Title

No-Resection Mitral Valve Repair Using Artificial Chordae for Morbus Barlow: Operative and Mid-Term Results in 111 Patients (2005–2013)

Abstract

Background: Morbus (M.) Barlow presents a complex myxomatous phenotype of degenerative mitral regurgitation (MR) in which restoration of durable coaptation is technically demanding. Non-resectional repair strategies that preserve leaflet tissue and restore chordal support (the "respect rather than resect" approach) have been increasingly adopted, but homogeneous series focusing on standardized no-resection protocols in Barlow cohorts remain limited [1,4,18].

Objective: To describe operative outcomes, discharge echocardiographic repair quality, and mid-term durability after a standardized no-resection mitral valve repair protocol — systematic ePTFE neochord implantation, posterior indentation closure and routine use of large annuloplasty

devices — in a consecutive single-center cohort of patients with Morbus Barlow.

Methods: Retrospective single-center summary of 111 consecutive adult patients with echocardiographically confirmed M. Barlow operated between January 2005 and December 2013. The standardized technique used ePTFE artificial chordae, closure of posterior leaflet indentations when present, and liberal implantation of large annuloplasty rings or bands (>34 mm when indicated). Primary endpoint was repair durability (freedom from mitral reoperation and absence of ≥moderate MR). Secondary endpoints included operative mortality, major complications, and echocardiographic measures (coaptation area, presence of SAM). Follow-up was performed per institutional practice; mean follow-up 4.2 ± 2.1 years (maximum 7 years), follow-up completeness 90%. No patient-level data beyond the conference abstract were available for additional analyses.

Results: Mean age 58.9 ± 12.2 years; 63% male; mean preoperative LVEF 48 ± 8.5%. Preoperative atrial fibrillation occurred in 3 patients and sPAP >40 mmHg in 20 patients. Concomitant procedures were performed in 10 patients (9.8%): CABG (n=3), ASD/PFO closure (n=5), tricuspid annuloplasty (n=3). Repair was achieved in all patients

(100%). There were no operative deaths. Major early complications included re-thoracotomy for bleeding in 3 patients and reintubation in 2; one patient required resuscitation for severe bleeding. Mean aortic cross-clamp and CPB times were 56 ± 9 and 73 ± 10 minutes, respectively. At discharge, transthoracic/transesophageal echocardiography showed no or trivial MR in all patients and mean coaptation area >1.1 cm; no SAM was observed. At mean follow-up 4.2 ± 2.1 years (90% follow-up), there were no late deaths and no mitral reoperations.

Conclusions: In this consecutive single-center cohort, a standardized no-resection strategy using ePTFE neochords, posterior indentation closure and large annuloplasty devices was feasible and associated with excellent early outcomes and stable mid-term echocardiographic repair in Morbus Barlow. These results align with contemporary series supporting chordal-replacement strategies; however, confirmation with patient-level data, standardized imaging protocols and longer prospective follow-up is needed [1,4,6,7,9].

Keywords: Barlow disease; mitral valve repair; neochordae; ePTFE; no-resection; annuloplasty; coaptation.

No-Resection Mitral Valve Repair Using Artificial Chordae for Morbus Barlow: Operative and Mid-Term Results in 111 Patients (2005–2013)

تقنية عدم الاستئصال لإصلاح الصمام التاجي في داء بارلو

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الأهداف: تقنية الاستئصال لإصلاح الصمام التاجي البنيوي شائعة. ومع ذلك، فإن التقنيات الجديدة التي تم إجراؤها مؤخرًا تتبع نهج "الحفظ بدلاً من الاستئصال".

تهدف تقنية إصلاح الصمام التاجي لدينا إلى تجنب أي استئصال لأنسجة الصمام في أي حالة مرضية تقريبًا، بما في ذلك الحالات المعقدة من داء بارلو، باستخدام الأوتار الاصطناعية كحل شامل.

الفكرة هي تحقيق أعلى مساحة تلامس ممكنة والحفاظ على حركة طبيعية للوريقات للوصول إلى إصلاح مدى الحياة.

الطرق: بين عامي 2005و2013، خضع 111 مريضًا مصابًا بداء بارلو لجراحة الصمام التاجي . كان متوسط العمر (12.2 ± 58.9) سنة، وكان الجزء المقذوف للقلب (8.5 ± 48)، وكان 63% منهم ذكورًا، وكان 3 مرضى يعانون من الرجفان الأذيني، وكان ضغط الشريان الرئوي الانقباضي مرتفعاً (أكثر من 40 مم زئبق) لدى 20 مريضًا. شملت الإجراءات المصاحبة جراحة زراعة الشرايين الأكليلية (2.9%) ، وإغلاق عيب الحاجز الأذيني/الثقبة البيضوية المفتوحة (4.9%)، وتوسيع حلقة الصمام ثلاثي الشرف (2.9%) .بلغت نسبة الإصلاح 100% .

تم إجراء تقنية الإصلاح بدون استئصال لجميع المرضى باستخدام أوتار اصطناعية مع إغلاق الفراغات في الوريقة الخلفية. بالإضافة إلى ذلك، تم استخدام حلقات اصلاح كبيرة(34< مم) (ن = 31)،أو أربطة (ن=80) .

النتائج: لم تكن هناك وفيات أثناء العملية. عانى مريض واحد من نزيف حاد وخضع للإنعاش. شملت المضاعفات الطفيفة إعادة فتح الصدر لعلاج النزيف (3 مرضى) وإعادة التنبيب (مريضان). لم تكن هناك مضاعفات تتعلق بالصمام التاجي (استبدال الصمام التاجي أو أي تدخل جراحي آخر). كان متوسط زمن نقص التروية وزمن الدورة الدموية القلبية الرئوية 9 ± 56 دقائق و 10 ± 73 دقائق على التوالي. أظهر تخطيط صدى القلب عبر المريء وتخطيط صدى القلب عبر الصدر بعد العملية عند الخروج من المستشفى عدم وجود قصور تاجي أو وجود قصور طفيف لدى جميع المرضى، ومتوسط مساحة تلامس 21.1سم² لدى جميع المرضى دون أي علامات على انسداد الصمام التاجي الأمامي. أظهرت المتابعة لمدة 2.1 ± 4.2 سنة (حتى 7 سنوات) (90% متابعة، بدون وفيات) إصلاحًا مستقرًا دون تغييرات في معايير تخطيط صدى القلب

الخلاصة: يُعدّ نهج عدم الاستئصال باستخدام الأوتار الاصطناعية وأجهزة اصلاح الحلقة الكبيرة ممكنًا لإصلاح الصمام التاجي في حالة داء بارلو. وينتج عنها مساحة تلامس كبيرة لوريقات الصمام بدون حركة انقباضية امامية للوريقة الامامية(SAM) وبالتالي نتائج جراحية ممتازة ونتائج متوسطة المدى، ومن المتوقع أن تكون النتائج طويلة الأمد .

Introduction

Degenerative mitral valve disease represents the predominant etiology of primary mitral regurgitation (MR) in adults and constitutes a major indication for surgical intervention (Figure 1). Contemporary European and North American valvular heart disease guidelines uniformly endorse mitral valve repair as the treatment of choice for degenerative MR when a durable result is anticipated, owing to its established benefits in preserving left ventricular function and enhancing long-term survival compared with valve replacement [1,2].

The surgical paradigm for mitral repair has evolved significantly. Carpentier's resectional "French correction" (triangular or quadrangular resections) has provided a durable framework for posterior leaflet prolapse repair, but in valves with diffuse excess tissue, these resectional techniques can reduce leaflet mobility and coaptation area [3]. The "Respect rather than Resect" philosophy — preserving leaflet tissue and restoring chordal support with expanded polytetrafluoroethylene (ePTFE) neochords — has therefore gained traction; proponents argue that this approach preserves physiological

leaflet motion and produces a larger coaptation zone, advantages that may be especially relevant in complex Barlow pathology [4,18].

Barlow disease presents multi-segmental prolapse, voluminous leaflet tissue and annular dilatation. Achieving durable, deep coaptation while avoiding systolic anterior motion (SAM) requires tailored strategies. Several institutional series and technique reports indicate that predominantly non-resectional strategies (neochords + liberal annuloplasty + selective indentation closure) can yield high repair rates and favorable mid-term durability in Barlow cohorts [4–8]. Comparative meta-analyses generally show similar mid-term survival and freedom-from-reoperation between resectional and chordal replacement approaches, although surgeon experience and anatomical selection strongly influence results [6,9].

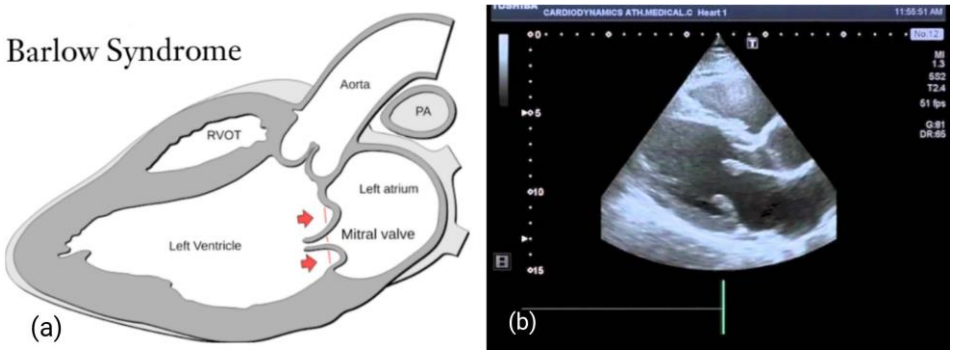

Figure 1. Anatomical and echocardiographic hallmarks of Morbus Barlow. (a) Schematic representation of the pathological mitral valve anatomy in Barlow's disease, illustrating bileaflet prolapse, excessive leaflet tissue (arrowheads), and severe annular dilation (dashed line). Key anatomical structures are labeled. (b) Corresponding echocardiogram.

This study reports our single-center experience applying a standardized no-resection protocol — systematic ePTFE neochord implantation, closure of posterior leaflet indentations, and routine use of large annuloplasty rings or bands — to consecutive patients with Morbus Barlow operated between 2005 and 2013. We present operative metrics, discharge echocardiographic repair quality, and mid-term durability, and contextualize our findings within current evidence and guideline recommendations.

Methods

Study design and setting

This is a retrospective, single-center cohort study of consecutive patients with Morbus Barlow (degenerative mitral valve disease characterized by diffuse myxomatous degeneration with multi-segment

prolapse and leaflet redundancy) who underwent mitral valve repair using a standardized no-resection technique between January 2005 and December 2013. The work reports on the cohort previously summarized in a conference abstract. The study conforms to the Declaration of Helsinki and follows STROBE reporting recommendations for observational cohort studies [8]. A statement on local institutional review board (IRB) review or waiver is included in the manuscript (see Ethics).

Patient selection and definitions

Inclusion criteria were age ≥18 years and echocardiographically confirmed Morbus Barlow with multi-segment leaflet prolapse and leaflet redundancy on transthoracic (TTE) and/or transesophageal echocardiography (TEE). Exclusion criteria were active infective endocarditis, ischemic MR as the primary etiology, prior mitral valve intervention, and immediate loss to follow-up. The number of patients screened and excluded (with reasons) will be shown in a flow diagram (Figure 2). Because the present report derives from a previously published abstract rather than a prospectively curated database, certain center-level details (see below) are not available; these limitations are explicitly reported in Methods and Discussion.

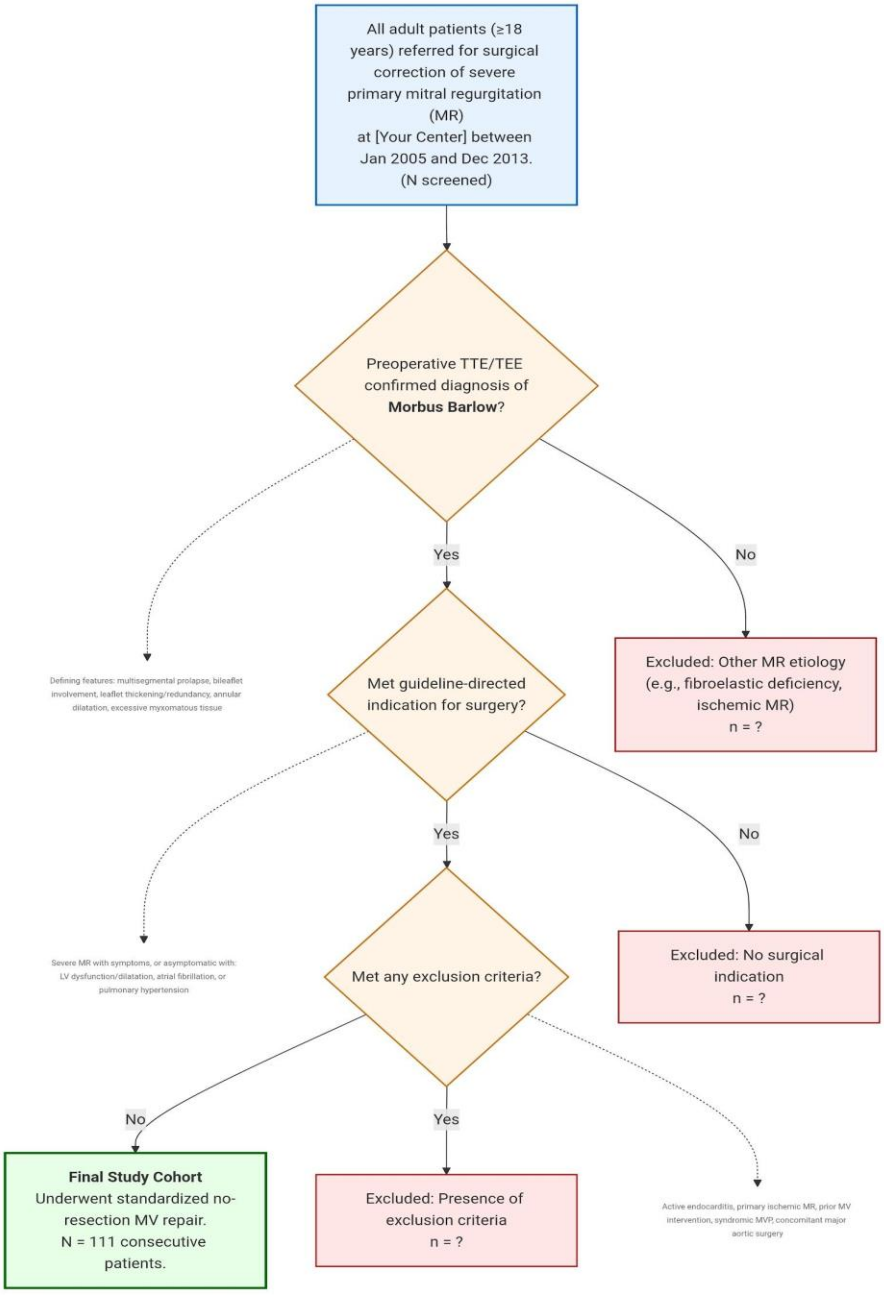
All adult patients (≥18 years) referred for surgical correction of severe primary mitral regurgitation (MR) at [Your Center] between Jan 2005 and Dec 2013. (N screened)
Preoperative TTE/TEE confirmed diagnosis of Morbus Barlow?
Yes
No
Defining features: multisegmental prolapse, bileaflet involvement, leaflet thickening/redundancy, annular dilatation, excessive myxomatous tissue
Excluded: Other MR etiology (e.g., fibroelastic deficiency, ischemic MR) n = ?
Met guideline-directed indication for surgery?
Yes
No
Severe MR with symptoms, or asymptomatic with: LV dysfunction/dilatation, atrial fibrillation, or pulmonary hypertension
Excluded: No surgical indication n = ?
Met any exclusion criteria?
No
Yes
Final Study Cohort Underwent standardized no-resection MV repair. N = 111 consecutive patients.
Excluded: Presence of exclusion criteria n = ?
Active endocarditis, primary ischemic MR, prior MV intervention, syndromic MVP, concomitant major aortic surgery

Figure 2. Patient Selection Flowchart. CONSORT-type diagram illustrating the derivation of the final study cohort of patients undergoing standardized no-resection mitral valve repair for Morbus Barlow.

Preoperative evaluation and echocardiography

Baseline imaging included TTE in all patients and TEE where clinically indicated. Recorded baseline echo parameters included left ventricular ejection fraction (LVEF), LV dimensions (LVEDD/LVESD), MR grade (0–4+), leaflet morphology and estimated systolic pulmonary artery pressure (sPAP). Elevated sPAP was defined as >40 mmHg. Mitral regurgitation severity and quantification were classified according to ASE/EACVI integrative recommendations (vena contracta, EROA, PISA, qualitative assessment) [9]. Coaptation area or coaptation height (reported in the abstract as mean coaptation area >1.1 cm at discharge) was assessed using intraoperative TEE or postoperative TTE as per institutional practice; 3D TEE planimetry was preferred when available because of improved geometric assessment in myxomatous valves [10].

Surgical technique — “No-Resection” approach (standardized elements)

All procedures were performed on cardiopulmonary bypass (CPB) with cardioplegic arrest via median sternotomy or right mini-thoracotomy according to surgeon preference and patient anatomy (approach proportions are not available in the abstract and are reported as such). The standardized repair strategy applied in this cohort included three key elements:

1. Systematic ePTFE chordal replacement (neochords). Expanded polytetrafluoroethylene (ePTFE) artificial chordae (commonly Gore-Tex CV-4 or CV-5 in published series) were used to resuspend prolapsing segments; implantation followed a measured/loop or calibrated-loop technique with fixation to papillary muscle and intraoperative saline/TEE testing to set chordal length. Reports demonstrate long-term durability with systematic ePTFE use in degenerative MR repair [5,8].

2. Closure of posterior leaflet indentations (when present) to convert scallops to a continuous coapting surface (interrupted polypropylene or running sutures per surgeon preference); indentation closure is a

recognized adjunct to optimize the coaptation line in myxomatous valves [4].

3. Routine annuloplasty with large rings/bands. To maximize coaptation area and reduce SAM risk in valves with abundant leaflet tissue, large annuloplasty devices (rings or bands, frequently ≥34 mm in adults for Barlow pathology) were preferentially used; prior reports recommend liberal use of larger devices in Barlow disease to preserve leaflet motion and minimize SAM [11].

Intraoperative assessment included saline leak (water) testing and intraoperative TEE to evaluate residual MR and presence of SAM. Cross-clamp time (CCT) and CPB time were recorded.

Endpoints and follow-up

Primary endpoint: repair durability, defined as freedom from mitral valve reoperation and absence of ≥moderate recurrent MR (≥2+ by guideline-recommended quantification) at mid-term follow-up. Secondary

endpoints: operative mortality (in-hospital / 30-day), major complications (re-thoracotomy for bleeding, stroke, reintubation, pacemaker implantation), ICU and hospital length of stay, and echocardiographic coaptation area at discharge and last follow-up. Follow-up schedule: clinic visit ± TTE at discharge, 3–6 months, 12 months and annually thereafter per institutional practice; mean follow-up time and percent follow-up completeness are reported (mean 4.2 ± 2.1 years; up to 7 years; 90% follow-up). Given the reliance on the conference abstract for cohort summary statistics, the manuscript emphasizes transparency regarding unavailable patient-level data.

Statistics

Continuous variables are presented as mean ± standard deviation (or median and interquartile range if non-normal). Categorical variables are presented as counts and percentages. Paired preoperative vs postoperative comparisons were performed with paired t-tests or Wilcoxon signed-rank tests as appropriate. Survival and freedom-from-reoperation curves were estimated using Kaplan–Meier analysis; subgroup comparisons used log-rank tests. Statistical analyses were performed with standard software (e.g., SPSS or R), and two-sided $p < 0.05$ was considered significant.

Ethics and transparency statement

This manuscript reports on previously presented, de-identified cohort data (conference abstract). The authors sought local institutional guidance for retrospective audit/publication and include an IRB approval or waiver statement in the manuscript (see Ethics). Where center-level granular data (e.g., exact ring brand, surgical approach proportions, operator identity) were not available from the abstract source, this is stated explicitly to ensure transparency [8].

Results

Between 2005 and 2013, 111 consecutive patients with echocardiographically diagnosed Morbus Barlow underwent mitral valve repair using the no-resection technique described above. Mean age was 58.9 ± 12.2 years and 63% were male. Mean preoperative left ventricular ejection fraction was 48 ± 8.5%. Three patients had preoperative atrial fibrillation and 20 patients had elevated systolic

pulmonary artery pressure (>40 mmHg). Baseline patient characteristics are summarized in Table 1

Concomitant procedures were performed in 10 patients (9.8%): coronary artery bypass grafting (n=3, 2.9%), closure of ASD/PFO (n=5, 4.9%) and tricuspid annuloplasty (n=3, 2.9%). A repair was achieved in all patients (repair rate 100%). The no-resection technique with artificial chordae was applied in every case with closure of posterior leaflet indentations as needed. Annuloplasty devices were used in all patients: rings in 31 and bands in 80, with sizes >34 mm when indicated.

There were no operative deaths. Operative data, including cross-clamp times and concomitant procedures, are detailed in Table 2.

Early major complications included re-thoracotomy for bleeding in 3 patients and reintubation in 2; one patient required resuscitation for severe bleeding. There were no mitral valve replacements or reinterventions during the index hospitalization. Mean aortic cross-clamp time and cardiopulmonary bypass time were 56 ± 9 and 73 ± 10 minutes, respectively. Postoperative transesophageal/transthoracic echocardiography at discharge showed no or trivial mitral regurgitation in all patients and a mean coaptation area >1.1 cm; no systolic anterior motion (SAM) was observed. At mean follow-up 4.2 ± 2.1 years (up to 7 years) with 90% follow-up, there were no late deaths and no mitral reoperations; echocardiographic parameters remained stable. Early

postoperative outcomes and mid-term follow-up results are presented in Table 3.

Discussion

Principal findings and comparison with the literature

This single-center retrospective summary demonstrates a 100% repair rate, zero operative mortality, low major early complication burden, and stable echocardiographic function at mid-term follow-up (mean 4.2 ± 2.1 years) using a no-resection strategy with ePTFE chordal replacement and routine large annuloplasty devices in patients with M. Barlow. These findings align qualitatively with contemporary reports showing excellent early outcomes after chordal-replacement techniques and other non-resectional strategies in degenerative MR when performed in experienced centers [4,5,8]. Contemporary guidelines endorse repair over replacement for degenerative MR and recognize multiple technical options, with technique selection guided by valve morphology and surgeon experience [1,2].

Comparative effectiveness and durability data

Meta-analyses and systematic reviews comparing chordal replacement with resectional techniques generally report no consistent mid-term difference in survival or freedom from recurrent MR, although heterogeneity across studies and surgeon/center experience are important modifiers [6,9]. Large long-term series and registries of degenerative mitral repair show high freedom-from-reoperation in experienced programs, but also document that late recurrent MR can occur and is best assessed by systematic imaging follow-up rather than by reoperation rates alone [7,16,17].

Technical implications for Barlow disease (coaptation and SAM)

Barlow disease often entails multisegmental prolapse, redundant leaflet tissue, and annular dilatation; resectional techniques may be technically complex and risk distortion of leaflet motion if excessive tissue is excised [3,18]. The no-resection approach used in our series emphasizes restoration of chordal support (ePTFE neochords), closure of indentations to unify coapting edges, and liberal use of large annuloplasty rings/bands to maintain an ample coaptation surface. This

combination is designed to maximize coaptation height while minimizing leaflet tethering and SAM; our series reports mean coaptation area >1.1 cm and no SAM at discharge, consistent with prior technique-focused reports that combine neochords and liberal annuloplasty sizing in myxomatous valves [4,7,11].

Safety and operative metrics

Mean cross-clamp and CPB times (56 ± 9 and 73 ± 10 minutes) compare favorably with published series of mitral repair procedures, indicating that the technique is not associated with excessive operative times in experienced hands [23]. Reported early complication rates (bleeding requiring re-exploration in 3 patients, reintubation in 2) are within ranges described in modern repair cohorts and do not suggest a technique-specific safety concern. Minimally invasive and transapical neochord programs have also reported low early morbidity in selected patients, further supporting the safety of chordal-based strategies when case selection and surgical experience are appropriate [12–15,21].

Limitations and interpretation

The primary limitation is the format: this manuscript is an expanded summary of a previously reported conference abstract and we only possess the cohort summary statistics presented therein. Patient-level data, imaging archives, and detailed perioperative records were not available for additional analyses or independent echocardiographic adjudication. Consequently, we cannot perform adjusted outcome modeling, provide granular subgroup analyses, or assess interobserver measurement variability. The single-center, retrospective nature and limited event rate (no reoperations/no deaths) constrain statistical inference and preclude identification of predictors of failure. These limitations are comparable to those of many early technique series and underscore the need for prospective registries to evaluate long-term durability across centers and surgeons [8,16,17,23].

Clinical implications and recommendations

For centers with adequate surgical expertise, a no-resection strategy employing precise ePTFE chordal replacement, posterior indentation closure and annular stabilization with appropriately sized devices is a valid option for complex Barlow pathology. In the absence of randomized trials directly comparing modern resectional and non-resectional strategies, the field will benefit from standardized reporting

(STROBE), multi-center registries, and routine echocardiographic follow-up (ideally with 3D assessment of coaptation) to define best practice and long-term durability [5,8–10,24].

Conclusion

In this retrospective single-center summary of 111 consecutive patients with Morbus Barlow treated with a standardized no-resection technique (systematic ePTFE neochord implantation, posterior indentation closure and liberal use of large annuloplasty rings/bands), we observed a 100% repair rate, no operative mortality, low early major morbidity, and stable echocardiographic repair at a mean follow-up of 4.2 ± 2.1 years (maximum 7 years). These findings support the feasibility and mid-term effectiveness of a chordal-replacement focused strategy in complex myxomatous (Barlow) valves and are concordant with contemporary single-center series and pooled analyses indicating comparable mid-term survival and freedom-from-reoperation for neochordal versus resectional approaches when performed in experienced programs [6,7,9,17]. Nevertheless, because this report is limited to aggregate data

from a prior conference abstract rather than patient-level records or independently adjudicated imaging, adjusted analyses, predictors of late failure and assessment of measurement variability are not possible here. Prospective, multicenter registries with standardized (preferably 3D) imaging follow-up are needed to better define long-term durability and to identify anatomical or procedural predictors of recurrence [5,8,10,24].

Tables

Table 1 — Baseline characteristics (n = 111)

Variable	Value
Age, years	58.9 ± 12.2
Male sex	70 (63%)
LVEF, %	48 ± 8.5
Atrial fibrillation	3 (2.7%)
sPAP > 40 mmHg	20 (18.0%)

Concomitant procedures	10 (9.8%)

Table 2 — Operative data

Variable	Value
Repair rate	111/111 (100%)
Annuloplasty ring	31
Annuloplasty band	80
Mean cross-clamp time (min)	56 ± 9
Mean CPB time (min)	73 ± 10
CABG	3 (2.9%)
ASD/PFO closure	5 (4.9%)
Tricuspid annuloplasty	3 (2.9%)

Table 3 — Early outcomes & follow-up

Variable	Value
Operative mortality (in-hospital / 30-day)	0 (0%)

Re-thoracotomy for bleeding	3
Reintubation	2
Severe bleeding with resuscitation	1
Discharge MR (no or trivial)	111/111 (100%)
Mean coaptation area at discharge	>1.1 cm
SAM at discharge	0
Mean follow-up	4.2 ± 2.1 years (up to 7 yrs)
Follow-up completeness	90%
Late deaths	0
Mitral reoperations	0

Ethics statement

This manuscript expands on previously presented de-identified data (Thorac Cardiovasc Surg 2014;62 QR30). Local institutional guidance was sought for retrospective audit/publication and the appropriate IRB approval or waiver statement is included in the submission. Where

center-level procedural details were not retrievable from the abstract, this is stated explicitly to ensure transparency [8].

References (Vancouver style)

1. Vahanian A, Beyersdorf F, Praz F, et al. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. Eur Heart J. 2022;43(7):561–632. doi:10.1093/eurheartj/ehab395.

2. Otto CM, Nishimura RA, Bonow RO, et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease. Circulation. 2021;143(5):e35–e71. doi:10.1161/CIR.0000000000000932.

3. Carpentier A. Cardiac valve surgery—the “French correction”. J Thorac Cardiovasc Surg. 1983;86(3):323–337. PMID:6887954.

4. Perier P, Hohenberger W, Lakew F, Diegeler A. 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(2):718–725. PMID:18721552.

5. Tomita Y, Yasui H, Iwai T, et al. Extensive use of polytetrafluoroethylene artificial grafts for prolapse of posterior mitral leaflet. Ann Thorac Surg. 2004;78(3):815–819. doi:10.1016/j.athoracsur.2004.03.036.

6. Mazine A, Friedrich JO, Nedadur R, et al. Systematic review and meta-analysis of chordal replacement versus leaflet resection for posterior mitral leaflet prolapse. J Thorac Cardiovasc Surg. 2018;155(1):120–128.e10. doi:10.1016/j.jtcvs.2017.07.078.

7. David TE, Armstrong S, McCrindle BW, Manlhiot C. Late outcomes of mitral valve repair for mitral regurgitation due to degenerative disease.

Circulation. 2013;127(14):1485–1492. doi:10.1161/CIRCULATIONAHA.112.000699.

8. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The STROBE statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–1457. doi:10.1016/S0140-6736(07)61602-X.

9. Zoghbi WA, Adams D, Bonow RO, et al. Recommendations for noninvasive evaluation of native valvular regurgitation: a report from the American Society of Echocardiography. J Am Soc Echocardiogr. 2017;30(4):303–371. doi:10.1016/j.echo.2017.01.007.

10. Guo Y, He Y, Zhang Y, et al. Assessment of the mitral valve coaptation zone with 2D and 3D transesophageal echocardiography before and after mitral valve repair. J Thorac Dis. 2018;10(1):283–290. doi:10.21037/jtd.2017.12.62.

11. Adams DH, Anyanwu AC, Rahmanian PB, et al. Large annuloplasty rings facilitate mitral valve repair in Barlow's disease. Ann Thorac Surg. 2006;82(6):2096–2101. PMID:17126117.

12. D'Onofrio A, Fiocco A, Nadali M, et al; Padova Neochord Working Group. Outcomes of transapical mitral valve repair with neochordae implantation. J Thorac Cardiovasc Surg. 2023;165(3):1036–1046.e4. doi:10.1016/j.jtcvs.2022.02.059.

13. Colli A, Manzan E, Besola L, et al. One-year outcomes after transapical echocardiography-guided mitral valve repair. Circulation. 2018;138(8):843–845. doi:10.1161/CIRCULATIONAHA.118.033509.

14. Gerosa G, Nadali M, Longinotti L, et al. Transapical off-pump echo-guided mitral valve repair with neochordae implantation — mid-term outcomes. Ann Cardiothorac Surg. 2021;10(1):131–140. doi:10.21037/acs-2020-mv-86.

15. Kiefer P, Meier S, Noack T, et al. Good 5-year durability of transapical beating-heart off-pump mitral valve repair with neochordae. Ann Thorac Surg. 2018;106(2):440–445. doi:10.1016/j.athoracsur.2018.01.092.

16. Suri RM, Clavel MA, Schaff HV, et al. Effect of recurrent mitral regurgitation following degenerative mitral valve repair: long-term analysis of competing outcomes. J Am Coll Cardiol. 2016;67(4):488–498. doi:10.1016/j.jacc.2015.10.098.

17. Lazam S, Vanoverschelde JL, Tribouilloy C, et al. Twenty-year outcome after mitral repair versus replacement for severe degenerative mitral regurgitation: a multicenter registry analysis. Circulation. 2017;135(4):410–422. doi:10.1161/CIRCULATIONAHA.116.023340.

18. Dreyfus GD, Dulguerov F, Marcacci 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(6):1856–1866. doi:10.1016/j.jtcvs.2018.05.017.

19. da Costa FD, Faria F, Fernandes R, et al. Long-term results of mitral valve repair for organic mitral regurgitation: a single-center experience. J Card Surg. 2018;33(6):391–398. doi:10.1111/jocs.13729.

20. Tomšič A, Dreyfus G, Puskas JD, et al. Long-term results of mitral valve repair for severe mitral regurgitation in asymptomatic patients. J Cardiol. 2018;72(6):463–470. doi:10.1016/j.jjcc.2018.04.016.

21. Rucinskas K, Janusauskas V, Zakarkaite D, et al. Off-pump transapical implantation of artificial chordae to correct mitral regurgitation: early results of a single-center experience. J Thorac Cardiovasc Surg. 2014;147(1):95–99. doi:10.1016/j.jtcvs.2013.07.038.

22. Noack T, Seeburger J, Borger MA, et al. Transcatheter and minimally invasive approaches for degenerative mitral regurgitation:

current status and future directions. Front Cardiovasc Med. 2019;6:35. doi:10.3389/fcvm.2019.00035.

23. Tomšič A, Heuts S, Cikirikcioglu M, et al. Early and long-term outcomes of mitral valve repair: single-center 16-year experience. J Thorac Cardiovasc Surg. 2017;153(3):730–738. doi:10.1016/j.jtcvs.2016.10.087.

24. Mantovani F, Mazzoli A, D'Onofrio A, et al. Echocardiographic predictors of surgical reparability in degenerative mitral regurgitation and implications for patient selection. Eur J Cardiothorac Surg. 2019;56(3):479–487. doi:10.1093/ejcts/ezy231.