



# Mitral valve repair with the edge-to-edge technique: A 20 years single-center experience

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## Abstract

**Objectives:** For tailored treatment of primary mitral regurgitation (MR), surgeons developed different repair techniques. One of them, the edge-to-edge repair has recently seen a revival, especially for Barlow's disease.

**Methods:** This study was designed to assess the outcomes of the edge-to-edge technique in mitral valve (MV) repair. Preoperative, perioperative, and postoperative data were prospectively collected in a dedicated database and analyzed retrospectively.

**Results:** Between March 1999 and July 2019, a total of 152 patients (mean age:  $60 \pm 13$ ) received an edge-to-edge repair combined with annuloplasty for degenerative MR at our institution. MR resulted from posterior leaflet prolapse in 23 patients (15.1%), anterior leaflet prolapse in 19 (12.5%), and bileaflet prolapse in 110 (72.4%). Of those who had a bileaflet prolapse, 91 (82.7%) had Barlow's disease. Follow-up was complete in 97.4% ( $6.4 \pm 5.7$  years). Echocardiographic assessment was achieved in 85.5% ( $5.1 \pm 5.6$  years). Overall survival after 10 years was  $73.7 \pm 5.0\%$ . Twelve patients required valve-related reoperations due to ring dehiscence ( $n = 2$ ), leaflet suture dehiscence ( $n = 2$ ), progression of native valve disease ( $n = 6$ ), or due to device failure (ring fracture) ( $n = 2$ ). The cumulative incidence of valve-related reoperation at 10 years was  $8.4 \pm 3.0\%$  ( $5.2 \pm 4.1\%$  in patients with Barlow's disease). At latest follow-up, echocardiography revealed excellent valve function with no or mild MR in 93 patients (88.6%). The mean gradient was  $2.9 \pm 1.3$  mmHg at discharge and decreased to  $2.4 \pm 1.3$  mmHg. Three patients (2.8%) had more than moderate MR.

**Conclusion:** Edge-to-edge MV repair is a simple method with excellent results in terms of valvular function and durability especially in patients with Barlow's disease.

## KEYWORDS

heart valve surgery, mitral valve surgery, outcomes (includes mortality, morbidity)

## 1 | INTRODUCTION

It is widely accepted that mitral valve repair (MVR) in degenerative mitral valve disease is preferred to replacement whenever possible. Current guidelines recommend MVR even in asymptomatic patients with severe mitral regurgitation (MR) when performed in a Heart Valve Center of Excellence.<sup>1</sup>

Simpler pathologies, such as MR due to prolapse of the posterior mitral leaflet, can be repaired with a variety of techniques including quadrangular and triangular resection or the use of artificial chords in addition with ring annuloplasty. In these cases, results and durability are excellent.<sup>2</sup> However, the repair of complex mitral lesions remains challenging. The underlying mitral valve pathology affects the durability of MVR.<sup>2,3</sup> In addition, complex pathologies require the application of advanced repair techniques.<sup>4</sup> Particularly in Barlow's disease, both the complexity of the repair and the recurrent MR remain a concern even in the hands of experienced surgeons.<sup>5-7</sup>

In these particular cases, a functional correction instead of a complex anatomical correction could provide an adequate treatment option to achieve mitral valve competency.

A functional reconstruction can be achieved by approximation of the free edge from both leaflets at the regurgitation site with a suture, thereby creating a double-orifice mitral valve. This technique, called "Alfieri stich" or edge-to-edge MVR, was first described by Alfieri et al. in 1995.<sup>8</sup>

At our institution, we performed the edge-to-edge technique in a variety of mitral valve lesions, mainly Barlow's disease. The aim of this study was to evaluate the outcomes of this approach in terms of survival, the need for redo mitral valve surgery and recurrent MR.

## 2 | METHODS

### 2.1 | Study design

All consecutive patients undergoing MV repair with edge-to-edge technique for degenerative MR at our institution were included in this study. Preoperative, periprocedural, and postoperative data were prospectively collected in a dedicated database and analyzed retrospectively.

### 2.2 | Study objectives

The study had three primary end points: (a) to assess the durability of MVR in terms of recurrent MR, (b) to determine the need for reoperation, and (c) to determine the valve function on the basis of the measured transvalvular gradients. Secondary end points included survival and functional outcome (defined as New York Heart Association [NYHA] class).

### 2.3 | Data collection and echocardiography

Baseline data collected preoperatively included age, gender, ejection fraction, cardiac rhythm, NYHA class, regurgitation grade, and type of mitral valve pathology. Procedural data were recorded at the time of intervention and during hospital stay. Echocardiography was performed preoperatively, at discharge and at latest follow-up. Transthoracic echocardiography was performed in all patients preoperatively and at discharge. MR was graded as none/trivial (0+), mild (1+), moderate (2+), or severe (3+). Follow-up echo was either obtained by our outpatient department or by the referring physician. All evaluations were carried out according to standard techniques recommended by current guidelines.<sup>9</sup> Routine transesophageal echocardiography was performed in all patients immediately before and after surgery. Clinical symptoms, hemodynamic data, and the functional outcome were obtained from medical records, patients' follow-up visits, mailed questionnaires, telephone interviews with the patient or family members, and communications from the referring physicians.

### 2.4 | Ethical statement

The study complied with the declaration of Helsinki and was approved by the local governmental Ethics Committee (approval reference number: 564/16 S, December 14, 2016). Written informed consent was obtained from each participant.

### 2.5 | Statistical analysis

Statistical analysis was performed with IBM SPSS 22 (SPSS Inc.) and R (version 3.5.2; R Foundation for Statistical Computing). Normally distributed continuous variables are presented as mean  $\pm$  standard deviation (SD). Categorical variables are presented as number (%). Overall survival was analyzed with Kaplan–Meier methods and the log-rank test. Freedom from reoperation were analyzed with cumulative incidence functions for competing risks. A  $p < .05$  was considered significant.

## 3 | RESULTS

### 3.1 | Patient characteristics

Between March 1999 and July 2019, a total of 3393 MVR procedures were performed at our institution. During this period, 152 patients with severe degenerative MR were treated with the edge-to-edge technique. MR resulted from posterior leaflet prolapse in 23 patients (15.1%), anterior leaflet prolapse in 19 (12.5%), and bileaflet prolapse in 110 (72.4%). Of those who had a bileaflet prolapse, 91 (82.7%) had Barlow's disease. The baseline data are summarized in Table 1.

**TABLE 1** Baseline data

Patients, <i>n</i>	152
Age, <sup>a</sup> years (mean ± SD)	59.6 ± 12.9
Male, <i>n</i> (%)	110 (72.4)
Ejection fraction, %	62 ± 13
Atrial fibrillation, <i>n</i> (%)	50 (32.9)
NYHA class, <i>n</i> (%)	
I	0
II	25 (16.4)
III	106 (69.7)
IV	21 (13.8)
Pulmonary hypertension, <i>n</i> (%)	15 (9.9)
Previous cardiac surgery, <i>n</i> (%)	3 (2.0)

Abbreviations: MV, mitral valve; NYHA, New York Heart Association.

<sup>a</sup>Results are presented as mean ± standard deviation.

### 3.2 | Operative technique

In 78 patients (51.3%), a median sternotomy was performed and in 74 (48.7%) a right anterolateral thoracotomy. All procedures were performed on cardiopulmonary bypass under moderate systemic hypothermia and myocardial protection was achieved by antegrade application of cold crystalloid or blood cardioplegia. The MV was exposed through a left atrial or a trans-septal approach, depending on the preference of the surgeon. The results of the detailed valve analysis are displayed in Table 2.

Due to the underlying pathology, the operating surgeon decided to perform an edge-to-edge repair plus a ring annuloplasty. Types of implanted annuloplasty devices and ring sizes are pertained in Table 2, as well as cardiopulmonary bypass- and cross-clamp times and concomitant procedures. The implementation of the edge-to-edge technique was based on the principles of Alfieri et al. and is already well described and published.<sup>10,11</sup> In the beginning, the Alfieri stich was used additionally to various other techniques, such as closure of cleft-like indentations, use of artificial chords, or leaflet resection to achieve an optimal result. In fact, we used this technique predominantly as a bail-out strategy in this initial era. However, due to new evidence, we realized the advantages of the method in a specific population.<sup>12,13</sup>

Therefore, this combined approach was gradually replaced resulting in the current strategy that almost only patients with Barlow's disease (defined as bileaflet flail or prolapse, excessive leaflet tissue, and annular dilatation) or a pronounced prolapse of the anterior leaflet undergo an edge-to-edge MVR in our institution (Figure 1).

### 3.3 | Follow-up

Follow-up was complete in 97.4% of patients with a mean follow-up of 6.4 ± 5.7 years. Four patients were lost to follow-up. Study

**TABLE 2** Operative data

Etiology of MR, <i>n</i> (%)	
Flail/prolapse AML	19 (12.5)
Bileaflet prolapse	110 (72.4)
Barlow's disease	91 (59.9)
Chordal replacement with ePTFE sutures	47 (30.7)
CR with ePTFE sutures + closure of CLI	10 (6.5)
Closure of cleft-like indentations	24 (15.7)
PML segmental resection	21 (13.7)
AML segmental resection	7 (4.6)
Minimally invasive, <i>n</i> (%)	74 (48.7)
Aortic cross-clamp time, min <sup>a</sup>	90.4 ± 29.3
Ring used for annuloplasty, <i>n</i> (%)	
Duran ring	26 (17.1)
Duran band	1 (0.7)
CG future band	35 (23)
CG future annuloplasty ring	19 (12.5)
Carpentier-Edwards physio annuloplasty ring	2 (1.3)
Carpentier-Edwards physio II ring	1 (0.7)
Sorin memo 3D	2 (1.3)
Profile 3D annuloplasty ring	9 (5.9)
Medtronic simulus	57 (37.5)
Mean size of annuloplasty ring (mm) <sup>a</sup>	35.1 ± 3.5
Concomitant procedures, <i>n</i> (%)	82 (53.6)
ASD/PFO closure	24 (15.7)
CABG	23 (15)
Tricuspid valve repair/replacement	31 (20.3)
Aortic valve repair/replacement	13 (8.5)
Ablation of AF	27 (17.6)
Congenital	3 (2)

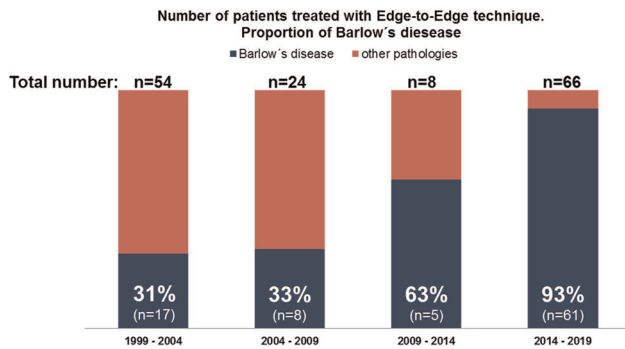
Abbreviations: AF, atrial fibrillation; AML, anterior mitral valve leaflet; ASD, atrial septum defect; CABG, coronary artery bypass graft; CLI, cleft-like indentation; CR, chordal replacement; ePTFE, expanded polytetrafluoroethylene; MR, mitral regurgitation; PFO, persistent foramen ovale; PML, posterior mitral valve leaflet.

<sup>a</sup>Results are presented as mean ± standard deviation.

endpoints were analyzed according to the "Guidelines for Reporting Morbidity and Mortality after Cardiac Valvular Operations".<sup>14</sup>

### 3.4 | Survival

No intraoperative deaths occurred. The 30-day mortality was 0.6% (1/152). At the time of follow-up, 120 patients (78.9%) were alive



**FIGURE 1** Number of patients treated with edge-to-edge technique: proportion of Barlow's disease

with an overall survival after 10 years of  $73.7 \pm 5.0\%$  (Figure 2). Twenty-nine patients (20%) died after a mean time of  $10.8 \pm 4.5$  years. The cause of death could be assessed in 10 patients and were cardiac related in 4 patients and not cardiac related in 6 patients.

### 3.5 | Echocardiographic data

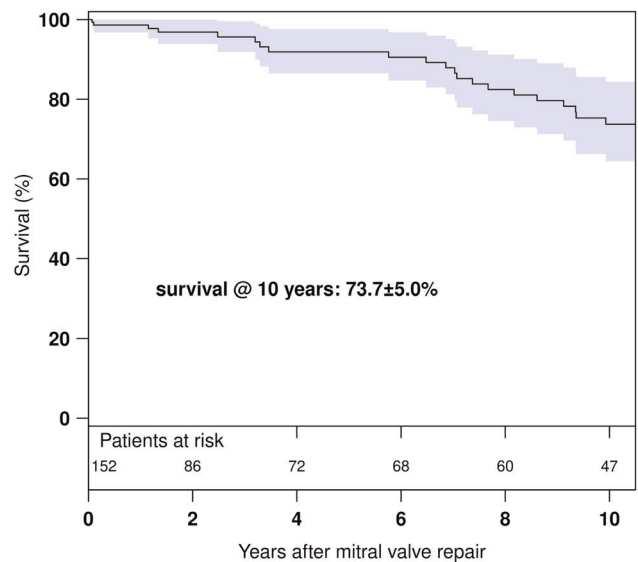
At discharge, 115 patients (75.7%) had no, 33 (21.7%) mild, and 1 (0.6%) moderate MR. No patient had more than moderate MR at discharge. At the end of follow-up ( $5.1 \pm 5.6$  years), echocardiographic examinations of 98 patients (93.3%) were available, showing no MR in 69 patients (70.4%), mild in 21 (21.4%), and moderate in 5 (5.1%). At latest follow-up, three patients (3.1%) presented with more than moderate MR (Figure 3). The mean gradient was  $2.9 \pm 1.3$  mmHg at discharge and decreased to  $2.4 \pm 1.3$  mmHg ( $p < .01$ ) (Figure 4). At latest follow-up, there was no patient with a significant stenosis.

### 3.6 | Reoperations

During follow-up, 12 patients required a mitral valve-related reoperation (mean time to reoperation,  $6.4 \pm 5.2$  years). Reoperations were caused by ring dehiscence ( $n = 2$ ), leaflet suture dehiscence ( $n = 2$ ), progression of native valve disease ( $n = 6$ ), and due to device failure (ring fracture) ( $n = 2$ ). The cumulative risk for mitral valve-related reoperations was  $8.4 \pm 3.0\%$  at 10 years (Figure 5). In patients with Barlow's disease, the cumulative incidence for valve-related reoperation was  $5.2 \pm 4.1\%$  (Figure 6). In contrast, the analysis of the other pathologies, except Barlow's disease, showed a comparatively higher incidence with a reoperation rate of  $11.1 \pm 4.3\%$  at 10 years.

### 3.7 | Functional status

Functional status at latest follow-up was obtained in 105 patients: 82 patients (78.1%) were in NYHA class I, 17 (16.2%) were in class II, 3 (2.9%) were in class III, and 3 (2.9%) were in class IV.

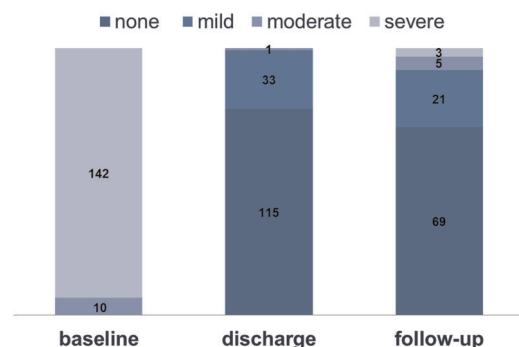


**FIGURE 2** Survival

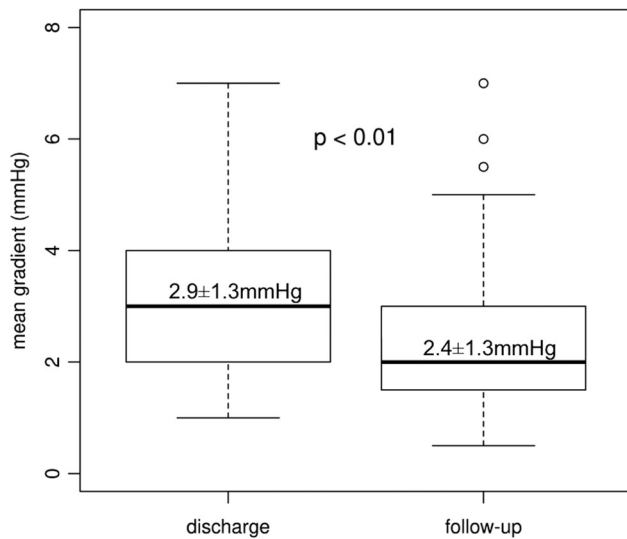
## 4 | DISCUSSION

Over the past decades, multiple techniques for MVR have been established for the tailored repair of degenerative MR, such as tri- or quadrangular resection, sliding plasty or implantation of artificial chordae.<sup>15</sup> All these techniques are based on the concept of an anatomical MVR, first introduced by Alain Carpentier in 1983.<sup>16</sup> In the mid-1990s, Alfieri presented a method for functional repair by suturing the prolapsing free edges of the opposing leaflets together, thus creating a double-orifice valve.<sup>8</sup> Despite good mid- and long-term results, the edge-to-edge technique has often been discredited as nonphysiologic and therefore less durable than anatomical corrections. However, the technique has recently seen a revival for Barlow's disease.

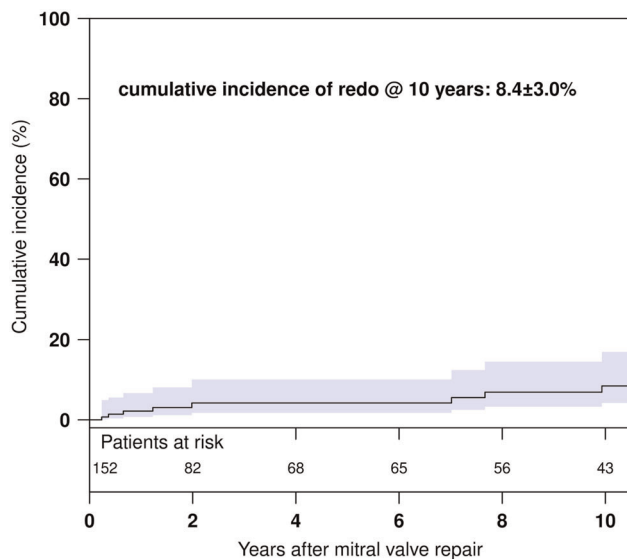
Large clinical trials showed an overall MVR rate between 54.8% and 61.8%, with significant differences among hospitals and surgeons.<sup>17-19</sup> However, in high volume valve centers, repair of complex mitral valve lesions is performed with excellent long-term results.<sup>20</sup>



**FIGURE 3** Changes in the degree of mitral regurgitation at different stages

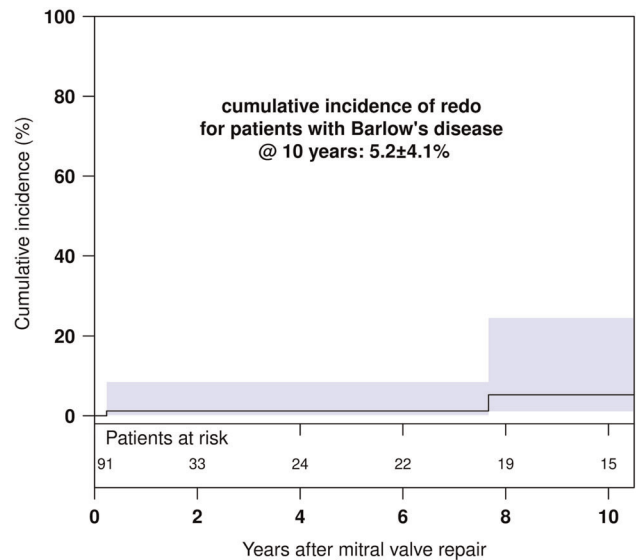


**FIGURE 4** Pressure gradient across the mitral valve at discharge and follow-up



**FIGURE 5** Cumulative incidence of reoperation

To stratify the complexity of MVR, Adams et al. developed a scoring system based on the underlying pathology of the mitral valve.<sup>4</sup> The Authors showed that the three strata (simple, intermediate, and complex) correlated with cross-clamp time and the need for additional and advanced techniques to complete the repair successfully. The cross-clamp time in the complex group (63% Barlow's disease) was  $155 \pm 51$  min. In the present cohort, the mean cross-clamp time with the edge-to-edge repair was only  $90.4 \pm 29.3$  min. In practice, less experienced surgeons may choose a replacement over a repair when a complex lesion requires advanced repair techniques. Therefore, the implementation of a simple repair method, such as the edge-to-edge technique which is also applicable for complex lesions, may lead to increased repair rates.



**FIGURE 6** Cumulative incidence of reoperation in patients with Barlow's disease

In 1999, we introduced this method as an additional technique for repair of complex mitral valve lesions. In the present population predominantly edge-to-edge repair together with ring annuloplasty was carried out. In some cases, mainly in the first period, Alfieri's stitch was used additionally to other techniques such as leaflet resection or artificial chords to achieve a competent mitral valve. This combined approach was gradually replaced resulting in our current policy that almost only patients with Barlow's disease undergo an edge-to-edge MVR in our institution. The change of policy is well illustrated in Figure 1. However, the overall 10-year reoperation rate was 8.4% and was even lower in patients with Barlow's disease (5.2%). In contrast, the analysis of the other pathologies, except Barlow's disease, showed a higher incidence with a reoperation rate of  $11.1 \pm 4.3\%$  at 10 years.

Maisano and colleagues<sup>10</sup> reported on a subgroup of 82 patients with Barlow's disease and found a freedom from reoperation of 86% at 5 years. The authors emphasized the low rate of residual MR, but were not able to explain the high reoperation rate in their population, which was considered a severe limitation. Of note was the short aortic cross-clamp time for that complex mitral valve pathology (mean, SD:  $38 \pm 12$  min). Nevertheless, they propagated this technique as a standardized approach in Barlow's disease.

In 2012, De Bonis et al.<sup>13</sup> reported long-term results of the edge-to-edge and ring annuloplasty technique in patient with predominant bileaflet prolapse (128 of 174). Freedom from reoperation was 89.6% after 14 years, comparable to our results with the edge-to-edge repair and also to the results of studies with anatomical correction.<sup>21</sup> Da Rocha and colleagues<sup>12</sup> compared the neochord ("loop") technique with the edge-to-edge technique in Barlow's disease.<sup>12</sup> The freedom from reoperation at 4 years was 90.9% in patients who underwent neochordal ("loop") repair compared with 92.8% in patients with edge-to-edge repair

( $p = .94$ ). The incidence of recurrent MR was low and comparable in both groups. The edge-to-edge repair showed shorter aortic cross-clamp times (64.1 vs. 95.9 min) but showed higher trans-valvular gradients compared with the loop technique. The fact that the Alfieri repair results in a significant reduction in aortic cross-clamp times can be important in cases in which concomitant procedures are required.

Despite these excellent results we do not use this method as a standardized approach for MVR. Adjusting our indications, we apply this method nowadays mostly in patients with Barlow's disease and a bicommissural distance of at least 45 mm. In these patients, we attempt to implant a larger annuloplasty ring to avoid downsizing and preventing a smaller opening area. These criteria are essential to avoid a stenotic result with increased postoperative mitral valve gradients. In case of excessive leaflet tissue, the edge-to-edge technique eliminates the risk for systolic anterior motion. This happens because the anterior leaflet cannot move in the direction of the left ventricular outflow tract due to its fixation with the posterior leaflet.

## 5 | LIMITATIONS

This study has several limitations. This is a single-center, nonrandomized retrospective study. The decision to perform an edge-to-edge repair was at the surgeon's discretion. Due to a lack of specific indications for the application of this technique, results may be influenced. Since 2015, we performed this technique mainly on patients with Barlow's disease. This leads to a limited amount of patients within this specific subpopulation and may influence the follow-up time.

## 6 | CONCLUSIONS

Edge-to-edge MVR is a simple and reproducible method with excellent results in terms of valvular function and durability especially in patients with Barlow's disease.

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### CONFLICT OF INTERESTS

Ruediger Lange and Bernhard Voss are consultants for Medtronic. The remaining authors declare that there are no conflict of interests.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on reasonable request from the corresponding author. The data are not publicly available due to institutional data protection and ethical restrictions.

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