Minimally Invasive Mitral Valve Annuloplasty with Realignment of Both Papillary Muscles: Pathophysiological Correction of IIIb Functional Mitral Regurgitation

Objective: Pathophysiological background of IIIb type functional mitral regurgitation (FMR) is a progressively increasing distance between papillary muscle tips and mitral annular plane. Standard surgical treatment of such FMR by means of undersized mitral annuloplasty is associated with a high recurrence rate.

Methods: We propose a simple subannular maneuver to correct IIIb type FMR while combining standard mitral annuloplasty with a controlled realignment of both papillary muscles, thereby fixing the distance between mitral annular plane and papillary muscle tips. The differences of this subannular maneuver as compared to the previously published techniques are as follows: (1) relocation of bilateral papillary muscles, (2) fixation of the papillary muscles to mitral annulus distance on an annuloplasty ring, and (3) application in a 3D endoscopic mini-thoracotomy setting.

Results: We describe a surgical technique of minimally-invasive mitral valve repair performed due to severe IIIb type FMR which includes a novel subannular maneuver to realign both papillary muscles (i.e., feasibility study). Preliminary results of the first 10 patients who underwent this procedure at our institution are presented. There was no in-hospital mortality and follow-up echocardiography (mean echocardiographic follow-up: 10±6 months) demonstrated stable functional result.

Conclusions: Our initial experience indicates that adding of this simple subannular maneuver to the standard annuloplasty and thereby fixing the distance between papillary muscles and mitral annular plane has a potential to improve results of surgical FMR treatment.
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Re: “Minimally invasive mitral valve annuloplasty with realignment of both papillary muscles: pathophysiological correction of IIIb type functional mitral regurgitation”

Dear Dr. Damiano:

We respectfully submit the above-named article for consideration for publication by the Innovations journal. It should be considered under the category of Original Article.

The material in this paper has not been previously published or submitted elsewhere for publication. All authors have read and approved the manuscript. There is no ethical problem or conflicts of interest to declare. Subject to acceptance, authors will transfer copyright to the Publisher.

Unfortunately, we are unable to produce CMYK files for Figure 1.

Thank you very much for considering our manuscript and we look forward to hearing your review.

Sincerely,

Evaldas Girdauskas
Minimally invasive mitral valve annuloplasty with realignment of both papillary muscles: pathophysiological correction of IIIb functional mitral regurgitation

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Running head: realignment of bilateral papillary muscles

No conflict of interest to declare
No funding was received, no financial support or industry affiliations

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Word count: 1692

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Key Words: mitral regurgitation, functional mitral regurgitation, mitral valve repair, minimally invasive surgery, subannular technique
Introduction

Standard surgical treatment of IIIb type functional/ischemic mitral regurgitation (FMR) by means of undersized mitral annuloplasty is associated with a high recurrence rate and questionable long-term prognosis [1]. Mitral valve replacement has been advocated as an alternative technique to address IIIb type FMR, which is basically a replacement of a structurally normal mitral valve [2]. Recent meta-analyses unequivocally demonstrated increased perioperative mortality in FMR patients after mitral valve replacement as compared to mitral valve repair [3]. Few subannular techniques were suggested to improve results of surgical FMR treatment [4-6]. However, none of them have been implemented systematically in prospective trials. Herewith, we present a simple and fast subannular maneuver to address IIIb type FMR, which may be easily implemented in the fully endoscopic mitral valve surgery setting.

Surgical technique

A standard non-rib-spreading fully endoscopic approach to mitral valve is achieved through a 3-4cm right anterolateral mini-thoracotomy, as described previously [7]. Femoro-femoral cardiopulmonary bypass (CPB) with systemic cooling (i.e., 32C°) is implemented and cardiac arrest is achieved by means of antegrade crystalloid cardioplegia. Most recently, right axillary artery cannulation has been used for arterial CPB inflow in patients aged >70 years.

After surgical analysis of mitral valve and confirmation of Carpentier type IIIb FMR mechanism, both papillary muscles are endoscopically visualized. In the first step of procedure, doublearmed pledgeted 3-0 PTFE sutures are passed through the trunks of bilateral papillary muscles in a U-formed fashion (Figure1A). While advancing these sutures, special care is taken not to distort the native chordae. Both suture ends are subsequently passed through the posterior mitral valve annulus (i.e., in the P1 segment for anterolateral papillary muscle and in the P3 segment.
for posteromedial papillary muscle) from the ventricular to atrial side (Figure 1B). Additional traction sutures on the free margin of posterior leaflet / primary chordae may be used during this maneuver to improve the exposure of posterior mitral annulus and to prevent the impingement on native PML chordae. Both sutures are retrieved outside the chest subsequently and secured by Mosquito clamps for later use after placement of annuloplasty ring.

Mitral annuloplasty is accomplished in a standard fashion, using a complete undersized annuloplasty ring with a reduced antero-posterior diameter (e.g., Carpentier-McCarthy-Adams IMR ETlogix ring). Both PTFE sutures are kept outside the annuloplasty ring while the ring is being lowered down on the native mitral annulus. After ring sutures are completely tied thereby securing the annuloplasty ring, both PTFE sutures are passed through the posterior aspect of annuloplasty ring (i.e., in the P1 and P3 segments, respectively) (Video 1).

In the next step of procedure, both papillary muscles are fixed in a stable distance to the mitral annular plane. This is being accomplished by filling the left ventricle with a cold saline and thereby inducing a maximally possible tenting of mitral leaflets. While the left ventricle is maximally filled, stepwise traction is applied to both PTFE sutures until leaflet tethering disappears and a mild “pseudo-prolapse” of anterior mitral leaflet occurs. Both sutures are tightly knotted while keeping this traction and the knots are additionally secured with hemoclips (Video 1). This maneuver allows for a very controlled realignment of both papillary muscles thereby reaching an appropriate distance between papillary muscle tips and mitral annular plane. The effect of subannular correction is demonstrated by intraoperative TEE which reveals a significantly improved systolic mobility of the AML and disappearance of leaflet tethering (Video 1).

Preliminary series

We implemented this surgical technique in the preliminary series of 10 patients with type
Consecutive patients with type IIIb functional mitral insufficiency were prospectively selected for this procedure, if they fulfilled the following criteria: (1) moderate-severe reduction of systolic LVEF ≤ 40%, (2) LVEED > 60mm, (3) tenting height > 10mm, and (4) evidence of bi-leaflet tethering (i.e., patients with an isolated PML restriction were excluded). The demographics and echocardiographic parameters of those patients are displayed in Table 1. Two patients who required simultaneous CABG underwent the surgery through a median sternotomy, while the remaining had a right anterior mini-thoracotomy (n=8). Even those patients presenting with very large LV diameters (i.e., LVEDD ≥ 75 mm) were included.

There was no need for perioperative circulatory support and no in-hospital mortality in this selected subgroup. Echocardiographic follow-up is limited (i.e., mean echocardiographic follow-up 10±6 months) and is of maximally 20 months’ duration in the first two patients. Until now, mitral valve repair is stable (i.e., no/trivial MR in 7 patients and mild MR in 2 patients), with an exception of one patient who experienced a recurrent mild to moderate MR at 3 months’ post-surgery. Of note, this patient underwent relocation of posteromedial papillary muscle only and his mitral regurgitation recurred at the level of the (unfixed) anterolateral commissure. No papillary muscle dehiscence/detachment of PTFE suture was observed during the follow-up.

Based on our preliminary results, we believe that adding of this simple subannular maneuver to the standard annuloplasty and thereby fixing the distance between papillary muscles and mitral annular plane has a potential to improve results of surgical FMR treatment. A very controlled realignment of both papillary muscles with a fixation of realignment sutures on the stable annuloplasty ring, through a fully 3D endoscopic mini-thoracotomy access has potential advantages as compared to previously described techniques [5].
References


Table 1. Preliminary series (10 patients who underwent subannular correction)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60 ± 16 (31 – 79)</td>
</tr>
<tr>
<td>Male gender (%)</td>
<td>5 (50%)</td>
</tr>
<tr>
<td>MR &gt; II degree</td>
<td>10 (100%)</td>
</tr>
<tr>
<td>Preoperative MR degree (°)</td>
<td>3.1 ± 0.5 (3 - 4)</td>
</tr>
<tr>
<td>Ischemic MR</td>
<td>4 (40%)</td>
</tr>
<tr>
<td>Non-ischemic functional MR</td>
<td>6 (60%)</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>32 ± 5 (10 - 40)</td>
</tr>
<tr>
<td>LVEDD (mm)</td>
<td>69 ± 8 (61 - 80)</td>
</tr>
<tr>
<td>Bi-leaflet tenting</td>
<td>10 (100%)</td>
</tr>
<tr>
<td>Preoperative coaptation depth (mm)</td>
<td>14 ± 3 (11 - 17)</td>
</tr>
<tr>
<td>Preoperative tenting area (cm²)</td>
<td>3.2 ± 0.9 (4.2 - 2.5)</td>
</tr>
<tr>
<td>Preoperative PML angle (°)</td>
<td>55 ± 9 (43 - 75)</td>
</tr>
<tr>
<td>Relocation of bilateral papillary muscles</td>
<td>8 (80%)</td>
</tr>
<tr>
<td>Annuloplasty ring (mm)</td>
<td>27.8 ± 1.1 (26 -30)</td>
</tr>
<tr>
<td>Additional procedure *</td>
<td>7 (70%)</td>
</tr>
<tr>
<td>Post-repair MR (intraoperative)</td>
<td>0.3 ± 0.4 (0 – 1)</td>
</tr>
<tr>
<td>Post-repair coaptation depth (mm)</td>
<td>1.0 ± 1.0 (0 – 2)</td>
</tr>
<tr>
<td>Post-repair coaptation length (mm)</td>
<td>5.5 ± 2.5 (4 – 10)</td>
</tr>
<tr>
<td>Post-repair tenting area (mm)</td>
<td>0.3 ± 0.3 (0.1 – 0.6)</td>
</tr>
<tr>
<td>Post-repair MR (at discharge)</td>
<td>0.5 ± 0.5 (0 - 1)</td>
</tr>
<tr>
<td>Follow-up MR (last follow-up)</td>
<td>0.5 ± 0.6 (0 – 1.5)</td>
</tr>
</tbody>
</table>

* CABG, tricuspid annuloplasty, endocardial cryoablation, closure of left atrial appendage
LVEF- left ventricular ejection fraction; LVEDD- left ventricular end-diastolic diameter; MR-mitral regurgitation; PML-posterior mitral leaflet

Figure 1A/B. Placement of papillary muscle realignment sutures through the posteromedial papillary muscle (A); and through the posterior mitral annulus, in the P3 segment (B); Video1. Intraoperative TEE showing tethering of mitral leaflets before the procedure (A); implantation of annuloplasty ring (B); Fixation of PTFE sutures on the mitral annuloplasty ring (C); bilateral adjustment of optimal papillary muscle distance to mitral annular plane (D), and, subsequently, the echocardiographic result after bilateral papillary muscle realignment (E)
Supplemental Video File
MIC MKR with repositioning of both papillary muscles_EG.wmv