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)

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.

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
mean the same thing as billowing in his manuscript and
clearly separates billowing from prolapsing valves. The
correction of the prolapse of both voluminous and
deformed leaflets caused by advanced degeneration is techni-
cally demanding, and echo assessment reveals that late recur-
rent mitral regurgitation (MR) is quite common. 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 seg-
ments. 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 pro-
lapse. 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 reduc-
tion 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 polytetra-
fluoroethylene (ePTFE) sutures for AL prolapse (67/67; 100%) and leaflet resection for posterior leaflet (PL) prolapse (67/67; 100%). In 56
patients (56/67; 83.6%) with a high PL, the sliding leaflet technique was
used 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 patients. Remodeling annuloplasty us-
ing 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. The basic concept of our annuloplasty technique
for EBP valves is to retain the shape of the patient’s own redundant AL to
to ensure normal functioning of the AL (physiologic remodeling annulo-
plasty) (Figure 1, C). Although the selection of the material was influenced
by 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 iso-
velocity surface area method. The grade of MR was determined quantita-
tively according to the American College of Cardiology/American Heart
Association 2006 Guidelines. 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. The pul-
monary artery systolic pressure was measured using Doppler echocardiogra-
phy, 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. TEE 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 anal-
ysis 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% con-
fidence 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 se-
ries. 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, respec-
tively. In both cases, the reason for reoperation was recur-
rent 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 de-
tected by intraoperative TEE. In 3 of these 6 patients
without significant MR, SAM disappeared after discontinu-
ation of inotropic agents or volume challenge. In the other 3

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

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

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 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.

### 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        |                                              |
| Carpenter-Edwards Physio           | 8 (11.9)                                     |
| Carpenter-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.
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 $6.7 \pm 3.3\%$ (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. 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.

However, other publications show a greater risk of reoperation or greater recurrence rate of MR after MV repair in patients receiving AL repair and BL repair. Flameng and colleagues 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, 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. 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. Carpenter classified degenerative MR into 2 groups. One is fibroelastic deficiency and the other is myxoid degeneration. He clearly differentiated billowing valves (Barlow) from prolapsing valves; defining billowing valves as those in which excess leaflet tissue

| Variable                        | $P$ value | HR (95% CI)   |
|---------------------------------|-----------|---------------|
| Number of artificial chordal    | .032      | 0.60 (0.36-0.96) |
| replacement                     |           |               |
| 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.
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 colleagues²¹ 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 colleagues²⁰ 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 colleagues²¹ 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 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, 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