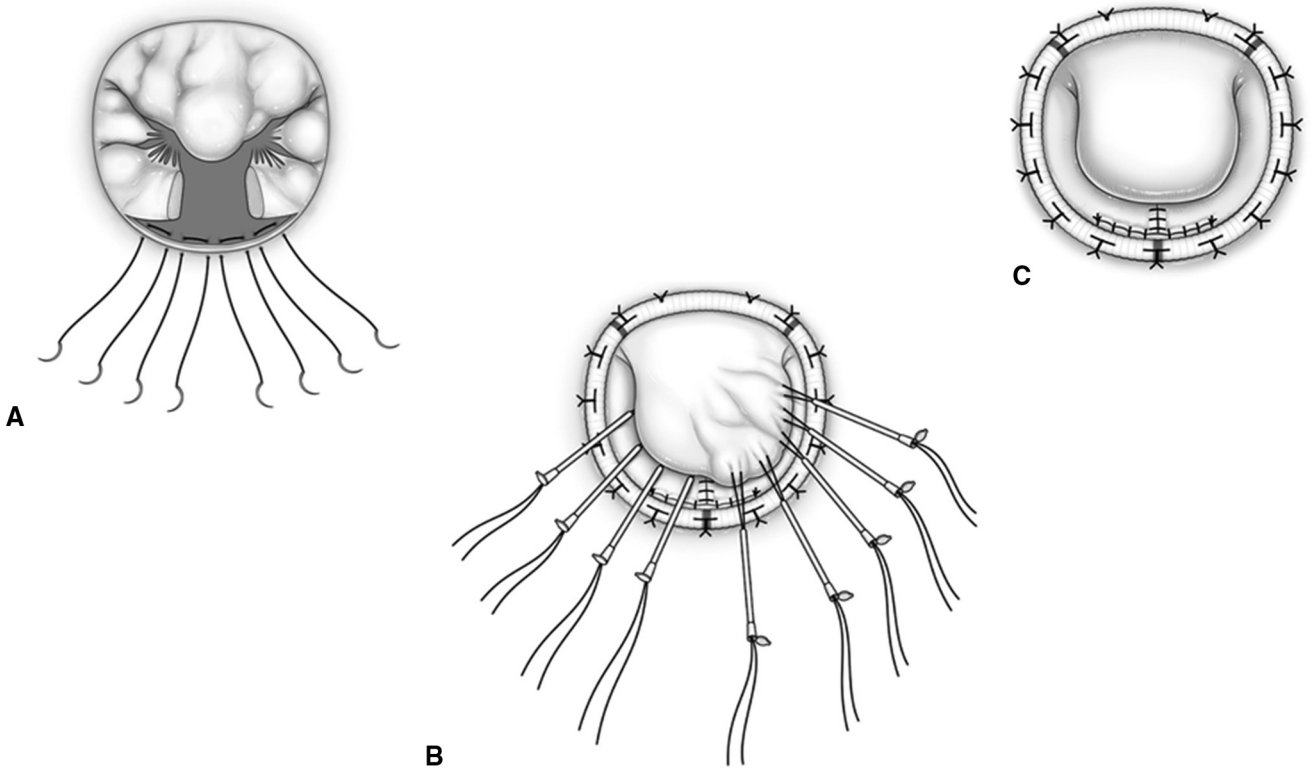


FIGURE 1. A, Volume reduction of the leaflets using sliding leaflet technique. B, Wide use of artificial chordae for anterior leaflet (AL) repair. C, Physiologic remodeling annuloplasty to retain the shape of the patient's own redundant AL.

patients with moderate MR, the SAM was corrected by changing the type or size of annuloplasty ring under second cardiac arrest.

TABLE 1. Baseline characteristics

Preoperative characteristic	Mean ± SD or number (ratio)
Age, y	46.6 ± 12.9
Male	47 (701)
NYHA class	
I	33 (49.3)
II	30 (44.8)
III	4 (5.9)
IV	0
Atrial fibrillation or flutter	13 (19.4)
History of infective endocarditis	3 (4.5)
Mitral regurgitation	
Moderate	6 (9.0)
Moderate-severe	6 (9.0)
Severe	55 (82.0)
LVEF, %	65.9 ± 7.0
LVESD, mm	34.9 ± 5.9
LAD, mm	44.5 ± 7.1
Pulmonary hypertension	17 (25.4)

SD, Standard deviation; *NYHA*, New York Heart Association; *LVEF*, left ventricular ejection fraction; *LVESD*, left ventricular end-systolic diameter; *LAD*, left atrial diameter.

During the follow-up, 2 patients developed severe MR and moderate MR in 9 patients. Figure 3 shows the estimated probability of recurrent moderate MR. At 10 years, the probability of recurrent moderate or severe MR was 11.2 ± 4.0% (Figure 3). Table 3 shows the results of the

TABLE 2. Operative data

Finding or technique	Median (interquartile range) or number (ratio)
Chordal rupture	25 (37.3)
Leaflet resection for PL	67 (100)
Without sliding plasty	11 (16.4)
With sliding plasty	56 (83.6)
Artificial chordal replacement for PL	36 (53.7)
Leaflet resection for AL	5 (7.5)
Artificial chordal replacement for AL	67 (100)
Commissure leaflet plication	15 (22.4)
Mitral annuloplasty	67 (100)
Type of mitral annuloplasty	
Carpentier-Edwards Physio	8 (11.9)
Carpentier-Edwards Physio II	4 (6.0)
Duran	20 (29.9)
Tailor St Jude Medical	20 (29.9)
Autologous pericardium	15 (22.4)
Annuloplasty ring size, [range]	35 [28-40]

PL, Posterior leaflet; *AL*, anterior leaflet.

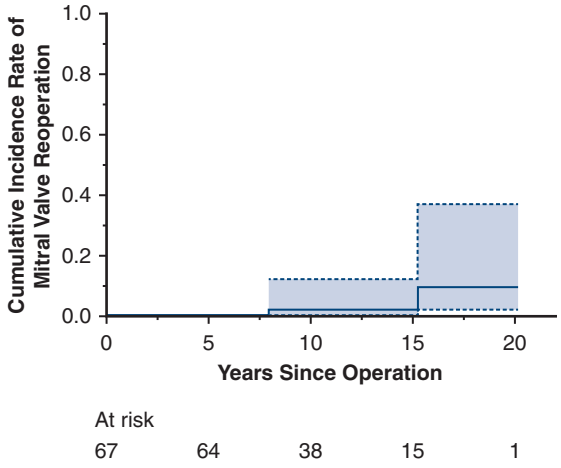


FIGURE 2. Cumulative incidence rate of mitral valve reoperation.

univariable analysis on variables associated with recurrent moderate MR. Figure 4 shows the estimated probability of recurrent severe MR.

At 10 years, the probability of recurrent severe MR was 6.7 ± 3.3% (Figure 4). The number of artificial chordal replacements was associated with decreased risk of recurrent moderate MR (hazard ratio, 0.60; 95% confidence interval, 0.36-0.96, $P = .032$).

DISCUSSION

MV repair is considered the preferred treatment for degenerative MR.[12] A recent multicenter study analyzing very long-term outcomes after MV repair and replacement for degenerative MR with a flailing leaflet demonstrated that MV repair was associated with lower operative mortality, better long-term survival, and fewer valve-related complications compared with MV replacement.[11]

However, other publications show a greater risk of reoperation or greater recurrence rate of MR after MV repair in

TABLE 3. Univariable models of recurrent moderate or severe mitral regurgitation

Variable	*P* value	HR (95% CI)
Number of artificial chordal replacement	.032	0.60 (0.36-0.96)
LAD (10-mm increment)	.054	2.38 (0.98-5.82)
Surgery year (5-y increment)	.065	0.43 (0.17-1.05)
Atrial fibrillation or flutter	.078	3.50 (0.86-13.33)

HR, Hazard ratio; *CI*, confidence interval; *LAD*, left atrial diameter.

patients receiving AL repair and BL repair.[12,13] Flameng and colleagues[14] revealed a greater recurrence rate in patients with Barlow disease (6.0%) and a lower one in those with fibroelastic deficiency (2.6%).

Although several papers have been published recently reporting good long-term results for MV repair in patients with Barlow disease,[15–17] the spectrum of the pathology of the patients is different or unclear in these studies because there is no clear definition of Barlow disease. In one recent paper, the diagnosis of Barlow disease was based on the patient's medical history and preoperative 2-dimensional echocardiography showing dilatation of the annulus, excess valvular tissue with billowing leaflets, and leaflet thickening. Formes frustes with excess tissue localized onto several segments of the PL and commissures were included in this report.[15] In another article, the diagnosis of Barlow disease was based on intraoperative TEE and surgical inspection revealing excess leaflet tissue with BL prolapse or a chordal elongation, and annular dilatation with or without calcification. In this article, formes frustes were not included.[16] Carpentier classified degenerative MR into 2 groups.[1] One is fibroelastic deficiency and the other is myxoid degeneration. He clearly differentiated billowing valves (Barlow) from prolapsing valves[2]; defining billowing valves as those in which excess leaflet tissue

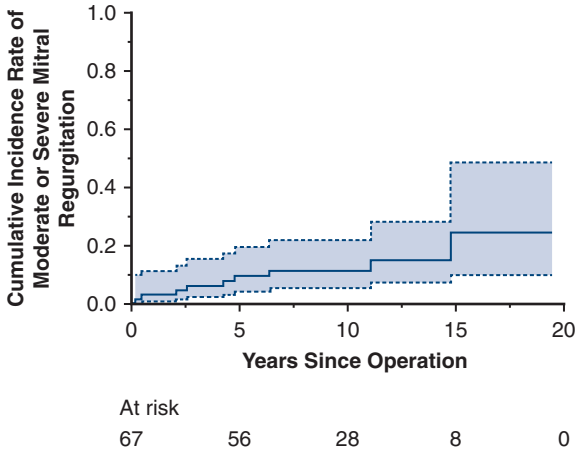


FIGURE 3. Cumulative incidence rate of moderate or severe mitral regurgitation.

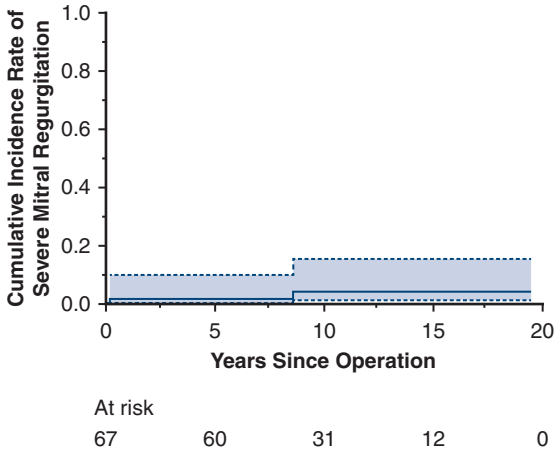
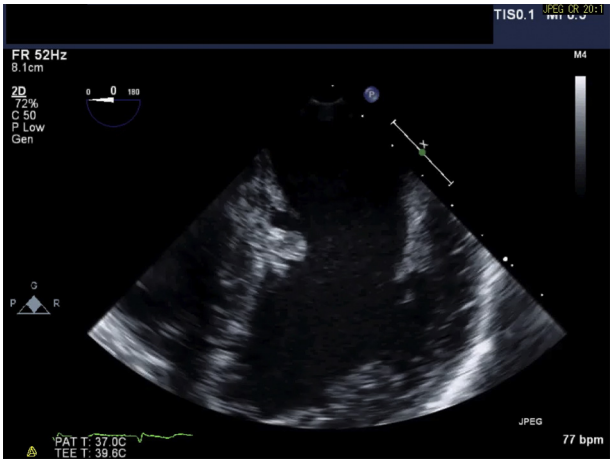


FIGURE 4. Cumulative incidence rate of severe mitral regurgitation.



VIDEO 1. In this case with a generalized billowing and prolapsing valve, a sliding plasty for the huge posterior leaflet (sufficient volume reduction to attain a near-normal configuration of the MV) was performed. A physiologic remodeling annuloplasty using a flexible ring and a chordal replacement using 6 pairs of ePTFE sutures for AL was also performed. The intraoperative TEE revealed no MR and good functioning of the MV. Follow-up echo taken at the outpatient clinic 7 years after the operation still showed a competent valve. Video available at: https://www.jtcvs.org/article/S2666-2736(22)00146-2/fulltext.

protrudes into the atrium during systole with the free edge of the leaflets remaining in apposition below the plane of the mitral annulus. So, according to Carpentier's definition, if we discuss MV repair for Barlow, we should say MV repair for a prolapsed Barlow or for a billowing and prolapsing valve.

We believe it is necessary to find a proper term for valves having BL prolapse with excess tissue on both leaflets, situations that most surgeons find difficult to repair the valve. In this manuscript, to clearly define the spectrum of the pathology, we defined a EBP valve as a valve with prolapse of 2 or more of the 3 segments of each leaflet and excess tissue present on both leaflets. Long-term results of MV repair using our strategy for patients with EBP valve are presented in this study.

Difficulty in repairing the EBP valve stems from its anatomical features, characterized by a redundant leaflet protruding to left atrium and excess tissue on both leaflets. Voluminous or 3-dimensional leaflets complicate MV repair. Excess tissue on the rough zone of the leaflets may inhibit smooth coaptation. The movement of the anterior part of the 3-dimensional structure of a EBP valve tends to become restrictive after normal remodeling annuloplasty using a semirigid or rigid ring. The long or high AL, often encountered in EBP valves, causes SAM after annuloplasty[20] if the prosthetic ring used for repair has a 3:4 anteroposterior–transverse dimension. Furthermore, the high closing stress of the voluminous leaflets may cause a progression of the degeneration of the chordae tendinea, mitral annulus, and leaflets.

After an initial experience of MV repair for EBP between 1992 and 1996, we developed a physiologic strategy to manage the repair of EBP valves. Our strategy for repairing EBP valves consists of (1) sufficient volume reduction of the leaflets to avoid a lack of smooth coaptation and SAM, (2) proper annuloplasty to retain the function of the AL, and (3) wide use of artificial chordae for AL repair to attain smooth coaptation and avoid recurrence of chordal elongation.

Volume reduction means the removal of the main features of the EBP valve. In those cases, with huge PL, sliding plasty is effective to avoid SAM (Figure 1, *A*). In this study, we used sliding plasty in 56 of 67 patients (84.3%).

Proper (physiologic remodeling) annuloplasty can be defined as annuloplasty that adapts to the voluminous AL depending on its variety of configurations. It is especially useful in patients with a long AL to avoid SAM. We believe annuloplasty with a ring or band is an indispensable part of MV repair in these patients. The type of annuloplasty varied among patients in this study. Our basic strategy for mitral annuloplasty in this series was to select a flexible band first and sometimes use rigid/semirigid ring annuloplasty for patients with severe annular dilatation. We prefer to use a flexible material in this subgroup of patients because flexible material adapts more easily to the voluminous and large AL. In this study, 55 (82.1%) of the 67 patients with ring/band annuloplasty were treated with flexible material. Newcomb and colleagues[3] also used flexible material in 93% of the patients who received annuloplasty using ring/band in MV repair for advanced myxomatous degeneration. Proper annuloplasty for those patients with long AL results in vertically long annuloplasty (Figure 1, *C*). Adams and colleagues[20] reported an excellent early outcome of MV repair in patients with Barlow disease using large size ring based on the true size of the AL and described that large annuloplasty rings help minimize the risk of SAM. Their concept is similar to ours in respecting the true size of the AL in remodeling annuloplasty. Quigley and collegues[21] reported a MV repair reducing the height of the AL using elliptical excisions of the base of the AL to prevent SAM in patients with severe myxomatous MV having long AL.

Wide use of artificial chordae for AL repair is necessary because the free margin of the voluminous AL in this subgroup of patients is long and not smooth (Figure 1, *B*). Even though a small number of artificial chordae may be able to correct the prolapse of the AL, such a number will not control the leakage from a long coaptation line nor prevent recurrence of prolapse. In this study, the mean number of ePTFE sutures used for the AL repair was 3.7 pairs (range, 1-9 pairs). The tourniquet technique uses for chordal replacement in this series is reliable even when using a large number of ePTFE sutures.[4,5,22]

In this series, 50% of the patients with EBP valve had a long AL defined by the anteroposterior dimension being greater than the transverse dimension. Only 3 incidences of SAM with significant MR were detected intraoperatively, and all were corrected during the operation by changing the type of annuloplasty.

This study consists of a special subgroup of patients with degenerative BL prolapse in whom the degree of billowing with excess tissue and prolapse is extensive. Jouan and colleagues[15] reported long-term echocardiography results of 200 patients with Barlow disease defined as annular dilatation, excess tissue, and leaflet prolapse. At 10 years, the probability of recurrent moderate MR was 11.2%. The results are excellent; however, since the series includes patients with isolated PL prolapse and formes frustes, it is very difficult to compare the results of their report with the results of ours. In the report of Jouan and colleagues,[15] 44% of the 453 patients who received MV repair for degenerative MR were diagnosed with Barlow disease. In our study, the 73 patients were only 5.4% of the 1344 patients who underwent MV repair for degenerative MR.

Long-term echographic follow-up demonstrated excellent results of MV repair for EBP valves using our strategy. However, late recurrence of moderate MR is not rare, and further investigation of the department of the spectrum of the pathology of EBP valves is certainly necessary (Video 1).

Limitations

This is a retrospective review of a series of clinical experience and small patient population. As this report spans more than 20 years, the details of the technique have changed over the years. For example, the number of artificial chordae increased over the 16 years of the study. The 67 patients enrolled in this study were operated on by 3 surgeons, not by a single operator. Although the basic strategy of MV repair for EBP valves was the same among these 3 surgeons, there might have been small differences in judgement made during the operations.

CONCLUSIONS

We defined the prolapse of more than two-thirds of each leaflet with excess tissue present on both leaflets as a EBP valve. Long-term echo follow-up demonstrates excellent results of MV repair for such EBP valves using volume reduction and proper annuloplasty associated with extensive usage of artificial chordae for AL repair.

Conflict of Interest Statement

The authors reported no conflicts of interest.

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

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Key Words: mitral valve repair, billowing valve, mitral valve prolapse, Barlow