

## Premolded Bovine Pericardial Chords for Replacement of Ruptured or Elongated Chordae Tendineae

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### ABSTRACT

**Background:** The aim of this study was to assess by Doppler echocardiography (ECO) the functioning of the mitral valve apparatus in patients who have undergone implantation of standardized bovine pericardium chordae (SBPC) for replacement of ruptured or elongated chordae tendineae with significant thinning.

**Methods:** SBPC were implanted in 31 patients who had mitral insufficiency due to rupture of chordae tendinae or elongated chordae with significant thinning. Patient ages ranged from 19 to 85 years (mean of 58 years). The most frequent cause of mitral insufficiency was fibroelastic degeneration in 25 patients (80.6%). The SBPC were fashioned as a set, joined at their extremities by 2 polyester-reinforced rods forming a monobloc. The SBPC were 2-mm wide and were positioned parallel to one another at a distance of 3 mm. Each set of SBPC had a corresponding measurer, and their length ranged from 20 to 35 mm. In 21 patients (67.7%) the SBPC were implanted in the posterior leaflet and in 10 patients (32.3%) in the anterior leaflet (in 2 patients concurrently in the anterior and posterior leaflets). All patients were assessed by ECO postoperatively, with a 20-month mean follow-up time (range 6–45 months).

**Results:** One patient (3.2%) died of pulmonary embolism during the early postoperative period. Postoperative ECO showed absence of mitral regurgitation in 17 patients (54.8%), mild regurgitation in 9 (29.0%), and mild-to-moderate regurgitation in 4 (12.9%). Opening and mobility of the mitral valve were normal in the 30 surviving patients.

**Conclusion:** The ECO revealed good functionality of the mitral valve apparatus with appropriate leaflet coaptation in patients who had undergone implantation of SBPC for replacement of ruptured or elongated and thinned chordae. A longer follow-up is required to assess absence of calcification and/or degeneration of the SBPC.

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### INTRODUCTION

Mitral insufficiency (MI), defined as blood regurgitation from the left ventricle to the left atrium through the valve, is a situation predisposing to left ventricular dysfunction, increase of the left atrium, and atrial arrhythmias, regardless of the etiology. MI is more common in rheumatic disease with fibroelastic degeneration [Rushmer 1956; Carabello 1988]. Mitral valve prolapse identified by redundancy of the anterior and/or posterior leaflet, papillary muscle dysfunction, and chordae tendineae elongation or rupture may evolve to MI. Mitral valvuloplasty is an elective procedure for repair of MI, with better results than prosthesis implantation [Akins 1994].

Regarding the case of chordae tendineae rupture, numerous techniques have emerged for the replacement of the ruptured chordae and valve preservation. Techniques such as transference of chordae from the posterior leaflet to the anterior, partial transference of the tricuspid valve to the mitral, creation of neochords with anterior leaflet patches, and implantation of synthetic or biological artificial chords are some of the procedures used [Carpentier 1978; Frater 1983; Gregory 1988; David 1991; Gregori 1999]. Repair of anterior leaflet prolapse is more difficult than that of the posterior and, in the majority of cases, requires the use of associated techniques. Annuloplasty is a complementary technique necessary in all cases. In our study the technique used was similar to partial transfer of chordae tendineae from the tricuspid valve to the mitral valve, replacing the ruptured chordae. Bovine pericardium treated with 0.5% glutaraldehyde is widely used in cardiovascular surgery, thereby making its use a rather familiar procedure [Braile 1983].

The aim of this study was to assess by Doppler echocardiography the mitral valve apparatus function in patients who had undergone implantation of standardized bovine pericardium chordae (SBPC) treated with glutaraldehyde for replacement of ruptured or elongated chordate tendineae with significant thinning.

### METHODS

Between May 2006 and November 2008, 31 patients with severe MI caused by rupture of the chordae tendineae or elongation with significant thinning underwent implantation of SBPC (Braile Biomédica, Indústria, Comércio e



Figure 1. Standardized bovine pericardium chordae.

Representações S/A<sup>®</sup>, São Paulo, Brazil). Seventeen patients (54.8%) were male and 14 (45.2%) were female. Age ranged from 19 to 85 years, mean 58 years. The most frequent cause of MI was fibroelastic degeneration in 25 patients (80.6%), followed by ischemia in 2 (6.5%), Barlow syndrome in 2 (6.5%), and infectious endocarditis in 2 (6.5%). Before surgery, 6 patients (19.4%) were in New York Heart Association functional class II, 19 (61.3%) in class III, and 6 (19.4%) in class IV. Atrial fibrillation was present in 6 patients (19.4%).

Assessment by Doppler echocardiography showed significant regurgitation in all cases, with preserved left ventricular function in 26 patients (83.9%) and decreased ejection fraction in 5 (16.1%).

The degree of regurgitation was considered mild when lower than 20%, moderate from 20% to 40%, and significant when higher than 40%. Rupture or elongation with a high degree of thinning of the chordae tendineae in the anterior leaflet was observed in 10 patients (32.3%) and in the posterior leaflet in 21 patients (67.7%) (in both anterior and posterior leaflets in 2 patients). Posterior mitral annular dilatation occurred in all patients.

The SBPC were fashioned as a monobloc (Braile Bio-médica) joined at their extremities by 2 polyester-reinforced strips. The SBPC were 2 mm wide and 3 mm distant from each other (Figure 1). Standardization of the chordae was confirmed by using measuring instruments ranging in length from 20 to 35 mm (Figure 2). The bovine pericardium was treated with 0.5% glutaraldehyde, subjected to anticalcification treatment with glutamic acid, and preserved in 4% formaldehyde

solution. Resistance and durability tests showed rupture levels of approximately 15 kg/cm<sup>2</sup> [Braile 1990]. The SBPC were implanted in numbers of 35, 30, 25, and 20 in 7, 17, 3, and 4 patients, respectively. The chordae length was determined based on the distance from the top of the papillary muscle to the edge of the leaflet in its original nonprolapsed position.

The mean cardiopulmonary bypass time and cross-clamping times were 99 minutes (range 69-179 minutes) and 57 minutes (27-119 minutes), respectively.

The implantation procedure began with anchoring of the prosthesis on the top end of the papillary muscle associated with the ruptured chordae, using 1 or more 5-0 polypropylene threads anchored in a Dacron pad. Subsequently, the other end was attached, using individual 5-0 polypropylene sutures, to the free edge of the affected leaflet. The prosthesis, with 5 standardized chordae, may be reduced to as few as 2 chordae, as required. Mitral annuloplasty was performed using a flexible bovine pericardium ring [Braile 1990] in 14 patients and with an open rigid ring in 17 [Gregori 1994]. Quadrangular resection of the posterior leaflet was performed in 7 patients (22.6%), sliding of the posterior leaflet in 4 (12.9%), shortening of elongated chordae in 6 (19.4%), sectioning of retractile chordae in 3 (9.7%), and enlargement of the posterior leaflet with bovine pericardium in 1 (3.2%) [Alvarez 1996]. Three patients underwent bypass grafting; grafting procedures included 1 atrial-septal defect closure and 3 tricuspid annuloplasty [De Vega 1973].

All patients underwent Doppler echocardiographic study postoperatively and during a mean follow-up of 6-35 months. Function of the mitral valve apparatus was analyzed by observing movement of the SBPC and the degree of mitral valve regurgitation.

Patient data were collected from their corresponding records, and written informed consent was signed by all patients prior to the surgical procedure.

## RESULTS

One patient (3.2%) died postoperatively from massive pulmonary embolism. Twenty-three patients (74.2%) were in New York Heart Association functional class I, 5 (16.1%) in class II, and 2 (6.5%) in class III (patients with low ejection fraction preoperatively). On clinical examination, absence of systolic murmur was observed in 20 patients (64.5%), mild systolic murmur in 6 (19.4%), and moderate systolic murmur in 4 (12.9%). Of the 6 patients with previous atrial fibrillation, 2 began to present junctional rhythm, and the remaining patients maintained sinus rhythm.

Doppler echocardiographic analysis disclosed absence of mitral regurgitation in 17 patients (54.8%), mild regurgitation in 9 (29.0%), and mild-to-moderate regurgitation in 4 (12.9%). Left ventricular function was preserved in 25 patients (80.6%) and with dysfunction in 5 (16.1%) (already existing preoperatively). Valve opening and leaflet mobility were satisfactory in all of the 30 surviving patients. No significant mitral transvalvular gradient was observed.

Anatomopathological examination of the patient who died disclosed a competent and nonstenotic mitral valve.

## DISCUSSION

In the mid-1950s, with technological advances in cardiovascular surgery, some surgeons started a surgical conservative approach to surgery of the mitral valve, using an annular plicature in patients with MI [Lilehei 1952; Kay 1978].

Later, studies by Carpentier, published in the 1970s, showed the short- and long-term superiority of reconstructive treatment of the valve apparatus compared to replacement by prostheses, encouraging an increasing number of surgeons to become interested in these techniques.

A recent metaanalysis of 29 published studies [Shuhaiber 2007] compared clinical outcomes of mitral valvuloplasty versus mitral valve replacement. The odds ratio for early mortality, comparing replacement with plasty, was 2.24 (1.78–2.80), indicating a worse prognosis in patients who underwent mitral valve replacement. Based on this evidence, the authors reported that mitral valvuloplasty is the treatment of choice and that surgeons are obliged to make efforts for mitral valve reconstruction.

Several techniques for mitral valve reconstruction were reported over the years. However, extensive knowledge of the anatomy and of alterations in the mitral valve apparatus are needed to use the appropriate technique.

The mitral valve comprises the mitral annulus, leaflets, chordae tendineae, papillary muscles, and left ventricle wall. The annulus has anterior and posterior portions. The anterior portion is anchored by the right and left fibrous trigones of the heart and faced by the aortic annulus, and the posterior portion is fibrous and supported by the free wall of the left ventricle. During left ventricular systole, the annulus contracts similarly to a sphincter and assumes a reniform appearance [Sarris 1988].

Elongation and rupture of the chordae tendineae are the complications most often found in fibroelastic degeneration. The surgical technique used for valve repair depends on the level of impairment and location of the injured chordae. The posterior leaflet is frequently the most affected. In our study the posterior leaflet was affected in 21 patients (67.7%), a rate similar to reported data [Pearson 1990].

Transference of chordae from the posterior leaflet to the anterior [Carpentier 1978] and partial transference of the tricuspid valve to the mitral valve [Gregori 1999] are some of the techniques employed. These techniques require manipulation of chordae with normal function and anatomy. A neo-chord with a patch of the anterior leaflet is an alternative that may be used, but this method is almost always indicated only for cases in which the mitral valve anterior leaflet has a well-developed area, as in fibroelastic degeneration and Barlow syndrome [Gregory 1988].

Synthetic and biological materials have been used for replacement of chordae tendineae. Polytetrafluorethylene (PTFE), advocated by David et al [David 1991], is the material most often used in patients with ruptured chordae. Another more recent study [Kobayashi 2000] using PTFE showed excellent results over 5 to 10 years, with reoperation not necessary in 93.3% and 81.7% of cases, respectively. However, the use of this technique requires an enormous



Figure 2. Measuring instruments ranging in length from 20 to 35 mm are used to confirm standardization of the chordae.

degree of subjectivity and is almost an individual skill. Dang et al, in 2005, described a more simplified method for use of multiple PTFE chordae [Dang 2005].

Frater et al were the first to employ bovine pericardium strips to replace chordae tendineae, with satisfactory initial outcomes [Frater 1983]. Their study was interrupted due to fear of calcification, however. This study compared 2 groups of patients. In one group PTFE was used and in the other bovine pericardium strips. It must be emphasized that the bovine pericardium strips were 4-mm wide and were not standardized with measuring instruments. The time of follow-up was longer in the group of patients with bovine pericardium, and in this group the level of calcification was not significant and therefore did not jeopardize late evolution.

Although calcification is a structural failure that is a matter of concern, much effort has been made to improve performance of bovine pericardium postimplantation, with the introduction of new chemical reagents. Currently, the bovine pericardium employed is fixed with glutaraldehyde and is widely used in cardiovascular surgery for biological prostheses and to occlude holes in congenital heart disease, in addition to reconstruction of right ventricular outflow tracts and closure of the left ventricle after resection of ventricular aneurysms. In mitral valve replacement with significant impairment of left ventricular function, bovine pericardium was used as chordae [Gomes 1990] to maintain the tension between the top of the papillary muscles and the mitral annulus. It has been proven that fixation with glutaraldehyde at 0.5% and anticalcification treatment with glutamic acid in alkaline pH improves the mechanical properties and minimizes calcification.

The prosthesis we describe is fashioned in a monobloc of bovine pericardium, treated with glutaraldehyde, in a diamond shape containing chordae joined at both extremities by 2 polyester-reinforced rods. Each 2-mm-wide chord, of which there are 5, is parallel, and chords are spaced at a distance of 3 mm from each other. Standardization of this prosthesis, which renders the procedure more feasible and rapid,

is achieved by objective analysis by means of special stainless steel measuring instruments in sizes ranging from 20 to 35 mm (Figure 2). Laboratory tests of the artificial chordae revealed a rupture level at 15 kg/cm<sup>2</sup>. It should be remembered that the tension to which the natural chordae tendineae are subjected in the left ventricle, with a systolic pressure of about 140 mm Hg, is approximately 0.5 kg/cm<sup>2</sup>, and as such is 30 times less than the rupture level.

Annuloplasty was performed in all patients and, whenever necessary, other techniques were also performed for a successful reconstruction of the valve apparatus.

No reoperation was necessary in our group, but we must emphasize that a longer follow-up period is required to confirm the effectiveness of the method.

Doppler echocardiography is an important diagnostic method. Diagnosis of MI due to rupture of chordae has been carried out since the time of mode M, which showed systolic echoes in the left atrium, systolic or diastolic vibrations of the mitral valve leaflets, and exaggerated and/or paradoxical movement of the posterior leaflet of the mitral valve. The advance of 2-dimensional Doppler echocardiography has enhanced diagnosis, allowing visualization of anomalous movement of the leaflet in the left atrium and consequent failure in coaptation of mitral valve leaflets. Doppler echocardiography helps the surgeon to elect preoperatively the best strategy for mitral valve preservation and furthermore is an excellent method to assess postoperative coaptation of the leaflets, degree of regurgitation and movement of the SBPC as well as the condition of the adjacent structures.

The satisfactory postoperative flexibility and coaptation of the leaflets observed in our patients was probably attributable to the significantly longer line of coaptation, once extensive leaflet resection was avoided. This fact was confirmed by Falk et al [2008] in a prospective randomized study comparing the use of PTFE neochordae with leaflet resection for posterior mitral valve prolapse. The benefit is more significant in patients with anterior leaflet prolapse; in such cases leaflet resection must be avoided.

## CONCLUSION

In this short period of postoperative assessment, the Doppler echocardiography has disclosed a significant decrease of mitral valve regurgitation with good coaptation and flexibility of the leaflets. A longer follow-up is required to assess absence of calcification and/or degeneration of the SBPC.

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