

Midterm outcomes of quadrangular versus butterfly resection in mitral valve repair for Barlow's disease

Barlow hastalığında mitral kapak onarımında kuadrangüler ve butterfly rezeksiyonun orta dönem sonuçları

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ABSTRACT

Background: This study aims to compare the mid-term clinical and echocardiographic outcomes of quadrangular resection (QR) and butterfly resection (BR) techniques in patients with isolated posterior leaflet prolapse and/or chordal rupture due to Barlow's disease.

Methods: Between May 2009 and January 2023, a total of 142 patients (89 males, 53 females; mean age: 56.6±11.9 years; range, 20 to 84 years) who underwent mitral valve repair with either QR (n=69) or BR (n=73) were retrospectively analyzed. Patients were evaluated using transthoracic and transesophageal echocardiography preoperatively, intraoperatively, and during mid-term follow-up. Clinical variables, echocardiographic parameters, and surgical data were compared between groups.

Results: Baseline characteristics and preoperative echocardiographic findings were similar between the two groups. Both techniques resulted in significant improvements in the New York Heart Association functional class, mitral regurgitation severity, and left ventricular dimensions. However, the BR group demonstrated significantly improved posterior leaflet mobility (Wilkins score 1.97±0.74 vs. 3.23±0.79; p<0.001) and lower mean mitral valve gradient (3 [range, 2 to 4] vs. 6 [range, 5 to 7] mmHg; p<0.001). Coaptation depth was also significantly reduced in the BR group, indicating a more annular-level coaptation.

Conclusion: Butterfly resection is a technically feasible, effective, and anatomically favorable technique for mitral valve repair in Barlow's disease. Its ability to preserve leaflet mobility and minimize mitral gradients makes it a valuable addition to the surgical armamentarium, particularly in anatomically complex cases.

Keywords: Barlow's syndrome, mitral valve, mitral valve insufficiency, treatment outcome, surgery.

ÖZ

Amaç: Bu çalışmada, Barlow hastalığına bağlı izole posterior leaflet prolapsusu ve/veya korda rüptürü olan hastalarda kuadrangüler rezeksiyon (KR) ve butterfly rezeksiyon (BR) tekniklerinin orta dönem klinik ve ekokardiyografik sonuçları karşılaştırıldı.

Çalışma planı: Mayıs 2009 - Ocak 2023 arasında KR (n=69) veya BR (n=73) ile mitral kapak onarımı yapılan toplam 142 hasta (89 erkek, 53 kadın; ort. yaş: 56.6±11.9 yıl; dağılım, 20-84 yıl) retrospektif olarak incelendi. Hastalar ameliyat öncesi, ameliyat sırası ve orta dönem takiplerinde transtorasik ve transözofageal ekokardiyografi ile değerlendirildi. Klinik değişkenler, ekokardiyografik parametreler ve cerrahi veriler gruplar arasında karşılaştırıldı.

Bulgular: Gruplar arasında başlangıç özellikleri ve ameliyat öncesi ekokardiyografik bulgular benzerdi. Her iki teknikte de New York Kalp Derneği fonksiyonel kapasite, mitral yetmezlik derecesi ve sol ventrikül boyutlarında anlamlı iyileşme sağlandı. Ancak BR grubunda posterior leaflet mobilitesi anlamlı derecede daha iyi (Wilkins skoru 1.97±0.74'e kıyasla 3.23±0.79; p<0.001) ve ortalama mitral kapak gradiyenti daha düşük (3 [dağılım, 2-4] ve 6 [dağılım, 5-7] mmHg; p<0.001) idi. Ayrıca, koaptasyon derinliği BR grubunda anlamlı olarak daha düşük olup, daha çok kapak düzeyinde bir koaptasyon olduğunu gösterdi.

Sonuç: Butterfly rezeksiyon, Barlow hastalığında mitral kapak onarımı için uygulanabilir, etkili ve anatomik olarak avantajlı bir tekniktir. Bilhassa anatomik olarak zor olgularda leaflet mobilitesini koruma ve mitral gradiyentleri azaltma açısından önemli katkılar sağlayarak cerrahi envantere değerli bir seçenek olarak eklenmelidir.

Anahtar sözcükler: Barlow sendromu, mitral kapak, mitral kapak yetersizliği, tedavi sonucu, cerrahi.

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Barlow's disease is a condition within the group of degenerative mitral valve diseases which causes deterioration of the fibroelastic structure of the connective tissue in the mitral valve leaflets.^[1] Although fibroelastic deficiency (FED) also belongs to the degenerative group, Barlow's disease exhibits different histopathological and macroscopic features. Histologically, Barlow's disease is characterized by diffuse myxoid degeneration, while macroscopically it presents with leaflet thickening, chordal elongation or rupture, and redundant tissue.^[2] These findings are characteristic of Barlow's disease and help differentiate it from FED.^[3,4] In Barlow's disease, all segments of the mitral valve may be involved. As the disease progresses, mitral leaflet prolapse, billowing, a feature more specific to Barlow's disease, and/or flail may occur, eventually leading to mitral regurgitation (MR).

This detailed morphological analysis plays a critical role in determining both the surgical indication and the strategy for mitral valve repair.^[5] Integration of imaging findings into Carpentier's classification provides the foundation for successful valve repair.^[6]

In the early years of mitral valve repair, surgical approaches often focused on restoring valve functionality, with less emphasis on precise anatomic correction.^[6] However, with growing surgical experience, techniques have evolved to restore not only function but also the anatomical structure of the valve. This paradigm shift is driven by the recognition that asymmetrical coaptation lines, though not initially associated with residual regurgitation, can predispose to recurrence over time. Anatomical correction becomes particularly important in cases of Barlow's disease characterized by excessive posterior leaflet tissue in terms of systolic anterior motion (SAM). When the P2 segment exceeds 20 mm, several techniques have been described to avoid SAM. Among the most established is the quadrangular resection (QR), which combines resection with plication of the posterior annulus.^[6] An alternative technique is the butterfly resection (BR), introduced by Asai et al.^[7] in 2011, which addresses increased posterior leaflet height through a combination of two triangular resections.^[7] A recent review emphasized that variations in the pathophysiology of MR have led to the development of multiple surgical repair strategies.^[8] Building on this perspective, in the present study, we present our institutional experience and mid-term clinical

and echocardiographic outcomes in patients with severe MR due to Barlow's disease, who underwent mitral valve repair using either the butterfly or QR techniques.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Ankara Bilkent City Hospital and Samsun University Faculty of Medicine, Department of Cardiovascular Surgery between May 2009 and January 2023. A total of 671 mitral valve repair procedures were performed by our surgical team. The surgical techniques performed included chordal reimplantation (n=112), chordal resection (n=74), resection of anterior and/or posterior leaflets (n=79), isolated ring annuloplasty (n=54), Fundaro-type posterior annuloplasty (n=35), bileaflet repair (n=105), and various combinations of these approaches (n=70). A total of 142 patients (89 males, 53 females; mean age: 56.6±11.9 years; range, 20 to 84 years) who underwent mitral valve repair using either the QR (n=69) or BR (n=73) technique were included in this study.

Eligible patients had degenerative mitral valve disease characterized by isolated posterior leaflet prolapse and/or chordal rupture, along with redundant leaflet tissue. Of these, 69 patients underwent valve repair with the QR technique between May 2009 and June 2015, while 73 patients received the BR technique between September 2015 and January 2023. In our cohort, the choice between QR and BR was based primarily on chronological changes in institutional practice rather than on specific anatomical considerations. After the introduction of the butterfly technique, QR was gradually abandoned due to the technical simplicity and effectiveness of BR. The patients who underwent concomitant coronary artery bypass grafting or other repair procedures such as neochordae implantation, in addition to leaflet resection were also excluded from the study. Written informed consent was obtained from each patient. The study protocol was approved by the Samsun University Clinical Research Ethics Committee (Date: 18.01.2023, No: SUKAEK-2023/1/9). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data including patient demographics (age, sex, body mass index), comorbidities, New York Heart Association (NYHA) functional class, preoperative electrocardiogram, preoperative transthoracic echocardiography (TTE), intraoperative transesophageal echocardiography (TEE), and

postoperative clinical and echocardiographic outcomes were recorded. As our institution serves as a tertiary referral center for valve repair, a substantial proportion of patients were referred from distant regions. Following an uncomplicated postoperative course, many subsequently continued their routine follow-up at local hospitals. Accordingly, for the present analysis, follow-up data were obtained from our institutional database, and the most recent postoperative data available at each patient's last visit to our center were included. In this study, and in line with general acceptance, mid-term follow-up was defined as postoperative evaluations performed between 12 months and five years after surgery.

Surgical technique

All patients underwent surgery via a median sternotomy. Following bicaval cannulation, cardiopulmonary bypass (CPB) was initiated. After cross-clamping and achieving cardioplegic arrest, the mitral valve was accessed through a transseptal approach via a right atriotomy. After placing annuloplasty ring sutures, initially to serve as stay sutures for improved exposure, all mitral valve segments were inspected thoroughly, with additional guidance from intraoperative TEE. The prolapsing segment, typically located at the P2 region of the posterior leaflet, was identified, and leaflet height was measured using a sterile ruler. In patients with a P2 segment height exceeding 20 mm, the QR technique, along with annular plication as described by Carpentier, was employed to reduce leaflet height. The resection margins were determined with precise measurements. To both reduce the leaflet height and

remove the prolapsing segment, the incision lines were extended toward the P1 and P3 scallops, each direction covering approximately half the width of the prolapsing segment at its base. After plication of the annulus to bring the edges together, the leaflet defect was closed using 5-0 polypropylene sutures.^[6,9]

In the BR technique, described by Asai *et al.*,^[7] two triangular excision fields marked on the redundant tissue of the P2 scallop, with the triangles sharing a common apex was created. The first triangle is equilateral (15 mm) and was drawn with its base as the free edge of the leaflet (Figure 1). The resection length along the free edge was planned to include any ruptured or elongated chordae, consistent with Carpentier's criteria for triangular resection. The second triangle was drawn adjacent to the posterior annulus, sharing the same apex with the first triangle. Its size was adjusted based on the extent of adjacent redundant tissue. In the presence of excessive leaflet tissue at the neighboring P1 and/or P3 scallops, the triangle's borders were extended parallel to the annulus to allow excision of the excess tissue (Figure 2). This excision helped reduce local leaflet height and minimize postoperative asymmetry in the coaptation line. The entire resection site was closed in a T-shape using a 5-0 polypropylene suture, passed through the apex of two triangles (Figure 3).

In both surgical approaches, ring annuloplasty was subsequently performed using an appropriately sized rigid ring, following the principles described by Carpentier. Ring sizing was performed according to Carpentier's method, based on the anterior leaflet surface area and the intertrigonal distance.^[6]

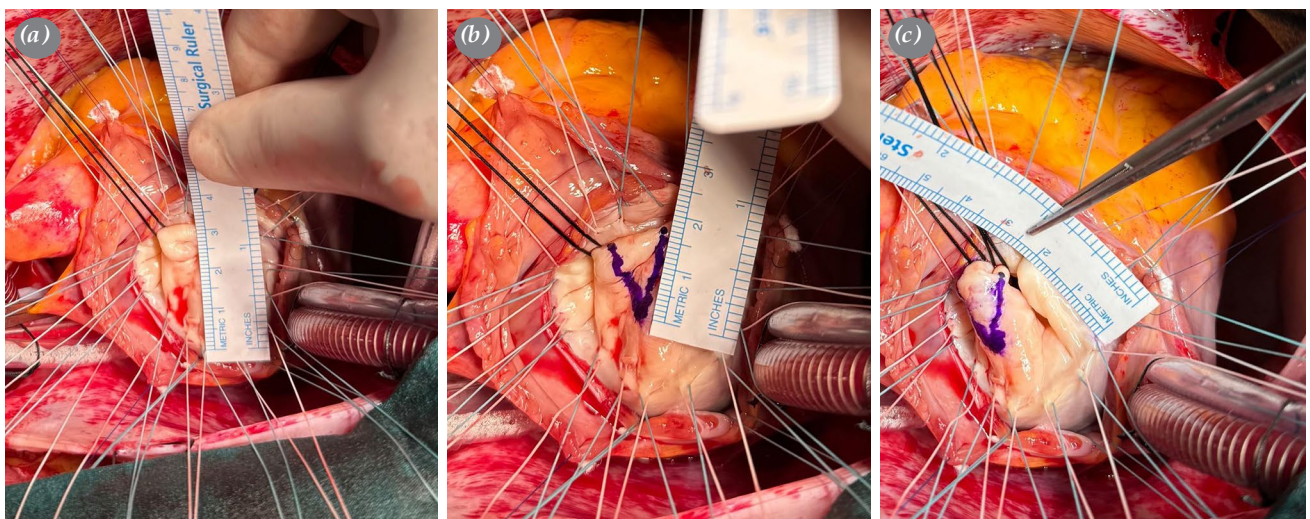


Figure 1. An equilateral triangle (15 mm) was drawn with its base aligned to the free edge of the leaflet.

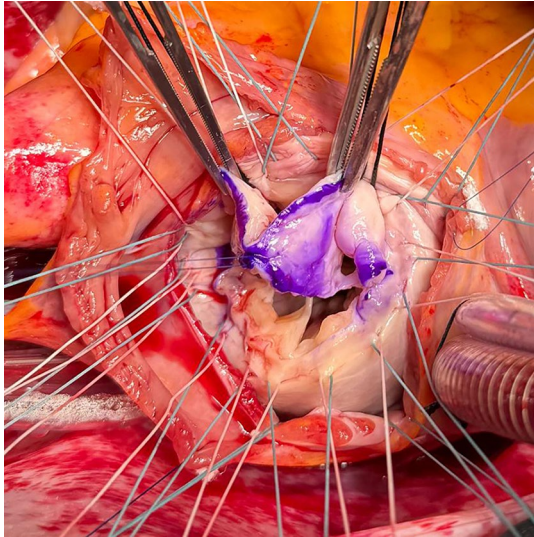


Figure 2. In cases with excessive leaflet tissue at the adjacent P1 and/or P3 scallops, the triangle's borders were extended parallel to the annulus to facilitate excision of the redundant tissue.

No concomitant Maze procedures were performed. Postoperatively, all patients received standard rate-control therapy according to institutional protocol, consisting primarily of beta-blockers, or non-dihydropyridine calcium channel blockers, if beta-blockers were contraindicated.

Echocardiographic evaluation

All patients underwent TTE preoperatively and during mid-term postoperative follow-up, as well as intraoperative TEE assessments. Preoperative TTE evaluations included MR grade, left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), systolic pulmonary artery pressure (SPAP), left atrial (LA) diameter, and left ventricular ejection fraction (LVEF). During intraoperative TEE, detailed assessments were performed including leaflet height (vertical distance between the annulus and the free edge), chordal elongation, and chordal rupture in individual scallops. After repair, the presence of residual regurgitation, coaptation length (C-length) (distance of the contact surface of the anterior and posterior leaflets during systole) and coaptation depth (C-depth) (distance between the coaptation point and the annular plane), and SAM were evaluated. In addition, at postoperative follow-up, mitral leaflet mobility was assessed using the Wilkins-Abascal scoring system and transmitral gradients were measured. In this context, only the leaflet mobility

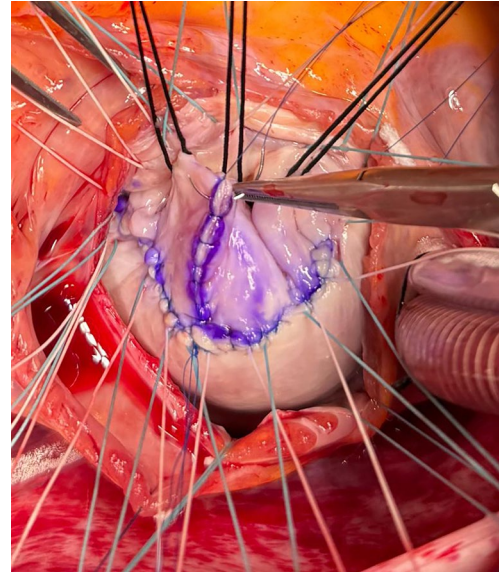


Figure 3. The resection site was closed in a T-shaped fashion using a 5-0 polypropylene suture, passed through the apices of the two triangles.

subcomponent of the Wilkins-Abascal scoring system was applied to provide an objective and reproducible assessment of mobility; the other parameters of the score (leaflet thickness, calcification, subvalvular apparatus) were not used.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 25.0 software (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed using the Kolmogorov-Smirnov test. Depending on the normality of the distribution, either parametric or non-parametric methods were applied. Continuous variables were expressed in mean $\pm$ standard deviation (SD) or median and interquartile range (IQR), while categorical variables were expressed in number and frequency. Group comparisons were performed using the Student t-test or Mann-Whitney U test for continuous variables, and the chi-square test or Fisher exact test for categorical variables. To evaluate pre- and postoperative changes within each group, paired Student t-tests or Wilcoxon signed-rank tests were used for continuous variables, and the McNemar test was used for categorical variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

A total of 142 patients including 69 in the QR group and 73 in the BR group were evaluated

Table 1. Baseline preoperative characteristics of the patients

Postoperative variables	Quadrangular resection group (n=69)				Butterfly resection group (n=73)				p		
	n	%	Mean±SD	Median	IQR	n	%	Mean±SD		Median	IQR
Age (year)			55.2±12.2					57.8±11.6		0.191	
Sex											
Male	44	63.8				45	61.6			0.794	
Body mass index (kg/m ²)			26.1±2.95					26.87±3.81		0.181	
Hypertension	18	26.1				25	34.2			0.382	
Diabetes mellitus	12	17.4				19	26.0			0.297	
COPD	12	17.4				14	19.2			0.954	
Chronic renal insufficiency	2	2.9				1	1.4			0.612	
Previous cerebrovascular event	3	4.3				1	1.4			0.356	
Smoking	12	17.4				19	26			0.297	
NYHA functional classification										0.655	
II	45	65.2				44	60.3				
III	18	26.1				24	32.9				
IV	6	8.7				5	6.8				
Preoperative rhythm										0.561	
Normal sinus rhythm	50	72.5				57	78.1				
Atrial fibrillation	19	27.5				16	21.9				
Mitral regurgitation (grade)										0.775	
III	58	84.1				59	80.8				
IV	11	15.9				14	19.2				
LVEDD (mm)				56	52-60				52	50-59	0.086
LVESD (mm)				41	38-44				40	34.5-44	0.338
Systolic pulmonary artery pressure (mmHg)				46	42-55				47	40-55	0.795
Left atrial diameter (mm)			49.84±5.71					50.93±7.72			0.342
LV ejection fraction (%)			55.33±7.67					53.81±6.61			0.206

SD: Standard deviation; IQR: Interquartile range; COPD: Chronic obstructive pulmonary disease; NYHA: New York Heart Association; LVEDD: Left ventricular end-diastolic dimension; LVESD: Left ventricular end-systolic dimension; LV: Left ventricular; p<0.05 was considered statistically significant.

SD: Standard deviation; IQR: Interquartile range; COPD: Chronic obstructive pulmonary disease; NYHA: New York Heart Association; LVEDD: Left ventricular end-diastolic dimension; LVESD: Left ventricular end-systolic dimension; LV: Left ventricular; p<0.05 was considered statistically significant.

Table 2. Comparison of the perioperative factors between two groups

Postoperative variables	Quadrangular resection group (n=69)					Butterfly resection group (n=73)					p
	n	%	Mean±SD	Median	IQR	n	%	Mean±SD	Median	IQR	
Intraoperative preprocedural TEE											0.412
P2 leaflet height (mm)			26.42±3.15					26.87±3.28			
Cross-clamp time (min)				85	75-109.50				84	77.50-106.50	0.781
Cardiopulmonary bypass time (min)				119	105-140.50				119	112-136.50	0.253
Annuloplasty ring size			29.12±2.40					33.15±2.03			<0.001
Intraoperative postprocedural TEE											
Mitral regurgitation (grade)											
No regurgitation	14	20.3				17	23.3				
I	51	73.9				53	72.6				0.836
II	4	5.8				3	4.1				
P2 leaflet height (mm)			16.1±0.62					15.92±0.66			0.095
Coaptation length (mm)			7.26±0.85					7.45±0.83			0.166
Coaptation depth (mm)			6.04±0.70					4.92±0.64			<0.001
Need for positive inotropic agents	17	24.6				16	21.9				0.853
Duration of intubation (h)				9	6-13				11	7-14	0.126
Intensive care unit stay (day)				1	1-2				2	1-2	0.191
Hospitalization duration (day)				6	5-7				7	6-7	0.179

SD: Standard deviation; IQR: Interquartile range; TEE: Transesophageal echocardiography; p<0.05 was considered statistically significant.

Table 3. Comparison of postoperative midterm outcomes between the two groups

Postoperative variables	Quadrangular resection group (n=69)					Butterfly resection group (n=73)					p
	n	%	Mean±SD	Median	IQR	n	%	Mean±SD	Median	IQR	
Follow-up time (mo)				28	15.50-42				23	20-31	0.602
NYHA functional classification											0.658
I	56	81.2				56	76.7				
II	13	18.8				17	23.3				
Rhythm at follow-up											0.540
Normal sinus rhythm	57	82.6				64	87.7				
Atrial fibrillation	12	17.4				9	12.3				
Mitral regurgitation (grade)											0.436
No regurgitation	6	8.7				10	13.7				
I	55	79.7				58	79.5				
II	8	11.6				5	6.8				
LVEDD (mm)				49	46-50				48	45-50	0.373
LVESD (mm)				37	32-40				36	31-39	0.480
Systolic pulmonary artery pressure (mmHg)				32	28.5-35				30	25-40	0.419
Left atrial diameter (mm)			39.61±5.23					39.25±7.65			0.741
LV ejection fraction (%)			54.14±8.31					52.81±5.82			0.272
Mean mitral valve gradient				6	5-7				3	2-4	<0.001
Leaflet mobility			3.23±0.79					1.97±0.74			<0.001

SD: Standard deviation; IQR: Interquartile range; NYHA: New York Heart Association; LVESD: Left ventricular end-diastolic dimension; LVEDD: Left ventricular end-diastolic dimension; LVESD: Left ventricular end-systolic dimension; LV: Left ventricular; p<0.05 was considered statistically significant.

retrospectively in terms of peri- and postoperative outcomes. There were no statistically significant differences between the groups in terms of age, sex, body mass index, hypertension, diabetes mellitus, chronic obstructive pulmonary disease, chronic kidney disease, prior cerebrovascular events, or smoking history. Preoperative NYHA functional class distribution and baseline rhythm status were also comparable between the groups. Preoperative

echocardiographic parameters, including MR severity, LVEDD, LVESD, SPAP, LA diameter, and LVEF, showed no significant differences between groups (Table 1).

The pre-procedural P2 leaflet height measured intraoperatively by TEE was similar between groups (26.42±3.15 vs. 26.87±3.28 mm; p=0.412). Cross-clamp time and CPB duration were also

Table 4. Comparison of clinical parameters before and after surgery in the quadrangular and butterfly resection groups

	Preoperative					Postoperative					p
	n	%	Mean±SD	Median	IQR	n	%	Mean±SD	Median	IQR	
Quadrangular resection group (n=69)											
NYHA functional classification											<0.001
I	-	-				56	81.2				
II	45	65.2				13	18.8				
III	18	26.1				-	-				
IV	6	8.7				-	-				
Rhythm											0.118
Normal sinus rhythm	50	72.5				57	82.6				
Atrial fibrillation	19	27.5				12	17.4				
Mitral regurgitation (grade)											<0.001
No regurgitation	-	-				6	8.7				
I	-	-				55	79.7				
II	-	-				8	11.6				
III	58	84.1				-	-				
IV	11	15.9				-	-				
LVEDD (mm)				56	52-60				49	46-50	<0.001
LVESD (mm)				41	38-44				37	32-40	<0.001
Systolic pulmonary artery pressure (mmHg)				46	42-55				32	28.5-35	<0.001
Left atrial diameter (mm)			49.84±5.71					39.61±5.23			<0.001
LV ejection fraction (%)			55.33±7.67					54.14±8.31			0.153
Butterfly resection group (n=73)											
NYHA functional classification											<0.001
I	-	-				56	76.7				
II	44	60.3				17	23.3				
III	24	32.9				-	-				
IV	5	6.8				-	-				
Rhythm											0.016
Normal sinus rhythm	57	78.1				64	87.7				
Atrial fibrillation	16	21.9				9	12.3				
Mitral regurgitation grade											<0.001
No regurgitation	-	-				10	13.7				
I	-	-				58	79.5				
II	-	-				5	6.8				
III	59	80.8				-	-				
IV	14	19.2				-	-				
LVEDD (mm)				52	50-59				48	45-50	<0.001
LVESD (mm)				40	34.5-44				36	31-39	<0.001
Systolic pulmonary artery pressure (mmHg)				47	40-55				30	25-40	<0.001
Left atrial diameter (mm)			50.93±7.72					39.25±7.65			<0.001
LV ejection fraction (%)			53.81±6.61					52.81±5.82			0.117

SD: Standard deviation; IQR: Interquartile range; NYHA: New York Heart Association; LVEDD: Left ventricular end-diastolic dimension; LVESD: Left ventricular end-systolic dimension; LV: Left ventricular.

comparable. However, the mean annuloplasty ring size used in the BR group was significantly larger than in the QR group (33.15 ± 2.03 vs. 29.12 ± 2.40 mm; $p < 0.001$). Post-repair intraoperative TEE findings, including MR severity ($p = 0.836$), C-length (7.26 ± 0.85 vs. 7.45 ± 0.83 mm; $p = 0.166$), and postoperative P2 height (16.1 ± 0.62 vs. 15.92 ± 0.66 mm; $p = 0.095$), were similar. However, C-depth was significantly greater in the QR group (6.04 ± 0.70 vs. 4.92 ± 0.64 mm; $p < 0.001$). The coaptation surface (C-length) was similar in both groups without statistically significant difference, whereas the greater C-depth observed in the QR group reflected a more apically displaced coaptation point. Among patients with Grade II MR on intraoperative TEE ($n = 7$), regurgitation decreased after adequate rate control without the need for re-cross-clamping; these patients remained stable with mild (Grade I-II) MR during follow-up, and none required reoperation. There was no significant difference in intraoperative inotropic support, intubation time, ICU stay, or total hospital stay (Table 2).

The median midterm follow-up duration was 28 (range, 15.5 to 42) months in the QR group and 23 (range, 20 to 31) months in the BR group ($p = 0.602$). The NYHA functional class distribution during follow-up remained similar ($p = 0.658$). The proportion of patients in sinus rhythm was 82.6% in the QR group and 87.7% in the BR group ($p = 0.540$). The severity of MR remained comparable between the groups ($p = 0.436$). In addition, LVEDD, LVESD, SPAP, LA diameter, and LVEF also showed no significant differences. However, the mean mitral valve gradient was significantly higher in the QR group (6 [range, 5 to 7] vs. 3 [range, 2 to 4] mmHg; $p < 0.001$). Additionally, leaflet mobility assessed by the Wilkins score was significantly better in the BR group (1.97 ± 0.74 vs. 3.23 ± 0.79 ; $p < 0.001$) (Table 3).

Intra-group pre- and postoperative comparisons showed significant improvement in NYHA functional class in both groups. Sinus rhythm improved from 72.5 to 82.6% in the QR group ($p = 0.118$), and from 78.1 to 87.7% in the BR group ($p = 0.016$). The MR severity significantly decreased in both groups postoperatively ($p < 0.001$). The LVEDD, LVESD, SPAP and LA diameter decreased significantly in both groups. The LVEF remained stable postoperatively in both groups (Table 4).

DISCUSSION

Barlow's disease presents a complex valvular pathology which challenges surgeons in terms of

mitral valve repair. The MR due to isolated posterior leaflet involvement typically manifests as either localized or excessive prolapse accompanied by redundant tissue. In cases of localized prolapse, triangular resection allows for straightforward repair.^[10] However, in more extensive prolapse with significant redundancy, it must be considered that the remaining abnormal tissue may undergo billowing due to systolic pressure load, in accordance with the Young-Laplace law. In such cases, the removal of the redundant tissue becomes essential, and the two key surgical techniques for this purpose are QR and BR.^[6,7] Quadrangular resection and annular plication both reduce the leaflet height and eliminate the prolapsed portion.^[10] Annular plication also leads to annular diameter reduction. In contrast, the butterfly technique does not include annular plication and involves less tissue resection compared to QR. Therefore, larger annuloplasty rings are usually used in this technique.^[11] Although ring sizing is determined according to Carpentier's method,^[6] our study, similar to that of Asai *et al.*,^[12] demonstrated that statistically significantly larger ring sizes were used in the butterfly group compared to the quadrangular group. We believe, as Asai noted, that this is primarily due to the relatively limited tissue excision in the butterfly technique. Indeed, the first triangular excision on the free edge of the leaflet in the butterfly technique resembles a standard triangular resection used in limited prolapse cases. The second triangular incision especially contributes to the removal of excess tissue. Also, this contribution creates a symmetric "smile-face" coaptation line along the posterior annulus without the need for annular reduction.^[13] We believe that the use of larger rings in this group reflects greater surgical confidence, as the use of larger ring may reduce the risk of SAM. Notably, no SAM was observed in either group in our study. Furthermore, both groups showed similar C-length and P2 leaflet height post-repair.

A key technical point for both resection methods is preserving the indentations between scallops of the posterior leaflet, which contribute to diastolic leaflet motion. In particular, excessive excision along the free edge of the P2 scallop may create tension-related separation between scallops, which can result in residual MR. Suturing this area may restrict diastolic motion. Therefore, preserving at least one or two indentations is usually advisable.^[9] Agricola *et al.*^[14] reported outcomes of 205 consecutive patients undergoing QR for prolapsed or flail posterior leaflet segments. In eight patients who developed

residual MR, intraoperative TEE revealed that the regurgitation was due to inter-scallop malcoaptation. In such cases, annular plication is critical to reducing leaflet tension and ensuring proper approximation of the resection margins. However, in patients with excessive tissue extending to adjacent scallops, achieving optimal plication length may be difficult, thereby compromising indentation preservation and potentially limiting posterior leaflet mobility. In the butterfly technique, the first triangle resembles a standard triangular resection and is limited to avoid tension at the free edge. The second triangle extends beneath the indentation region adjacent to the annulus, targeting the redundant tissue located there. Compared to the QR technique, the butterfly method often removes less tissue, making it easier to preserve scallop indentations and avoid motion restriction of the posterior leaflet. In our study, leaflet mobility was significantly better in the butterfly group compared to the quadrangular group. Additionally, mean mitral valve gradients were significantly higher in the quadrangular group. This difference may be explained by the use of smaller ring sizes. The C-depth was also significantly lower in the butterfly group, indicating that coaptation occurred closer to the annular plane. We interpret this finding as an indirect indicator of preserved leaflet mobility in the BR group, whereas the greater C-depth observed in the QR group may reflect restricted posterior leaflet motion caused by annular plication.

Currently, when the respect approach to mitral valve repair is gaining popularity in the literature, there is a view that ‘we respect everything we can do, but there is still a place for leaflet resection to achieve the goal.’^[15,16] In cases where resection is inevitable, both techniques appear to be effective and valuable tools for successful mitral valve repair. In our series, BR was associated with larger annuloplasty ring sizes, lower transmitral gradients, and improved posterior leaflet mobility compared to QR. These findings likely reflect the preservation of leaflet tissue and the avoidance of annular plication in the butterfly technique, which together allow for a wider coaptation surface and a more physiologic coaptation plane. Although QR still remains effective, its greater coaptation depth and smaller ring sizes may explain the higher postoperative gradients observed. More intriguingly, no patient in either group developed SAM, supporting the safety of both techniques in Barlow phenotype repair. When interpreted in the context of contemporary literature on ‘respect versus resect’ strategies, our results suggest that BR may offer hemodynamic

advantages without compromising durability. These findings offer valuable but preliminary observations, as long-term data are needed to determine whether the hemodynamic benefits we observed translate into sustained clinical outcomes.

Recent studies have highlighted the importance of mitral annular disjunction (MAD) in the spectrum of degenerative mitral valve disease, particularly in Barlow’s disease. Barlow pathology is now frequently subclassified into phenotypes such as FED–, FED+, forme fruste, MAD– Barlow, and MAD+ Barlow.^[17] The presence of MAD has been associated not only with annular enlargement and loss of saddle shape but also with increased risk of ventricular arrhythmias and adverse cardiac events.^[18] In our cohort, although all patients demonstrated intraoperative features consistent with Barlow’s disease, the dominant pathology was confined to the posterior leaflet, with anterior redundancy not contributing to regurgitation. Therefore, we analyzed this subgroup separately, acknowledging that Barlow’s disease with bileaflet involvement may require combined repair strategies. Although we have considerable experience with bileaflet repair in our overall practice, such patients were deliberately excluded from the present study in order to provide a clearer comparison of the two resection techniques. This distinction is important for appropriately interpreting our findings within the broader pathophysiological spectrum of degenerative MR.

Nonetheless, this study has several limitations. First, being a retrospective study, it is subject to potential data limitations and selection bias. Second, since the two techniques were applied in different time periods, surgeon experience and evolving technical approaches may have influenced the outcomes. Although we present mid-term results, data on long-term valve function, reoperation rates, and clinical outcomes remain limited. In addition, the selection of surgical technique was primarily time-based rather than anatomy-driven, which may introduce bias when interpreting the comparative outcomes. Finally, the relatively small sample size warrants cautious interpretation, and larger studies are needed to validate these findings. Future randomized-controlled trials and long-term follow-up data would be valuable to confirm these results.

In conclusion, the butterfly resection technique is sufficiently simple and effective to be successfully reproduced in the repair of Barlow’s disease, even in distant centers, solely on the basis of its published

description. We believe that the butterfly technique is not only a valuable tool to restore functional anatomy, but also a promising approach to achieve a more anatomically optimal and physiologically balanced mitral valve configuration. We advocate its inclusion as part of the surgical armamentarium for mitral valve repair.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. van Wijngaarden AL, Kruithof BPT, Vinella T, Barge-Schaapveld DQCM, Ajmone Marsan N. Characterization of degenerative mitral valve disease: Differences between fibroelastic deficiency and Barlow's disease. *J Cardiovasc Dev Dis* 2021;8:23. doi: 10.3390/jcdd8020023.
2. Fornes P, Heudes D, Fuzellier JF, Tixier D, Bruneval P, Carpentier A. Correlation between clinical and histologic patterns of degenerative mitral valve insufficiency: A histomorphometric study of 130 excised segments. *Cardiovasc Pathol* 1999;8:81-92. doi: 10.1016/s1054-8807(98)00021-0.
3. Trent JK, Adelman AG, Wigle ED, Silver MD. Morphology of a prolapsed posterior mitral valve leaflet. *Am Heart J* 1970;79:539-43. doi: 10.1016/0002-8703(70)90260-7.
4. Carpentier A, Chauvaud S, Fabiani JN, Deloche A, Relland J, Lessana A, et al. Reconstructive surgery of mitral valve incompetence: Ten-year appraisal. *J Thorac Cardiovasc Surg* 1980;79:338-48.
5. van Wijngaarden AL, Kruithof BPT, Vinella T, Barge-Schaapveld DQCM, Ajmone Marsan N. Characterization of degenerative mitral valve disease: Differences between fibroelastic deficiency and Barlow's disease. *J Cardiovasc Dev Dis* 2021;8:23. doi: 10.3390/jcdd8020023.
6. Carpentier A. Cardiac valve surgery--the "French correction". *J Thorac Cardiovasc Surg* 1983;86:323-37.
7. Asai T, Kinoshita T, Nishimura O, Kambara A, Suzuki T, Matsubayashi K. A novel design of posterior leaflet butterfly resection for mitral valve repair. *Innovations (Phila)* 2011;6:54-6. doi: 10.1097/IMI.0b013e31820c0107.
8. Can T, Kirov H, Caldonazo T, Mukharyamov M, Färber G, Doenst T. Surgical mitral valve repair technique considerations based on the available evidence. *Türk Gogus Kalp Damar Cerrahisi Derg* 2022;30:302-16. doi: 10.5606/tgkdc.dergisi.2022.23340.
9. Carpentier A, Adams DH, Filsoufi F. Techniques in type II posterior leaflet prolapse. In: Carpentier A, Adams DH, Filsoufi F, editors. *Carpentier's reconstructive valve surgery*. Chapter 11. London: Elsevier Health Sciences; 2010. p. 117-8.
10. Carpentier A, Relland J, Deloche A, Fabiani JN, D'Allaines C, Blondeau P, et al. Conservative management of the prolapsed mitral valve. *Ann Thorac Surg* 1978;26:294-302. doi: 10.1016/s0003-4975(10)62895-0.
11. Asai T, Kinoshita T, Hosoba S, Takashima N, Kambara A, Suzuki T, et al. Butterfly resection is safe and avoids systolic anterior motion in posterior leaflet prolapse repair. *Ann Thorac Surg* 2011;92:2097-102. doi: 10.1016/j.athoracsur.2011.07.087.
12. Asai T, Kinoshita T, Suzuki T, Shiraishi S, Koike M. Early and follow-up results of butterfly resection of prolapsed posterior leaflet in 76 consecutive patients. *J Thorac Cardiovasc Surg* 2015;149:1296-300. doi: 10.1016/j.jtcvs.2015.01.001.
13. Carpentier A, Adams DH, Filsoufi F. Techniques in type I dysfunction. In: Carpentier A, Adams DH, Filsoufi F, editors. *Carpentier's reconstructive valve surgery*. Chapter 8. London: Elsevier Health Sciences; 2010. p. 78-9.
14. Agricola E, Oppizzi M, Maisano F, Bove T, De Bonis M, Toracca L, et al. Detection of mechanisms of immediate failure by transesophageal echocardiography in quadrangular resection mitral valve repair technique for severe mitral regurgitation. *Am J Cardiol* 2003;91:175-9. doi: 10.1016/s0002-9149(02)03105-3.
15. Perier P, Hohenberger W, Lakew F, Batz G, Urbanski P, Zacher M, et al. Toward a new paradigm for the reconstruction of posterior leaflet prolapse: Midterm results of the "respect rather than resect" approach. *Ann Thorac Surg* 2008;86:718-25. doi: 10.1016/j.athoracsur.2008.05.015.
16. Dreyfus GD, Dulguerov F, Marcacci C, Haley SR, Gkouma A, Dommerc C, et al. "Respect when you can, resect when you should": A realistic approach to posterior leaflet mitral valve repair. *J Thorac Cardiovasc Surg* 2018;156:1856-66.e3. doi: 10.1016/j.jtcvs.2018.05.017.
17. Viani GM, Leo LA, Borruso MG, Klersy C, Paiocchi VL, Schlossbauer SA, et al. Mitral annulus morphometry in degenerative mitral regurgitation phenotypes. *Echocardiography* 2020;37:612-9. doi: 10.1111/echo.14647.
18. Torii Y, Tani T, Okada T, Sano M, Nagano M, Hamano A, et al. Association of cardiovascular events between mitral annular disjunction and left atrial reservoir strain in Barlow's disease. *Echocardiography* 2025;42:e70274. doi: 10.1111/echo.70274.