

Paradoxical Artificial Chords: New Technique to Prevent Systolic Anterior Motion Post Mitral Valve Reconstructions

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Abstract

We describe In this report, a new and simple technique to prevent SAM after mitral valve repairs, hence two artificial chords are implanted in the edge of anterior leaflet at five and seven o'clock positions, subsequently these are paradoxically anchored to the posterior annulus avoiding the mitral-septal contact or reducing this contact at the level of the tip of anterior leaflet particularly with notable bulging of the ventricular septum into the out-flow tract.

Keywords: Mitral valve repair; SAM; Systolic anterior motion

Introduction

Some studies have demonstrated that the Systolic Anterior Motion after degenerative mitral valve reconstructions is a common postoperative complication with an incidence of 11% [1]. The

mechanism of SAM is multifactorial, the redundant leaflets in the myxomatous disease is the root cause. An anteriorly displacement of papillary muscles, a non-dilated left ventricle, and a narrow mitral-aortic angle have also been proposed as contributing factors [2]. Another study has demonstrated that the two main reasons were the excess tissue of the posterior leaflet and inadequate ring sizing, resulting in a too small a ring for a too large anterior leaflet [3]. Essential changes occur to the left ventricular geometry after mitral valve repair by an important reduction of the aortomitral angle; this way the left ventricular filling compartment may become part of the sub-aortic zone which is worsened by a ring annuloplasty [4]. Although the medical treatment can be used to manage SAM, in some situations a further surgery is required to relieve the aortic obstruction and mitral insufficiency, so that the replacement of mitral valve is proposed as a corrective procedure [5]. Many resection and non-resection techniques are available to prevent SAM after mitral valve repair. The sliding plasty [6], triangular resection of the anterior leaflet [7], Elliptical excision at base of anterior leaflet [8], plication of the posterior leaflet [9], transposition of secondary chordae into the anterior leaflet [10], Alfieri's edge-to-edge suture [11], asymmetric Alfieri's stitch [12] and Papillary muscle-to-anterior annulus stitches [13] have been described to prevent or correct SAM.

We describe a new and simple technique to prevent SAM after mitral valve repair, hence two artificial chords are implanted in the edge of anterior leaflet at five and seven o'clock positions, subsequently these are paradoxically anchored to the posterior annulus avoiding the mitral-septal contact or reducing this contact at the level of the tip of anterior leaflet particularly with notable bulging of the ventricular septum into the outflow tract.

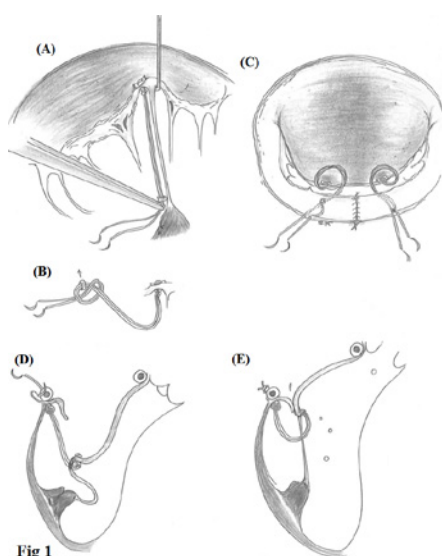


Figure 1:

- The anterior edge between the artificial chord's anchor and the native first-order chord's attachment is stretched by the assistant using a nerve hook. The new chord is pulled down with forceps parallel with the stretched native chord toward the appropriate papillary muscle; a metal clip is placed across the two arms at the level of the papillary muscle's tip.
- Non-sliding knot is tied against the metal clip, which is subsequently removed.
- Illustration represents the couple of sutures are anchored on the edge of anterior leaflet at five and seven o'clock positions, the posterior leaflet has been repaired by limited triangular resection. Before the ring's implantation, the two sutures are passed through the posterior annulus at five and seven o'clock locations, and are left untied.
- Cross-profile Illustration represents an annuloplasty Physio ring in its final position. The untied Gore-Tex suture is outside the ring and the two needles are passed through the posterior prosthetic sheath. Cross-profile shows the new stitches are tightly tied on the posterior prosthetic sheath and the paradoxical "function" of the new chords: thus they are slack while the other chords of the subvalvular apparatus are firmly stretched during the saline injection test.

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Surgical Technique

Once the mitral valve repair is completed choosing the appropriate strategies depending on the identified lesions, the anterior leaflet is accurately analyzed again using two nerve hooks. On the anterior leaflet margin five and seven o'clock positions are determined in reference of its semicircular shape, taking into consideration that the position of six o'clock is at the tip of A2 of the anterior leaflet. A double-armed 4-0 polytetrafluoroethylene (Gore-Tex; W.L. Gore & Associates, Flagstaff, AZ, USA) suture supported by a felt pledget is passed twice through the edge of anterior leaflet at five o'clock position from the atrial to the ventricular surface, and is tightly knotted. The surgeon's assistant stretches the anterior leaflet at 5 o'clock position by a nerve hook to explore the nearest healthy first-order chord (Figure 1-A). The height of stretched native chord determines the length of the new artificial chord,

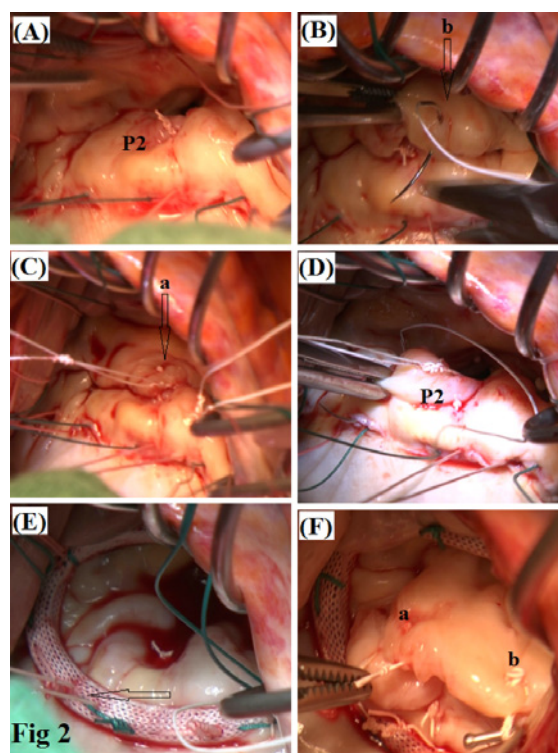


Figure 2: Intra-operative images:

- Intra-operative image shows the calcification at the base of a huge P2 which has been reconstituted by a non-resection strategy "Tent shape Technique".
- A double-armed 4-0 polytetrafluoroethylene (Gore-Tex) suture supported by a felt pledget is passed twice through the edge of anterior leaflet at five o'clock position from the atrial to the ventricular surface.
- The arrow indicates the anchored suture on the anterior leaflet edge at 5 o'clock position. The length of the chord is determined and mental clip is removed.
- The position of seven o'clock at the posterior annulus has been determined. One needle of the suture, which has been already anchored at seven o'clock position of the anterior leaflet edge, is passed through the posterior annulus at the determined position from the ventricular to the atrial side by means of a forehanded technique. This image demonstrates that the needle passes through the calcification of posterior leaflet in this selected case.
- Arrow indicates the two arms of the anchored suture at seven o'clock has been inserted in the posterior prosthetic sheath. This image shows that the posterior leaflet tissue has been totally conserved.
- The two implanted chords have been demonstrated by nerve hook and forceps.

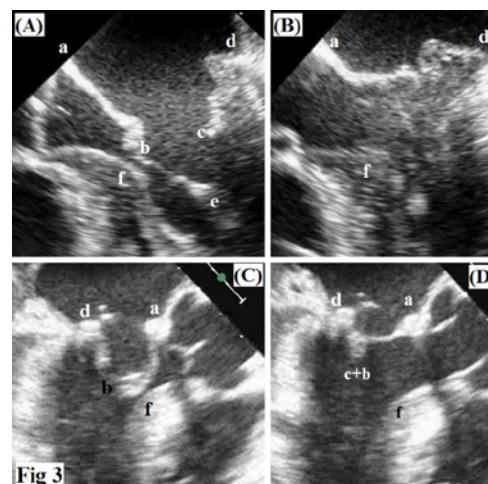


Figure 3: Intra-operative transesophageal echocardiography images:

- Pre-mitral valve repair during systole. Anterior leaflet is redundant, the second order chords seem to be slack so the tip of the leaflet kisses the bulging septum.
- Image demonstrates the insufficiency of mitral valve due to a prolapsed and huge P2 of posterior leaflet.
- Post-mitral valve repair during diastole. During the end diastole, the paradoxical chords ensure the avoidance of contact between the tip of the anterior leaflet and the bulging septum. The annuloplasty ring seems to be downsized. The image shows a large surface of coaptation between the two leaflets (c+b).

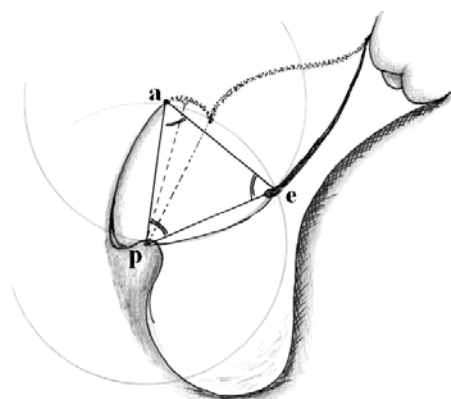


Figure 4: Cross-profile shows how the idea emerged:

- Posterior annulus (5 or 7 o'clock position), p. Papillary muscle, e. Edge of anterior leaflet (5 or 7 o'clock position). The triangle a.p.e is an equilateral triangle. The plane of the posterior wall of left ventricle outflow tract extends from the tips of the papillary muscles to the anterior annulus of mitral valve. In the physiological condition this plane is curved slightly during the end diastole. The length of the first order native chord of the anterior leaflet "p-e" has approximately the same length of the first and second order of the posterior leaflet. Therefore, the distance between the posterior annulus and the tip of appropriate papillary muscle (not always the third order chord of posterior leaflet) is equal to the length of the first order chord of the anterior leaflet which is located at the same cross profile level. The tip of papillary muscle "p" is considered the vertex of the angle between the posterior annulus-tip of papillary muscle ray "p-a" and the first order chord of the anterior leaflet ray "p-e" during the end diastole "filling angle", and by implanting a ring annuloplasty this angle is narrowed. Thus, to obtain the filling angle wide as much as possible, the triangle a.p.e during the end diastole should be an equilateral triangle, so e-a (new chord) equal to e-p (first order chord of anterior leaflet).

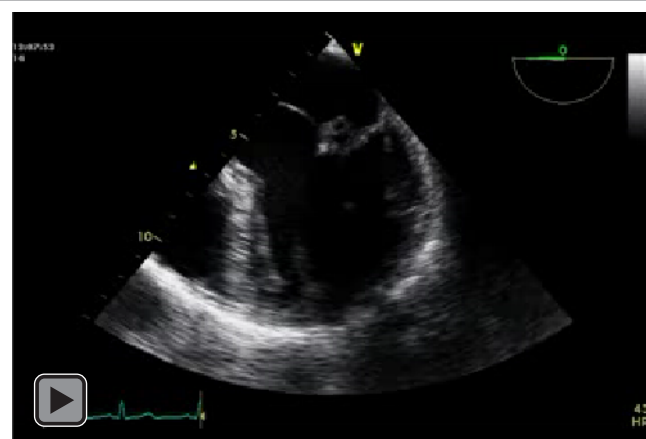
thus the new chord is pulled down with forceps beside the stretched native chord toward the papillary muscle that originates from; a metal clip is placed across the two arms at the level of the papillary muscle's fibrous tip (Figure 1-A). Subsequently, a non-sliding knot is tied against the metal clip, which is subsequently removed (Figure 1-B). A second similar suture of Gore-Tex is anchored on the edge of anterior leaflet at seven o'clock position using the same technique as above. Before the implantation of the chosen annuloplasty ring, the positions of five and seven o'clock at the posterior annulus are determined, taking into consideration that six o'clock is located at the mid posterior annulus. Thereafter, the two arms of the suture, anchored at five o'clock position of the anterior leaflet edge, are passed through the posterior annulus at five o'clock position from the ventricular to the atrial side by means of a forehanded technique keeping attention to not interfere with the native chords of the posterior leaflet, and the suture is left untied. This way, the two arms of the other suture are inserted into the posterior annulus at seven o'clock position (Figure 1-C). Finally, an annuloplasty Physio ring (Edwards Lifesciences LLC, Irvine, CA) is sized and added to complete the repair, maintaining free the untied Gore -Tex sutures outside the ring. After the ring is implanted, the Gore-Tex sutures are passed through the posterior prosthetic sheath (Figure 1-D), and tightly knotted (Figure 1-E). The left atrium is once again closed after acceptable fluid testing to confirm the valve's competence (Figure 1-E). (See Figure 2, intra-operative imagines).

Clinical Experience

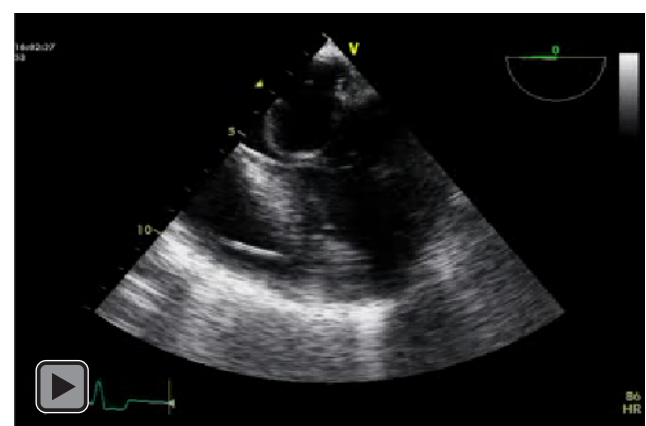
We have applied this technique on 8 patients with severe degenerative mitral regurgitation with redundant anterior leaflet and other factors predisposing them to develop SAM (Movie 1, Figure 3-A and Figure 3-B). In three patients, limited resection strategy "triangular resection of P2" has been deployed to repair the mitral valve, and non-resection strategies to repair posterior leaflet have been used in the other five patients. Intra-operative transesophageal echocardiography and early follow-up transthoracic echocardiography show the absence of SAM (Movie 2, Figure 3-C and Figure 3-D), and no evidence of mitral valve stenosis. We continue with this simple method as one of the non-resection strategies to prevent SAM post mitral valve repair in all patients believed to be at high risk, particularly when the anterior annulus is not well exposed, and the anterior leaflet is not easily manageable for performing another procedure to prevent SAM.

Comments

During end diastole and under the influence of different forces, the new chord - which extends from the posterior annulus to the free edge of the anterior leaflet and has the same length as the first order native chord of the anterior leaflet - allows the anchored point to reach the plane between the appropriate papillary muscle tip and the mitro-aortic continuity. This follows the physiological posterior wall of the left ventricular outflow tract (Figure 4). The chords extend diagonally from the anterior edge at 5 and 7 o'clock locations to the corresponding 5 and 7 o'clock positions at the posterior annulus and maintain the edge of A2 expansion without losing the concave surface shape of the anterior leaflet; thus maintaining the funnel shape of the inflow tract during the diastole without causing stenosis. The insertion of the sutures from the atrial to ventricular side of the anterior leaflet slightly folds the edge towards the atrial side in the pre-systole phase. This facilitates left ventricular outflow even if the central body of the anterior leaflet becomes morbidly in contact with the septum, as occurs in the case of a redundant anterior leaflet and very narrow mitro-aortic angle. This pathology may be aggravated by implanting a ring annuloplasty.



Movie 1: Intra-operative transesophageal echocardiography images: pre-mitral valve repair, anterior leaflet is redundant, the second order chords seem to be slack so the tip of the leaflet kisses the bulging septum. The insufficiency of mitral valve due to a prolapsed and huge P2 of posterior leaflet.



Movie 2: Intra-operative transesophageal echocardiography images: post-mitral valve repair. During the end diastole, the paradoxical chords ensure the avoidance of contact between the anchored point of the anterior leaflet and the bulging septum. The images show a large surface of coaptation.

When the mitral valve repair is completed using whichever strategy is chosen by the surgeon, and if SAM is diagnosed after CPB interruption, it is quite feasible to perform this technique. This negates the need to attempt further repair or to substitute the already implanted ring. If the surgeon has already used a resection strategy, the repetition of further resection strategies may injure the valvular tissue and lead to the surgeon becoming despondent and fatigued.

This technique improves the likelihood that the surgeon can use a reasonably undersized annuloplasty when encountering suboptimal circumstances during a mitral valve repair. This ensures a good coaptation and significant support to the mild or moderately prolapsed anterior leaflet by the corrected posterior leaflet.

In summary, we propose that the indications to follow the non-resection strategies for mitral valve repairs, which also increases the risk of post-repair SAM, may also be the indications to follow the Paradoxical Artificial Chordae Tendineae. This non-resection strategy has the potential to prevent SAM and may eliminate this phenomenon when it is diagnosed after mitral valve plasty.

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