The Edge-to-Edge Technique for Barlow’s Disease

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Introduction
The edge-to-edge technique has been introduced in the early nineties as a simple and effective surgical procedure for the treatment of mitral regurgitation due to complex lesions. The indications, operative steps and 5-year results of this approach have already been reported [1-3].

The basic concept of this technique is that mitral regurgitation can be corrected simply by suturing together the edges of the mitral leaflets just at the site where regurgitation occurs. In particular the free edge of the diseased leaflet is anchored to the corresponding edge of the opposing leaflet exactly where the regurgitant jet is located. When the jet of regurgitation is in the central part of the mitral valve, the application of the "edge-to-edge" technique produces a double orifice valve configuration (Figure 1). On the other hand, when the mitral lesion is commissural, the plication of this area creates a single orifice mitral valve with a relatively smaller area. The first instance is usually called double orifice repair, and the second paracommissural repair.

The edge-to-edge technique for Barlow’s disease
In Barlow's disease, all the components of the mitral valve apparatus are involved by a mixomatous degeneration which eventually leads to generalized bileaflet prolapse, severe annular dilatation and severe mitral insufficiency. The free edges of these myxomatous valves are often irregular, with an increased number of clefts (Figure 2) and multiple regurgitant jets at doppler echocardiography. In such a context, a conventional anatomical reconstructive approach requires a long operation addressing the multiple mitral defects at annular, valvular and subvalvular level. This type of correction, although successfully performed by many experienced surgeons, is technically demanding, not easily reproducible and sometimes associated to suboptimal results. The “edge-to-edge” technique allows a standardized correction of this complex condition just by suturing the middle scallop of the anterior and posterior leaflet (A2 to P2) followed by ring annuloplasty: a simple, standardized and easily reproducible surgical act allows the effective treatment of multiple and generalized anatomical mitral defects. The purpose of the edge-to-edge technique in Barlow's disease is to
correct leaflet redundancy (which is usually predominant in the middle of the leaflets), to force coaptation (reducing the delay between the beginning of the ventricular contraction and valve closure), to eliminate leaflets' prolapse and to prevent post-operative SAM. The presence of a flail leaflet is not a contraindication for the procedure, since the flail segment can be included in the edge-to-edge suture. Preoperative small valve area, which can be a contraindication for the edge-to-edge technique because of the increased risk of mitral stenosis, is usually not an issue in Barlow's disease since, in most of these cases, valve area is excessively wide. Finally, we currently do not advocate the edge-to-edge repair as an isolated procedure in presence of severely calcified annulus, when a ring prosthesis cannot be added to the procedure, since this has been associated with higher risk of repair failure.

Surgical technique and results
The "edge-to-edge" mitral-valve repair is performed during total normothermic cardiopulmonary bypass, after conventional aortic and bicaval cannulation. Midline sternotomy is usually adopted. In selected cases a minimally invasive approach through a small right thoracotomy has been successfully used. Myocardial protection is accomplished by intermittent antegrade cold-blood cardioplegia whereas retrograde cardioplegia is associated only in presence of aortic regurgitation. After dissection of the interatrial groove, mitral valve is approached through the left atrium and carefully inspected. In most of the patients with severe Barlow's disease, all portions of the valve are characterized by severe prolapse. The "edge-to-edge" suture has to be positioned exactly at the "anatomical middle" of the valve, which can be defined as the point of the anterior and posterior leaflets where the subvalvular structures converge. This region, corresponding approximately to the central part of the anterior and posterior leaflets, divides the mitral valve in two halves, each one connected by the underlying chordae tendineae to one papillary muscle. The "anatomical middle" of the mitral valve may be different from its "geometrical one", which is usually closer to the anterior rather than to the posterior commissure since the distribution of the chordae arising from the posterior papillary muscle is wider than that of the chordae coming from the anterior one. Once the "anatomical middle" of the mitral valve has been identified by inspecting the subvalvular apparatus with a nerve hook, a stay stitch is placed at this site through both leaflets and the symmetry of the two orifices created is immediately checked. A running suture is then passed in a standardized manner along the free edge of the middle scallop of the anterior and posterior leaflets to complete the repair (Figure 3). Two rows of suture are used, the first is continuous mattress and the second is over-and-over 4-0 polypropylene continuous suture. Pledgets are not necessary. Big bites (approximately 0.5 to 1 cm deep) should be taken to enhance the strength of the repair and reduce the leaflets height.
Minimal technical modifications are adopted according to the single case anatomy and pathology:

- Stitch depth may vary depending on the redundancy of leaflet tissue: as a general rule, the more redundancy is present, the deeper the stitch, and the wider the suture. If possible, the width of the suture should be minimized to reduce the risk of valvular stenosis. However, if valve prolapse and leaflet redundancy is severe, a wide suture, connecting the whole P2 free edge to the opposing A2, may be necessary.
- In presence of flail segments the position of the stitch may be somewhat asymmetric, corresponding to the center of the flail portion of the leaflet.

As with any other valve repair technique, annuloplasty is necessary to remodel and reduce the size of the annulus which is usually very dilated. Annuloplasty ring size is chosen by measuring the intertrigonal or intercommissural distance, and assessing the width of the anterior leaflet surface area.

After reconstruction, the residual mitral area is always measured by introducing Hegar valve dilators into the orifices: a global valve area of more than 2.5 cm$^2$ is usually considered acceptable for "normal size" patients. Competence is evaluated by forceful saline filling of the left ventricle.

Transesophageal echo-Doppler reassessment of the valve is routinely performed after weaning from cardiopulmonary by-pass: valve area may be assessed by Doppler methods, although we mostly rely on planimetric valve area, assessed in the transgastric, short-axis view. In case of doubts, pressure measurements of the transvalvular gradients may be obtained to exclude mitral stenosis intraoperatively.

The simplicity of the edge-to-edge technique makes it possible to repair complex Barlow's disease mitral valve with very short cross-clamp times which is one of the main determinants of the operative result. In our experience, mean cardiopulmonary by-pass time and aortic cross clamp time were 54±13.8 min and 39±6.7 min, respectively. Excluding patients undergoing associated cardiac procedures, mean cardiopulmonary by-pass and ischemic times were 47±9.1 min and 33±3.9 min.

Mid-term echocardiographic follow-up show good results of the repair, with stable competence and no progression of valve stenosis [2]. Freedom from reoperation is 91% ±3.4% at 5 years with no patients requiring late reoperation for mitral valve stenosis. Considering the unfavorable anatomical features and the complexity of the mitral valve lesions of patients affected by Barlow's disease, we consider these results very satisfactory.

Controversial issues

- The opportunity to associate an annuloplasty procedure to every "edge-to-edge" repair has been debated for many years, particularly because of the potential risk of stenosis. On the base of our

Figure 3: Surgical correction of severe mitral regurgitation due to Barlow's disease by the "edge-to-edge" technique followed by ring annuloplasty
experience, we would recommend to add always an annuloplasty to the "edge-to-edge" repair, if possible. We believe that the annuloplasty stabilizes the reconstruction reducing the stress on the "edge-to-edge" suture and increases the coaptation surface of the leaflets enhancing the competence of the valve. Moreover, the possibility of subsequent annular dilatation is prevented by the annuloplasty and this can potentially improve the long term results of the mitral correction. Indeed, the edge-to-edge repair without annuloplasty is associated in our experience to suboptimal short-term results.

- When the "edge-to-edge" technique is adopted as a double orifice repair, the morphology of the mitral valve becomes that of a double orifice valve which arises several controversial issues. In particular, a matter of concern is the possible implication of a non-physiological mitral orifice configuration on the hemodynamics of the valve during ventricular filling. Moreover, the distribution of the trans-mitral flow through the two orifices, which can be of significantly different sizes, has generated doubts regarding the possibility of assessing the hemodynamic of the mitral valve with the Doppler. A computational model, together with the clinical experience, however, has clearly demonstrated that the double orifice configuration of the valve does not have any influence on the mitral hemodynamics which depends exclusively on the total valve area and on the cardiac output (4). In double-orifice valve configuration, the velocity of the flow through each orifice is very similar to the one observed through a single orifice valve of area equal to the sum of the areas of the two orifices. Moreover the flow velocities through the two orifices are exactly the same, even when the orifice sizes are significantly different, which means that the Doppler sampling of any of the two orifices is sufficient to assess the hemodynamic of the mitral valve. Our clinical experience confirms these findings: in a series of ten patients, previously submitted to double orifice repair, in sinus rhythm, the velocities recorded at each orifice by doppler examination did not differ by more than 5%. Therefore, the hemodynamic performance of a double-orifice mitral valve is comparable to that of a single orifice one of equivalent effective orifice area; the ratio between the orifices areas does not influence the hemodynamic of the valve and Doppler-derived velocities are good indicators of pressure loss through the valve.

- The risk of increased thromboembolic complications due to the higher flow turbulence generated by the double orifice configuration has been postulated: we do not have in our experience any evidence supporting such a concern.

- Another major issue regarding this type of repair is the potential for creating functional mitral stenosis, especially with exercise. Low mitral gradients have been measured at rest in patients at short to medium-term follow-up [1]. Moreover, to study the hemodynamics of the double orifice valve under stress conditions, an exercise echocardiographic study to evaluate valve function in patients who underwent central double orifice mitral repair has been performed, showing that the artificially created double orifice valves follow a physiologic behavior during physical exercise, with a good valvular reserve in response to the increased cardiac output. Functional mitral stenosis does not develop either at baseline or under stress conditions also with concomitant ring annuloplasty (5).

Conclusions
We strongly believe that the "edge-to-edge" technique can be a very useful addition to the surgical armamentarium in mitral valve reconstruction, particularly in presence of mitral regurgitation due to Barlow’s disease because of its simplicity, reproducibility and effectiveness.

References