Mitral repair with the sole use of a semi-rigid band in a sub-population of patients with Barlow’s disease: a 4-year follow-up with stress echocardiography

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Abstract

OBJECTIVES: Surgical treatment of Barlow’s disease is usually demanding. In a sub-population of Barlow patients with bileaflets prolapse and central regurgitant jet, we performed mitral repair using only a semi-rigid annuloplasty band. Stress echocardiography follow-up was evaluated.

METHODS: Of a total of 350 consecutive patients with mitral prolapse, 69 had anatomical features of Barlow’s disease. Of these, 40 with multiple large central jets without chordal rupture were repaired only using an annuloplasty band, and these constituted the study group. An echocardiographic study of the acute change in valvular and ventricular morphology before and after surgery was carried out. Patients were evaluated at discharge and after a mean follow-up of 4.7 ± 3.2 years by stress echocardiography.

RESULTS: No death or reoperation occurred. Acute echocardiographic study revealed that mitral annuloplasty led to a significant migration of the leaflets towards the apex of the left ventricle. Coaptation length increased dramatically from 2.7 ± 0.8 to 11.3 ± 2.7 mm and a reduction in annular diameters and leaflet length was observed. The left ventricle was elongated (72.8 ± 6.9 vs 63.2 ± 8.1 mm) and the distance from the papillary muscle tip to the mitral annulus increased (anterior 30 ± 3.9 vs 20.3 ± 4.8 mm, posterior 29.7 ± 4.3 vs 20.8 ± 5.6 mm). At discharge, residual mitral regurgitation was mild in 1 case and trivial in 3. The results were confirmed at stress echocardiography follow-up with normal valve function at peak exercise.

CONCLUSIONS: In patients with severe mitral regurgitation due to Barlow’s disease with multiple central jet and without chordal rupture, mitral annuloplasty is effective in restoring mitral valve function owing to profound changes in mitral valve and left ventricle geometry. At follow-up, stress echocardiography confirms the results and the stability of the repair.

Keywords: Mitral valve • Regurgitation • Annuloplasty • Barlow’s disease

INTRODUCTION

The first systematic approach to mitral valve repair was developed during 1970s and 1980s by Carpentier [1]. Quadrangular resection is still considered the standard technique for correcting posterior leaflet prolapse. Several procedures, including triangular resection, chordal transfer, chordal shortening, edge-to-edge technique and papillary muscle repositioning, have been used to repair the anterior leaflet [2, 3]. The approach to bileaflets prolapse, typically present in patients with Barlow’s disease, usually requires several manoeuvres owing to the presence of multiple prolapsed scallops. The correction is often considered technically demanding and results are not always satisfactory [4, 5].

Progressive refinement in echocardiography provided new insights into mitral valve function in the beating heart and led to a variety of newer surgical techniques in mitral valve repair [6]. Three-dimensional (3D) echocardiography has attributed a pivotal role to the mitral annulus in contributing to mitral competency. Mitral regurgitation (MR) is almost always accompanied by mitral annular dilatation, especially in myxomatous valves. It appears that dysfunction of the mitral annulus causes ventricular-annular contraction decoupling, with loss of regurgitation-preventive mechanisms and leaflet separation [7].

Over an 8-year period, we have adopted a non-resectional approach to mitral valve repair for degenerative MR. Our strategy is based first on mitral annuloplasty with a semi-rigid open band to reshape annular geometry, followed by neo-chordae tendineae implantation to correct residual posterior or anterior leaflet prolapse. A subgroup of these patients, affected by diffuse and myxomatous MR, was treated solely with annuloplasty. The aim of this
study is (i) to identify anatomical and echocardiographic lesions characterizing those undergoing solely annuloplasty; (ii) to investigate acute postoperative changes in mitral valve spatial coordinates and (iii) to establish the durability of this simple treatment by stress echocardiography follow-up.

**METHODS**

**Population**

This observational study was conducted in a single cardiac centre. Between April 2006 and December 2013, 430 patients were referred to our institution for organic mitral valve regurgitation. Patients affected by endocarditis or rheumatic MR were excluded. Diagnosis of severe MR from mitral valve prolapse (MVP) (Carpentier type II) was confirmed in 350 cases. The grading of MR was reported according to the American Society for Echocardiography [8] and diagnoses of MVP (annular overshoot of leaflets >2 mm in long-axis views), flail segment and of thickened leaflets were based on recommended criteria [9, 10].

A total of 69 patients presented with large annulus size, myxomatous bileaflets prolapse and multiple chordal elongations with or without chordal ruptures, and were considered to have Barlow's disease. Of these 69 patients, 40 were cured only by using a mitral annuloplasty semi-rigid band and formed the study group.

**Surgical technique**

All procedures were performed through a full sternotomy using mild hypothermic cardiopulmonary bypass (CPB) with antegrade warm blood cardioplegia. A left atriotomy in the inter-atrial groove was used to access the mitral valve.

After exposing the mitral valve, interrupted annuloplasty sutures were positioned along the mitral annulus between the left and right fibrous trigones. The left ventricle was then filled with saline solution so as to complete assessment of the valve. If the hydrodynamic test confirmed satisfactory mitral competence in the absence of leaflets flail or prominent segmental prolapse, the annulus was measured for size and the semi-rigid band was sutured in place. In all patients, the annulus was sized as follows: the sizer fitting the interior contour as described by the annuloplasty sutures and corresponding to the actual valve orifice, including the posterior leaflet, was selected. A semi-rigid band was exclusively used (CG Future® Annuloplasty Band; Medtronic, Minneapolis, MN, USA) in each case. After the annuloplasty was completed, a second hydrodynamic test was performed. A satisfactory leaflet coaptation length was verified in the absence of residual segmental billowing, and left atriotomy was then sutured.

**Study design**

This was a retrospective observational study. Patients with MVP (Carpentier Type II) treated solely with a semi-rigid band, were assessed in terms of types of valvular lesions according to Carpentier's classification [1]. A systematic segmental valve analysis was carried out preoperatively by transthoracic and/or transoesophageal echocardiography (TEE) and confirmed intraoperatively by TEE and direct inspection during surgery.

The intraoperative results in terms of residual MR and presence of systolic anterior motion (SAM) were evaluated by TEE after weaning from the CPB once stable haemodynamic parameters were achieved. To investigate acute postoperative changes in mitral valve spatial coordinates, in the first 20 consecutive study patients, a detailed analysis of valve morphology was carried out by TEE immediately before the operation, and at the end of surgery after chest closure. Valve morphology was assessed as follows: leaflet length was measured in diastole from the annular hinge point to the free edge. Coaptation length was measured as the length of systolic leaflet contact. Coaptation depth was defined as the shortest distance between coaptation and the annular plane. Leaflet displacement across the annular plane was measured from the top of the prolapsing leaflet to the plane of the annulus. A negative value was given for displacement towards the left atrium. A longitudinal two-chamber view of the left ventricle was used to measure the distance between the papillary muscle tip and the plane of the mitral annulus, and to measure the systolic longitudinal and transverse axes of the left ventricle.

All patients were evaluated by standard trans-thoracic echocardiography (TTE) before hospital discharge. Follow-up was performed by stress echocardiography.

**Data collection**

The institutional ethics committee approved the study. The data of patients affected by MR due to MVP were collected prospectively in our institutional database for mitral valve disease. Data included general characteristics, the type of mitral valve lesions, repair technique, in-hospital echocardiographic parameters, in-hospital mortality and complications.

**Follow-up**

Follow-up was completed between January and June 2014 by clinical examination and stress echocardiography performed in our department.

Two-dimensional and colour-Doppler transthoracic echocardiograms were obtained with a Philips IE33 imaging system (Philips Medical Systems, Andover, MA, USA). All datasets were archived in a digital format (DICOM).

The exercise protocol was tailored to the capacity of the patient and was performed according to the recommendations for stress echocardiography [11]. Patients underwent exercise testing on a semi-supine bicycle. ECG and blood pressure were measured before, every 3 min during and after exercise. Peak exercise capacity was evaluated as peak double product (PDP) (heart rate x systolic blood pressure). Symptoms were continuously monitored. Resistance was increased by 25 watts every 3 min. All patients underwent 2D TTE at rest and during physical exercise. The severity of MR, mitral annulus diameter, peak and mean transmitral gradient, pulmonary systolic artery pressure (by adding the right atrial pressure to the peak tricuspid regurgitation gradient), left ventricular ejection fraction (Simpson's method) and left ventricular outflow obstruction were assessed through the exercise steps. All parameters were acquired according to the recommendations for quality echocardiography laboratory operations [12].

**Statistical analysis**

Clinical and echocardiographic data were entered into an MS Excel datasheet; all further calculations were made by importing
Intraoperative TEE confirmed the TTE findings and showed multiple diffuse central jets with a severe but symmetric prolapse of the mitral leaflet. Intraoperative echocardiography detected SAM owing to excessive tissue of the posterior leaflets. A second extracorporeal circulation was started. Edge-to-edge technique between A2 and P2 corrected the situation.

All patients showed a marked change in valve morphology, with a long leaflets coaptation displaced deeper inside the ventricle. In the first 20 consecutive patients, these acute changes were accurately recorded (Table 3). Leaflet coaptation was re-established inside the ventricle (5.2 ± 1.89 mm) and coaptation length increased dramatically (2.7 ± 0.8 vs. 11.3 ± 2.7 mm; P < 0.001). At post-repair TEE, all segments (100%) were classified as non-prolapsing and atrial leaflet displacement disappeared (Fig. 1). A reduction in annular diameters and leaflet length was observed. Left ventricular sizes increased and the distance between papillary muscle tip and mitral annulus was markedly increased (Table 3). All patients underwent postoperative TTE before discharge. One patient had mild MR and 3 patients had trivial MR; 36 patients (90%) had no MR. The presence of SAM was not observed in any patients.

Follow-up results: stress echocardiography

Mean follow-up time was 4.7 ± 3.2 years (range from 5 to 87 months). None of the patients were lost to follow-up. All patients were asymptomatic.

In 37 patients (93% of cases), stress echocardiography was performed in our institutional day-hospital. In the remaining 3 patients (8%), who were unwilling to travel, the follow-up was completed through questionnaires and telephone contact with their cardiologists.

Rest echocardiography evidenced that 1 patient had mild MR and 2 patients had trivial MR; in the others, MR was absent. Mean EF was 55 ± 6%. During exercise, none of the patients showed any increase in the degree of MR. Outflow tract obstruction or SAM was absent in all patients. None had evidence of mitral leaflets displacement or changes in annular diameters. Pulmonary artery pressure was normal in all cases (mean 27 ± 6 mmHg). Mean PDP was 22,298 ± 4,142: 33 patients achieved a double product over 20,000 mmHg × beats/min. Stress test was conducted at >125 Watts in all cases. None of the patients displayed transvalvular gradient either at rest or during exercise. Symptoms such as dyspnoea, chest pain or arrhythmias were not seen in any patients, and none developed significant hypertension.

DISCUSSION

Barlow’s disease is a specific syndrome characterized by late systolic MR owing to myxomatous degeneration of the mitral valve with redundant leaflet prolapsing into the left atrium [13, 14]. The term has been used in surgery to identify patients with the most severe form of degenerative disease, with redundant leaflets, elongated chordae, annular dilatation, papillary muscle hypertrophy and sometimes annular calcifications [15].

Owing to the massive degeneration of leaflets, Barlow’s patients have long been treated by valve replacement. More recently, reparative techniques based on resection of prolapsing segments in association with annuloplasty have been proposed [16]. Simplified techniques using artificial chordae tendineae to restore leaflets coaptation have also been used with success [17].
Although Barlow’s disease involves a major part of the mitral valve apparatus, the mitral annulus has been shown to play a significant role in the development of MR. In population-based studies, leaflets dimensions of patients with MR have been shown to be similar to those seen in patients without MR [18, 19], whereas mitral annular dilatation is almost always present in those affected by MR [20]. In myxomatous MR, mitral annulus is dynamic but profoundly different from the normal annulus. Comparisons between myxomatous patients and normal subjects have shown that the annular area is not only significantly larger, but many aspects of annular dynamics also appear to be different and to cooperate in producing leaflets prolapse and MR. The first feature is the loss of the so-called diastolic locking that promotes timely apposition of the leaflets into the left ventricle before left ventricular systole [21]. During the early systole, antero-posterior contraction is less apparent than in normal subjects and inter-commissural diameter increases markedly, causing the absence of physiological annular contraction and a failure of normal saddle-shape deepening during the early systole [22]. Later in systole, a further annular enlargement is evidenced. Antero-posterior diameter widens beyond its diastolic dimension towards end systole, contributing to leaflet separation [7]. In myxomatous disease, a ‘decoupling’ of annular and ventricular contraction [7], possibly caused by annular-ventricular disjunction, was widely observed [23]. Moreover, prolapsing mitral valve leaflets exert traction on papillary muscles, which move paradoxically towards the left atrium rather than towards the LV apex [24], causing a decrease in the distance between papillary muscle tip and mitral annulus plane in systole.

Figure 1: Transoesophageal views of mitral valve leaflets before and after surgical annuloplasty. Before annuloplasty, the leaflets exhibit an homogeneous prolapse (left) with multiple central regurgitating jets (right). After a simple annuloplasty, the coaptation depth and the coaptation height of the mitral valve leaflets increases (left) and mitral regurgitation disappears (right). LA: left atrium; LV: left ventricle; AO: ascending aorta.
MR in myxomatous disease still remains demanding in mitral valve surgery. We describe a very simple solution based solely on annuloplasty in a very selected sub-population. Analysis of valve lesions before surgery shows that a wide symmetrical bileaflets prolapse, the absence of chordal rupture, significant annular dilatation associated with a wide central regurgitant jet are always present and characterize these patients. In our opinion, these features identify a specific sub-population of myxomatous valve disease patients in whom annular dysfunction appears to be the trigger lesion responsible for MR despite the evidence of a prominent bileaflets prolapse.

Although annular dilatation as single mitral lesion has been accepted as pathogenesis of MR since the 1980s and classified as Carpentier type I, annular dilatation was only one of the multiple mitral lesions observed in our population in whom chordal elongation, excessive leaflets tissue and motion were always present and are typical of Carpentier type II myxomatous disease.

As a result of our detailed analysis of valve morphology after surgery, we observed two types of mitral changes. The first was directly linked to the annuloplasty and showed a remarkable reduction in posterolateral and inter-commissural diameters. Both systolic septo-lateral and systolic inter-commissural diameters revealed a significant decrease of about 40–50% (from a mean of 45 to 26 mm and from 50 to 32 mm, respectively) after annuloplasty. The second type of changes concerns the mitral leaflets and the left ventricle. Interestingly, without performing any manoeuvre on either leaflets or chordae tendineae, the leaflets moved from a massive prolapse into a normal position with a coaptation depth >0.5 cm and greatly increased coaptation. Moreover, when left ventricle parameters were analysed, significant elongation of the longitudinal axis and an increased distance between the papillary muscle tip and the mitral annulus plane were seen.

Our findings suggest that the restoration of the correct annular size in these sub-population of MVP patients promotes leaflets apposition and restoration of mitral valve competence, and induces changes in LV diameters that are instrumental in mitral valve function. As observed at postoperative TEE, papillary muscles move towards LV apex during systole and pull down the entire subvalvular apparatus, thereby contributing to relieve leaflets prolapse and restore a satisfactory mitral morphology. Even if leaflets were significantly increased in size, they exhibited excellent function and motion after annuloplasty. An excess of leaflet tissue in a reduced annulus did not seem to influence normal mitral function negatively. Stress-testing follow-up confirmed the encouraging results of sole annuloplasty in these cases. Interestingly, despite a significant variation in load conditions owing to the increase in heart rate and blood pressure during exercise, no changes in mitral valve function or morphology were revealed. None of the patients demonstrated MR, SAM or leaflet displacement. This suggests that, in this sub-population of patients with Barlow’s disease, annuloplasty prevents annular dysfunction and promotes more physiological leaflets apposition, both at rest and during exercise, thereby allowing stable and effective repair.

The size of the annulus has great relevance in this kind of repair. We based our choice simply on the sizer that fits the entire valve orifice, including the posterior portion of the mitral annulus, with the aim of matching annulus size to the increased leaflet surface. Massive leaflet elongation can be used to achieve a huge area of coaptation, which can act as a zone to dissipate stress, thereby enhancing the durability of the repair. However, in 2 cases, we observed SAM caused by redundancy of valve tissue. In 1 case, this was resolved by modifying loading conditions; in the other case, an adjunctive edge-to-edge procedure was necessary. In this case, use of neo-chordae implantation or posterior leaflet resection could be an effective option to treat SAM in these patients. In our opinion, edge-to-edge technique represents a simple and effective solution to this post-repair complication. The use of a large annuloplasty (38 mm semi-rigid band, as in this case) allows the use of this approach, minimizing the risk of mitral stenosis. Even though this series is too small to discuss this relevant issue in mitral repair, in both cases, SAM was completely resolved with a simple approach.

MR due to Barlow’s disease remains complex and challenging in mitral repair surgery. Since 2006, our approach has been based on mitral annuloplasty as the first manoeuvre, followed by neo-chordae implantation when necessary. However, in this sub-population of Barlow’s patients, a complete restoration of

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<th>Table 2: Postoperative course</th>
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<td>No. of patients</td>
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<td>Reoperation for bleeding</td>
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<tr>
<td>Need for inotropes</td>
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<td>Prolonged mechanical ventilation</td>
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<tr>
<td>Acute renal insufficiency</td>
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<td>Postoperative atrial fibrillation</td>
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<tr>
<td>Intensive care unit stay (h)</td>
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<td>In-hospital stay (days)</td>
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Acute renal insufficiency was defined as a postoperative creatinine serum level ≥2 mg/dl.

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<th>Table 3: Transoesophageal echocardiographic data</th>
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<td>Parameter</td>
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<td>PPM–annulus distance</td>
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<td>APM–annulus distance</td>
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<td>DSL distance</td>
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<td>AML coaptation depth</td>
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<td>PML coaptation depth</td>
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<td>Coaptation length</td>
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DIC: diastolic inter-commissural; SIC: systolic inter-commissural; AML: anterior mitral leaflet; PML: posterior mitral leaflet; NA: not available.
mitral competence was obtained after annuloplasty. Despite this being a very small population of patients, we would highlight the high uniformity and comparability of the mitral anatomofunctional characteristics allowing a simple and reproducible technique of repair.

Limitation of the study

This is a retrospective study of a subgroup of mitral patients. The study population is small (40 patients) and represents only the 11% of MVP patients referred to our cardiac centre during the study period. Follow-up time is short with respect to the durability of mitral valve repair (mean follow-up time 4.7 years).

The use of a semi-rigid band was based on our belief that it respects the mitral-aortic interaction and movements, guarantees a larger valve area and potentially reduces the risk of SAM. Based on our data, we cannot confirm that the results obtained in this study could be reproduced also by the use of a complete ring.

CONCLUSION

In conclusion, patients affected by Barlow’s disease are characterized by bileaflet prolapse, absence of chordae tendinae rupture and severe central regurgitant jet, and represent a sub-population of mitral patients in whom the sole use of a semi-rigid band annuloplasty can be considered as surgical option for mitral repair. Follow-up with stress echocardiography confirmed the stable and effective results of this approach.

Conflict of interest: none declared.

REFERENCES