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Echocardiographic evaluation of patients submitted to replacement of ruptured chordae tendineae

Avaliação ecocardiográfica em pacientes submetidos à substituição de cordas tendíneas rotas

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Abstract

Objective: **The objective of this study was to evaluate, using echocardiography, the functioning of the mitral valve apparatus in patients submitted to standardized bovine pericardium chordae implantation to substitute ruptured chordae tendineae or elongated chordae with a significant degree of thinning.**

Method: **Standardized bovine pericardium chordae were implanted in 23 patients with mitral valve insufficiency due to ruptured or elongated chordae with significant thinning. The ages of the patients varied from 23 to 84 years old (mean 62 years old). The most common cause was fibroelastic degeneration affecting 20 (87.0%) patients. The standardized bovine pericardium chordae were manufactured in sets connected at both ends by two polyester-reinforced rods thereby forming a single block. The bovine pericardium chordae measure 2 mm wide with 3 mm between the chordae. The sets of bovine pericardium chordae are produced in lengths varying from 20 to 35 mm. In 17 (73.9%) patients bovine pericardium chordae were implanted in the posterior cusp and in 6 (26.1%) in the anterior cusp. All the patients were evaluated in the postoperative period by echocardiography after a mean follow-up of six months.**

Results: **The echocardiography in the postoperative period demonstrated an absence of reflux in 11 (47.8%) patients, slight reflux in 8 (34.8%) and slight to moderate reflux in 3 (13.0%). The opening and mobility of the mitral valve was normal in the 22 surviving patients.**

Conclusion: **The echocardiography demonstrated good functioning of the mitral valve apparatus in patients submitted to the implantation of standardized bovine pericardium chordae to substitute ruptured chordae**

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tendineae or elongated chordae with a significant degree of thinning.

Descriptors: **Regurgitation. Mitral valve insufficiency. Chordae tendineae, surgery. Prostheses and implants. Biocompatible materials.**

Resumo

Objetivo: **O objetivo deste estudo é avaliar, ao ecodopplercardiograma (ECO), o funcionamento do aparelho valvar mitral, em pacientes submetidos ao implante de cordas padronizadas de pericárdio bovino (CP de PB) para substituição de cordas tendíneas rotas ou alongadas com grau importante de afilamento.**

Método: **Foram implantadas CP de PB em 23 pacientes portadores de insuficiência mitral por ruptura das cordas tendíneas ou cordas alongadas com afilamento importante. A idade variou de 23 a 85 anos (média de 62 anos). A causa mais freqüente foi a degeneração fibroelástica em 20 (87,0%) pacientes. As CP de PB foram confeccionadas em conjunto, unidas em suas extremidades por duas hastes reforçadas com poliéster formando um monobloco. As CP de PB medem dois mm de largura e distam entre si, paralelamente, por três mm. Cada conjunto CP de PB possui um medidor correspondente, variando seu comprimento entre 20 a 35 mm. Em 17 (73,9%) pacientes foram implantadas as CP de PB na cúspide posterior e, em seis (26,1%), na cúspide anterior. Todos os pacientes foram avaliados no pós-operatório pelo ECO, com tempo médio de seguimento de até seis meses.**

Resultados: **O ECO no pós-operatório demonstrou ausência de refluxo em 11 (47,8%) pacientes, refluxo discreto em oito (34,8%) e refluxo discreto/ moderado em três (13,0%). A abertura e mobilidade da valva mitral eram normais nos 22 pacientes sobreviventes.**

Conclusão: **O ECO demonstrou boa funcionalidade do aparelho valvar mitral nos pacientes submetidos ao implante das CP de PB para substituição de cordas tendíneas rotas ou alongadas e afiladas com adequada coaptação das cúspides.**

Descritores: **Insuficiência da valva mitral, cirurgia. Valva mitral, cirurgia. Cordas tendinosas, cirurgia. Próteses e implantes. Materiais biocompatíveis.**

INTRODUCTION

Mitral valve insufficiency (MI), defined as the regurgitation of blood from the left ventricle to left atrium through the valve, is a situation, independent of etiology, that may cause left ventricular dysfunction, enlargement of the left atrium and atrial arrhythmias, which is more common in rheumatic disease and degeneration of fibroelastic tissue [1,2]. Mitral valve prolapse (MVP), identified by the redundancy of anterior and/or posterior cusps, dysfunction of papillary muscles or elongation or rupture of chordae tendineae, can evolve to MI. Mitral valvuloplasty is the first-line procedure for MI correction, with better results compared to prosthesis implantation [3].

Numerous techniques have been suggested for chordae tendineae rupture with the objective of substituting the ruptured chordae and preserving the valve. The transference of the posterior cusp chordae to the anterior cusp, partial transference from the tricuspid valve to the mitral valve, creation of neochordae with anterior cusp patches and implantation of synthetic or biological chordae, are some of the procedures employed [4-9]. Correction of anterior cusp prolapse is more difficult than posterior cusp prolapse and, in most cases there is a necessity to use associated techniques. Annuloplasty is a complementary technique necessary in the great majority of cases. The technique used in our study is similar to partial transference of chordae tendineae from the tricuspid valve to the mitral valve, substituting ruptured chordae using bovine pericardium treated in 0.5% glutaraldehyde, which is a material widely used in cardiovascular surgery, making this procedure very familiar.

The objective of the current study was to evaluate mitral valve apparatus function using Doppler echocardiography in patients submitted to the implantation of standardized bovine pericardium chordae (SBPC) to substitute ruptured or elongated chordae tendineae with a high degree of thinning.

METHOD

This was a prospective, case series study. Between May 2005 and April 2007, 23 patients, with a diagnosis of significant MI due to ruptured or elongated chordae tendineae with significant thinning, were submitted to substitution of the chordae tendineae using standardized bovine pericardium chordae. Thirteen (56.5%) patients were male and 10 (43.5%) female. The ages varied from 23 to 85 years with a mean of 62 years. The most frequent cause was degeneration of fibroelastic tissue in twenty (87.0%) patients, followed by ischemia in two (8.7%) and Barlow's syndrome in one (4.3%). In the preoperative period, five

(21.7%) patients were in functional class II, 12 (52.2%) in functional class III and six (26.1%) in functional class IV (NYHA). Atrial fibrillation (AF) was present in six (26.1%) of the patients.

Doppler echocardiography evaluation in the preoperative period showed significant regurgitation in all cases, with the left ventricular function preserved in 18 (78.9%) and impaired in five (21.7%) – Figures 1 and 2.

The degree of regurgitation was considered slight when less than 20%, moderate between 20 and 40% and significant when greater than 40%. Rupture or elongation with a high degree of thinning of chordae tendineae of the anterior cusp was identified in six (26.1%) patients and in the posterior cusp in 17 (73.9%) patients. Posterior dilatation of the mitral ring occurred in all patients.

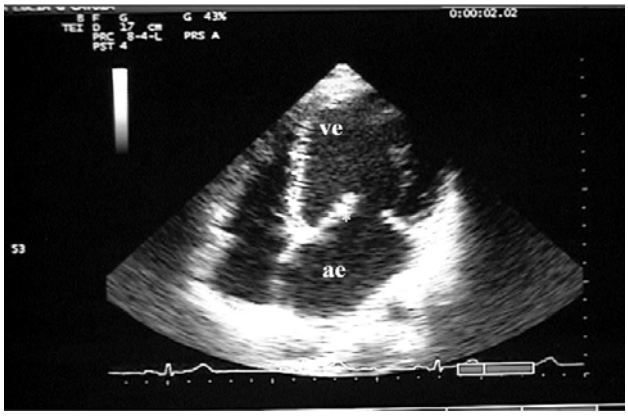

Fig. 1 – Four-chamber bidimensional apical view showing a significant increase in the left chambers and rupture of the primary chordae tendineae at the end of the anterior cusp of the mitral valve (asterisk)

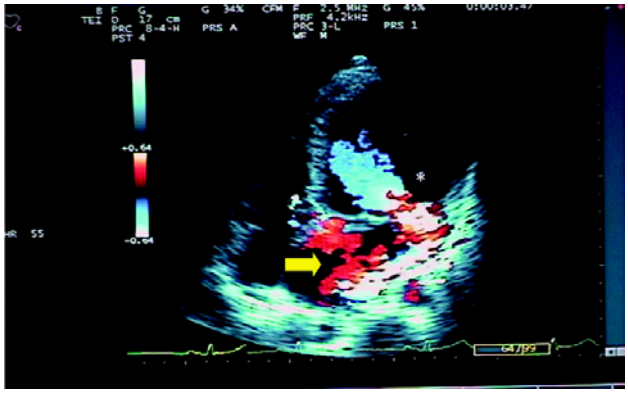

Fig. 2 – The same view with color-flow mapping showing a significant mitral valve regurgitation jet with the Coanda effect (arrow), regurgitant volume of 260 mL and vena contracta of 1.1 cm originating from the rupture site (asterisk)

SBPC are manufactured in a single block joined at the ends by two polyester-reinforced rods. The bovine pericardium chordae measured 2 mm wide with a 3-mm gap between chordae (Figure 3). Chordae standardization was confirmed using measurers of between 20 and 35 mm (Figure 4). The bovine pericardia were treated in 0.5% glutaraldehyde, submitted to anticalcifying treatment using glutamic acid and conserved in 4% formaldehyde. Routine resistance and durability tests demonstrated a mean rupture force of about 15 kg/cm2 [10,11]. SBPC Nº 35, 30, 25 and 20 were implanted in 7, 12, 1 and 3 patients, respectively.

Fig. 3 – Standardized bovine pericardium chordae

Fig. 4 – Prosthesis measurers

Implantation initiates with anchoring of the prosthesis utilizing a Dacron pad on top of the papillary muscle associated to the ruptured chordae, using one or more 5-0polypropylene threads. Subsequently, the other end is anchored using individual 5-0 polypropylene sutures to the free edge of the involved cusp. The prosthesis, with five standardized chordae may be reduced to as few as two chordae, depending on requirements. Mitral annuloplasty was achieved using a flexible Braile-type bovine pericardium ring in 11 patients and a Gregori-Braile ring in 12 [12,13]. Quadrangular resection of the posterior cusp was attained in six (26.1%) patients, sliding of the posterior leaflet in four (17.4%), shortening of chordae in six (26.1%), sectioning of retractile chordae in two (8.7%) and enlargement of the posterior cusp using bovine pericardium in one (4.3%) [14]. Three patients were submitted to myocardial revascularization, one to closing of an interatrial communication and two to De Veja-type tricuspid annuloplasty [15].

All patients were submitted to Doppler echocardiography in the postoperative period and at, on average, six months follow-up. The functioning of the mitral valve was analyzed in respect to the movements of the SBPC and the degree of mitral valve regurgitation.

Patients' data were collected from respective patients' records and written consent was given before performing the surgery.

RESULTS

One patient (4.3%) died in the postoperative period with massive pulmonary embolism. Fifteen (65.2%) patients are in functional class I, five (21.3%) in functional class II and two (8.7%) in functional class III (patients with less ejection fraction in the pre-operative period). Among the patients who had suffered atrial fibrillation, two have junctional rhythm and the others maintain sinus rhythm.

Analyses of Doppler echocardiography in the postoperative period demonstrated that there was no mitral regurgitation in 11 (47.8%) patients, slight regurgitation in eight (34.8%) and slight to moderate in three (13.0%). The left ventricular function was preserved in 17 (73.9%) patients but there was dysfunction in five (21.7%) – this was pre-existent in the preoperative period. The valve opening and cusp mobility were good for all 22 surviving patients. No significant mitral valve gradient was observed in any of the patients (Figures 5 & 6).

DISCUSSION

In the middle of the 1950s, with the technological developments in cardiovascular surgery, some surgeons started using a conservative approach to the valve apparatus with annular plicature in patients with mitral valve insufficiency [16,17].

Later, the studies of Carpentier, published in the 1970s, showed the short- and long-term superiority of conservative treatment in reconstruction or repair of the valve apparatus compared to replacement using prostheses, with a greater number of cardiovascular surgeons becoming interested in these techniques [4].

Recently, a metanalysis of 29 studies was published comparing the clinical outcomes of valvuloplasty versus mitral valve replacement. The odds ratio for early mortality, comparing replacement with valvuloplasty, was 2.24 (1.78-2.80), indicating a worse prognosis for patients submitted

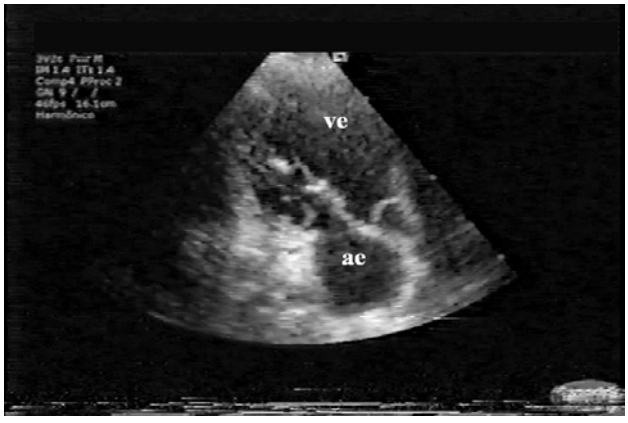

Fig. 5 - Four-chamber bidimensional apical view showing the implanted bovine pericardium chordae (asterisk)

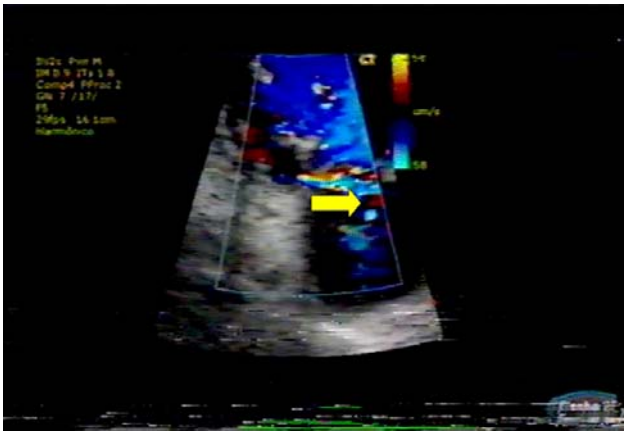

Fig. 6 - The same view with color-flow mapping illustrating the disappearance mitral valve regurgitation jet and showing points of residual regurgitation (arrows)

to mitral valve replacement. Based on these data, the authors believe that valvuloplasty should be the first-line treatment for mitral valve lesions, obliging surgeons to endeavor to achieve mitral valve reconstruction. Several techniques were demonstrated and published over the years, however, knowledge of the anatomy and of mitral valve alterations are essential to choose the best technique [18].

The mitral valve apparatus is formed from a mitral ring, cusps, chordae tendineae, papillary muscles and left ventricular wall. The ring has an anterior portion and a posterior portion. The anterior portion is fixed by the right and left fibrous trigones and the posterior portion is fibrous and supported by the free wall of the left ventricle. During left ventricular systole, the ring contracts similar to a sphincter and takes on a reniform shape [19].

The main anatomopathological alterations of the mitral valve are due to rheumatic disease or degeneration of the fibroelastic tissue, affecting the functioning of the mitral valve, leading to ring dilatation. The cusp may be retracted or redundant and the chordae tendineae may be retracted, elongated or ruptured. Commissural fusion, with or without calcification, may be associated in some cases [20].

Elongation and rupture of chordae tendineae are the most common complications in degeneration of the fibroelastic tissue and the operative technique to correct the valve depend on the degree of involvement and location of the injured chordae. The posterior cusp is frequently the most affected with studies showing involvement in up to 83% of cases. In our study, the posterior cusp was affected in 17 (73.9%) patients, which is similar to the published results [21].

Transference of chordae from the posterior to the anterior cusp and partial transfer of the tricuspid to the mitral valve are two of the techniques used. Even though these techniques are employed throughout the world, they are situations that demand translocation of chordae and, thus, there is a necessity to manipulate the chordae with normal function and anatomy. The creation of neochordae to replace chordae allows improvements in the reconstruction of the mitral valve apparatus. Neochordae using anterior cusp patches is an alternative that can be used. However, this is an indication almost exclusively for cases with the anterior cusp of the mitral valve with a well-developed area, as in degeneration of the fibroelastic tissue and in Barlow's syndrome [4-7].

Synthetic and biological materials have been used to substitute chordae tendineae. Polytetrafluoroethylene (PTFE), recommended by David et al. [8] in 1991, is the most commonly utilized material in patients with ruptured chordae. Another more recent study on PTFE showed excellent results over five and ten years with re-operation rates of 94.3% and 81.7%, respectively [22]. However, the use of this technique needs a great deal of subjectivity and is thus almost a craft.

Frater et al. [9], in 1983, were the first to use bovine pericardium strips to substitute chordae tendineae, with satisfactory initial results. However, the study was interrupted due to fear of calcification. This study compared two groups of patients; one group used PTFE and the other, bovine pericardium strips, however the follow-up period was longer in the Bovine Pericardium Group. It is also important to stress that the bovine pericardium strips were wide (4-mm) and were not standardized using measurers. Although the follow-up time was longer for the patients in the Bovine Pericardium Group, the level of calcification was not significant, and so, not affecting the long-term evolution.

Although calcification is a worrying structural failure, over the last 40 years much effort had been made to improve the performance of post-implantation bovine pericardium using new chemical agents. Nowadays, the bovine pericardium in use is, generally, fixed in glutaraldehyde and is being used extensively in cardiovascular surgery to manufacture biological prostheses, to occlude orifices in congenital heart diseases, as well as in the reconstruction of right ventricle outflow tracts and closing the left ventricle after resection of ventricular aneurysms, with low rates of rupture and calcification over 12 and 15 years. It has been demonstrated that fixing bovine pericardium in 0.5% glutaraldehyde and anti-calcification treatment using glutamic acid at pHs greater than 7 improves the mechanical proprieties and decreases calcification [10,23].

Based on these studies, we designed a prosthesis manufactured as a single block of bovine pericardium in a diamond shape treated in glutaraldehyde, with the chordae joined by two polyester-reinforced rods at the ends. Each set of five, 2-mm-wide, parallel chordae are separated by a gap of three millimeters. The standardization of this prosthesis makes the procedure more viable and faster, obtaining an objective analysis with the use of special stainless steel measurers with sizes varying between 20 and 35 mm. Tests of the artificial chordae showed a rupture force of 15 kg/cm2. We should remember that the tension to which natural chordae tendineae are submitted in the left ventricle, with a systolic pressure at around 140 mmHg, is approximately 0.5 kg/cm2, that is, 30 times less.

Dilatation of the mitral valve posterior ring is the most common alteration of mitral valve insufficiency; the posterior ring moves away from the anterior, increasing the anteroposterior diameters with more intensity on the right. We achieved annuloplasty in all patients and, when necessary, other techniques were associated so that the valve apparatus was successfully reconstructed.

Doppler echocardiography is an important diagnostic method. Diagnosis of MI due to ruptured chordae has been

carry 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. With progress, the bidimensional Doppler echocardiography improved diagnosis, allowing visualization of anomalous movement of the leaflet inside of left atrium and consequent failure of mitral valve coaptation [24,25]. Doppler echocardiography helps the surgeon to determine in the preoperative period the best strategy to preserve the mitral valve and it is also an excellent method to evaluate, in the postoperative period, cusp coaptation, the degree of regurgitation, movements of the SBPC and the conditions of adjacent structures.

CONCLUSION

The Doppler echocardiography evaluation, in the postoperative period, showed a reduction in mitral valve regurgitation, as well as coaptation of the cusps as well as showing that the SBPC were well anchored and flexible.

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COMMENTS

The main goals of the mitral valve repair are to reach a good coaptation surface; correct the leaflet abnormal mobility; and reestablish the shape as well as to stabilize the annulus of mitral valve. It seems that in this carefully and courageous study, the author and co-workers pursued such goals.

Professor João Carlos Leal and his colleagues are writing to point out the possibility to make the mitral valve repair a little more feasible amidst the cardiac surgeons.

In spite of the majority of the standard cords to have been implanted in the posterior cusp, this set of cords appears to be a good alternative to correct the prolapse of the anterior cusp. Even because some data support the idea that the repair of the anterior cusp is more challenging and does not provide as good results as the long-term repair of the posterior cusp.

Keeping up to date with the available techniques to correct the elongated cords and the rupture, the shortening has increasingly been ruled out, while the replacement of the tendinous cords and the repositioning of the papillary muscle have increased in the mitral valve repair.

Special attention should be given to the study of the anatomical references to choose the ideal length of the cord set. Patrick Perier suggest the plan of an implanted annulus to perform the annuloplasty as a reference just in case of abnormality in opposed and adjoining segments. In cases of normal opposed segment it is its height, which is suggested as a point of comparison.

Particularly, we have used Professor Gilles Dreyfus's recommendation; "Always analyze P1 height", once it is used to present normal. The purpose is to bring back to reference-point level of the free margin of the prolapsed area.

It seems right that the 2mm-prolapsed cusp may be corrected with annuloplasty through implantation of a prosthetic annulus, thus, reducing the mitral-aortic angle and bringing together the free margin of the anterior cusp of mitral valve downward. Thus, we must be aware to measure the height only after the annulus has been implanted.

The transference of the tendinous cords é an excellent method; nevertheless it may be limited by the number of tendinous cods available to treat an extensive area of the prolapsed cusp. Therefore, I see the alternative proposed by the São José do Rio Preto group as a good tool to when we come up to such a prolapse.

The shortening of the tendinous cord is not a direct method to reduce the elongated cords because the shortening effectiveness represents half of the length plunged into the cleft created in the papillary muscle. Eventually, the shortening of the tendinous cord requires experience in the mitral valve repair area. On the contrary, the replacement of the tendinous cords is directly related to the repositioning and the location inside the ventricular cavity which presents equal relation to length of the prolapse to be corrected. In this way, we believe that the technique presented by the author can be easy and safe. Besides, the shortening of the tendinous cord requires a great deal of precautions to avoid other sutures to get in touch with the manipulated cords, considering it can lead to rupture as times goes by.

Probably, due to this technical detail, some researchers, such as Gillinov, have reported the incompetence of the mitral valve repair using the shortening of the cords technique increasing the failure in the degenerative disease.

The failure rate makes imperative the need of research in alternative techniques. It seems that the replacement of the tendinous cords in block does not require a long learning

curve. This technique is fast and time-saving to perform other maneuvers.

The echocardiographic follow-up of the coaptation height should be seen as a starting point in a study where the stability and the durability of a new technique are being observed. Berrebi suggests 8 mm as an ideal height to leaflet coaptation. We followed this guidance, and we have recommended to the authors the inclusion of this datum in the echocardiographic follow-up. Thus, they can state with greater background knowledge, the good coaptation attained in the controls.

The studies of a series of cases are descriptive and, in these studies, the objective is the pure description of the facts. This is essential to the progress of medical knowledge, even presenting limitations such as not providing reliable information to compare both treatments. Information as therapeutics should be seen as a first link of the chain of evidences to be achieved rather than a definitive opinion.

Congratulations on your initiative and creativity.

Olívio Souza Neto

Author's answer

First of all, I would like to thanks Professor Olívio Souza Neto for his comments regarding our working group. Indeed, the repair of the prolapse of anterior cusp of mitral valve is a major challenge to the surgeon. However, Carpentier and Gregori Jr showed convincing outcomes with the techniques of tendinous cords translocations to the anterior cusp of mitral valve. The evidences of a better diagnosis of the mitral valve repair concerning implantable prostheses were presented in a metaanalysis published on Eur. J. Cardiothorac Surg. 2007. This comes to further strengthen the necessity to repair and preserve the mitral valve apparatus, even when there have been ruptures of the tendinous cords of the anterior cusp of the mitral valve. In our article, similarly to the literature, it was observed a bovine pericardium neocorda implant in the anterior cusp of mitral valve in only 26.1% of the cases.

Concerning to the size of the bovine pericardium neocorda to be implanted, we use standardized measures ranging from 20 to 35 mm. This standardization makes easy to analyze the ideal size of the neocorda. Also, we have associated the P1 height as recommended by Professor Dreyfus. We understand that the annuloplasty is a procedure that should be performed in each and every case to achieve an ideal coaptation of the cusps as demonstrated by the echodopplercardiogram in the patients' follow-up.

The neocorda implantation in the mitral valve apparatus is a well-known procedure in several cardiovascular surgery services. However, the objective of our study is to demonstrate a new alternative strategy to neocorda implant using bovine pericardium and standardized measures, making the mitral valve repair more feasible to the cardiovascular surgeon. As to the functionality, the bovine pericardium and the standardized measures have presented good fastening and flexibility as demonstrated by echodopplercardiogram.

Finally, on behalf of the entire staff, we would like to thank, particularly to Mr. Gregori Jr, MD, who did not spare himself to help when he was asked to. Also, I want to thank him for his highly efficient comments, which have added a new dimension to our article.

Thank you very much.

João Carlos Leal