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Papillary muscle repositioning: the gold standard technique to repair anterior mitral leaflet prolapse

Reposicionamento do músculo papilar: a técnica padrão para plastia do prolapso da cúspide anterior da mitral

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Abstract

Objective: **The aim of this study was to demonstrate that papillary muscle repositioning is a reliable technique to repair anterior leaflet prolapse. Therefore we describe this technique and its long term results to propose it as a gold standard.**

Methods: **Between 1989 and 2005, 120 mitral valve repairs were consecutively performed using papillary muscle repositioning in cases of anterior leaflet prolapse. There were 87 males and 33 females, the mean age was 59 ± 11.5 years. 59% of patients were in NYHA III or IV. Mean ejection fraction was 65.7 ± 8.9%. Predominant aetiology of mitral regurgitation (MR) was degenerative: Barlow (n=43) and dystrophic (n=62). The other aetiologies were: healed endocarditis (n=5), rheumatic (n=5), ischemic (n=4), congenital (n=1). A posterior papillary muscle repositioning was performed in 111 (92.5%) cases and an anterior in 38 (31.7%). Associated procedures were carried out in 76 (63.3%) patients.**

Results: **There were no in-hospital deaths. During the follow-up, 14 patients (11.7%) died, including 7 (5.8%) due to cardiac causes. The cumulated survival rates at 1, 5, 10 and 15 years were 98.3%, 97.2%, 94.1% and 81.4% respectively. Two patients (1.7%) were reoperated for recurrency of the regurgitation, they underwent a replacement of the valve 1 and 5 years after the repair and died 3 and 6 years, respectively after this replacement. There was no systolic anterior motion. The cumulated survival rates free from reoperation involving the mitral valve at 1, 5, 10 and 15 years were 97.4%, 97.4%, 92.8 % and 86.7% respectively. We did not find any risk factor of mortality or of reoperation. The follow-up was completed for all the patients. After a median follow-up time of 5.9 years (range from 0.1 to 15.6 years) 87 patients were in NYHA class I (72.5%), the echocardiographic control showed no or minimal insufficiency in 89 patients (74.2%), mild insufficiency in 8 patients (6.7%) and moderate insufficiency in 9 patients (7.5%).**

Conclusions: **Papillary muscle repositioning is a reliable and safe technique, with excellent clinical and echocardiographic long term results. Therefore we propose it as a gold standard to repair anterior leaflet prolapse.**

Descriptors: **Mitral valve repair, Anterior leaflet prolapse, Papillary muscle.**

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Resumo

Objetivo: **O propósito deste estudo é demonstrar que o reposicionamento do músculo papilar é uma técnica confiável para o reparo do prolapso da cúspide anterior, portanto, nós descrevemos esta técnica e seus resultados propondo-a como padrão.**

Método: **Entre 1989 e 2005, 120 plastias da valva mitral foram consecutivamente realizadas por meio do reposicionamento do músculo papilar no prolapso da cúspide anterior. Oitenta e sete pacientes eram do sexo masculino e 33 do feminino, sendo, a média de idade de 59 ± 11,5 anos. Cinqüenta e nove por cento dos pacientes estavam em classe funcional (NYHA) III ou IV, a média da fração de ejeção foi 65,7 ± 8,9%. A etiologia predominante na regurgitação da valva mitral (RM) foi doença degenerativa: Barlow (n=43) e distrofia (n=62). As outras etiologias eram: endocardite cicatrizada (n=5), reumática (n=5), isquêmica (n=4), congênita (n=1). O reposicionamento do músculo papilar posterior foi realizado em 111 (92,5%) casos e do anterior em 38 (31,7%). Procedimentos associados foram realizados em 76 (63,3%) pacientes.**

Resultados: **Não houve óbito hospitalar. Durante o acompanhamento, 14 (11,7%) pacientes foram a óbito, incluindo sete (5,8%) por causas cardíacas. As taxas da curva de sobrevida acumulada em 1, 5, 10 e 15 anos foram 98,3%, 97,2%, 94,1% e 81,4%, respectivamente. Dois (1,7%) pacientes foram reoperados por regurgitação recorrente, eles foram submetidos à troca da valva 1 e 5 anos depois do reparo e morreram 3 e 6 anos após esta troca valvar. Não houve movimento anterior sistólico. As taxas de sobrevida acumulada livre de reoperação envolvendo a valva mitral em 1, 5, 10, e 15 anos foram 97,4%, 97,4%, 92,8% e 86,7%, respectivamente. Nós não achamos nenhum fator de risco de mortalidade e de reoperação. O acompanhamento completo foi realizado em todos os pacientes. Após um tempo de acompanhamento mediano de 5,9 anos (de 0,1 a 15,6 anos), 87 (72,5%) pacientes estavam na classe I - NYHA, o controle ecocardiográfico mostrou nenhuma ou mínima regurgitação em 89 (74,2 %) pacientes, leve regurgitação em oito (6,7%) e moderada regurgitação em nove (7,5%).**

Conclusão: **O reposicionamento do músculo papilar é uma técnica confiável e segura, com excelentes resultados clínicos e ecocardiográficos a longo prazo. Desta maneira, estamos propondo-a como padrão para o reparo da cúspide anterior prolapsada.**

Descritores: **Prolapso das valvas cardíacas. Insuficiência da valva mitral, cirurgia. Valva mitral, cirurgia.**

INTRODUCTION

Mitral valve repair is the gold standard technique for the treatment of regurgitation [1,2]. No matter what type of injury, Carpentier clearly demonstrated that mitral valvar repair is lasting and offers the best therapeutic option in respect to left ventricle recovery and to the quality of life. Quadrangular resection is a surgical technique established for the repair of prolapsed posterior leaflets (PL) [1]. Some data still support the concept that anterior leaflet (AL) repair is more challenging and does not offer as good long-term results as PL repair. AL prolapse can be treated using different techniques: shortening of the chordae tendineae [1] when they are elongated, transference of chordae tendineae in the case of ruptured chordae and chordae replacement [7]. The fact is that chordae shortening has become progressively less used while replacement has increased in mitral valve repair. These two techniques, used by many surgeons, present questionable limitations and results [8,9]. In our experience, we repair anterior leaflet prolapse with a reproducible and safe technique: papillary muscle repositioning (PMR) [10,11]. The aim of this study was to describe the technique and the results and to recommend this technique as the standard procedure.

METHOD

Population and mitral valve characteristics

Analysis included 120 consecutive patients who were submitted to PMR for AL prolapse between 1989 and 2005. Eighty-seven of the patients were male and 33 female with a mean age of 59.1 ± 11.5 years. Twenty-one (18%) patients were in functional Class I (New York Heart Association); 28 (23%) in Class II; 55 (46%) in Class III and l5 (13%) in Class IV. The preoperative clinical data are presented in Table 1 while the echocardiographic data are shown in Table 2. Thirty-seven (30.8%) patients were found to have significant tricuspid regurgitation. Degenerative diseases were the predominant etiology: Barlow (n=43) and dystrophy (n= 62). Other etiologies included mitral valve regurgitation (MR) after endocarditis (n=5), rheumatic disease (n=5), ischemia (n= 4) and congenital disease (n=1). Associated procedures were performed in 76 (63.3%) patients: 57 (47.5%) tricuspid annuloplasties, 11 (9.2%) coronary artery bypass grafting surgeries, four (3.3%) aortic valve replacements, two (1.7%) maze surgeries, an aortic valve repair and a Yacoub surgery. The indications for surgery were severe mitral regurgitation and alterations to the final left ventricle systolic diameter, with or without involvement of the function.

Table 1. Preoperative clinical data

	N	%
Myocardial infarction	5	4.2
Stroke	3	2.5
Acute rheumatic failure	5	4.2
Chronic renal insufficiency	5	4.2
Respiratory insufficiency	4	3.3
Prior heart surgery	3	2.5
Diabetes	9	7.5
Atrial fibrillation	32	26.7

Table 2. Preoperative echocardiographic data

	Median ± standard deviation
Mitral regurgitation	3.6 ± 0.4
LVFSD (mm)	39.4 ± 5.2
LVFDD (mm)	62.8 ± 4.8
Size of the LA (mm)	49.4 ± 11
PAP, systolic (mmHg)	47.9 ± 12.9
EF (%)	65.7 ± 8.9

DSFVE: Left ventricle final systolic volume; DDFVE: Left ventricle final diastolic volume; LA: Left atrium; PAP: Pulmonary artery pressure; EF: Ejection fraction.

Anatomical considerations

The anterior papillary muscle normally has two components: anterior and posterior. On the other hand, the posterior papillary muscle normally has three components: anterior, intermediate and posterior (Figure 1). Chordae tendineae emerging from the anterior head are anchored to the anterior leaflet; chordae tendineae emerging from the intermediate head are anchored in the commissural regions and those that originate from the posterior head go to the posterior leaflet. The anterior head is always higher than the posterior. The separation of the anterior head from the intermediate and from the ventricular wall allows movement of the muscle in any direction, especially to a position below the ventricular chamber, if necessary. However, the entire elongated bundle emerging from the anterior head can be repositioned with the head of the papillary muscle being directed downwards, thereby correcting the prolapse. In relation to the vascularization of the papillary muscle, the separation must be vertical.

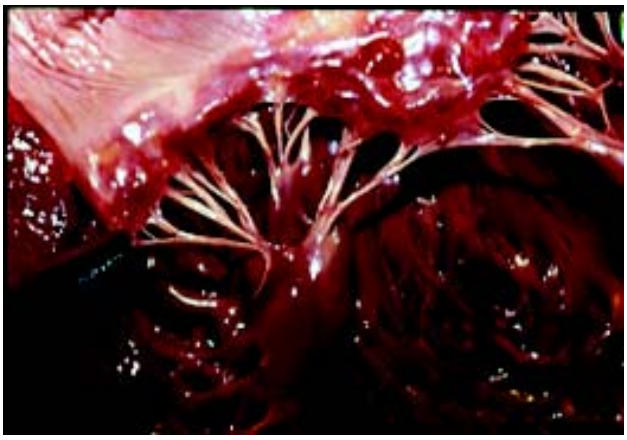

Fig. 1 - Papillary muscle anatomy. The three heads can be identified: anterior, intermediate and posterior

Operative technique

The surgeries were performed at normothermia; myocardial protection was established with cold crystalloid solution until 1993 and cold sanguineous cardioplegia after this date. Table 3 summarizes the injuries of the mitral valve found in the systematic intraoperative evaluation of all segments. When the prolapse involved the posterior region of the AL (A2/A3) posterior PMR was performed and when the anterior region (A1/A2) was involved, anterior PMR was performed. Much care was taken during chordal distribution to select the correct chordae tendineae. The associated repair techniques were those described by Carpentier [1].

Table 3. Lesions observed in the intra-operative period

Specific lesions	N
Prolapse of the Anterior Leaflet	120
Prolapse of the Posterior Leaflet	97
Prolapse of the Anterior Commissure	3
Prolapse of the Posterior Commissure	16
Rupture of the chordae tendineae	53
Restriction of the Posterior leaflet	7
Annular Dilatation	112
Annular Calcification	18

l) Posterior PMR was performed using the following procedures: in the first step, the anterior head was completely separated from the intermediate head. On some occasions, adhesions on the left ventricle wall were also resected (Figure 2). A 'U-shape' suture was then performed at the upper end of the head together to the fibrous part. The appropriate shortening was achieved pulling the anterior head downwards. The significance of the prolapse was precisely determined using two hooks: one hook pulled the

prolapsed free edge of the anterior leaflet; the other pulled the free edge of the posterior leaflet adjacent to the anterior leaflet. This procedure gives us the exact height of the prolapse. Consequently, the displacement of the papillary muscle equals the previously measured size of the prolapse. The suture previously fixed to the anterior head was anchored to the fibrous tissue of the posterior head or even deeper inside the muscle of the posterior head, if necessary (Figure 3). In some cases, a strip of autologous pericardial was used with the suture and pledge. The correct site was determined by the height of the prolapse.

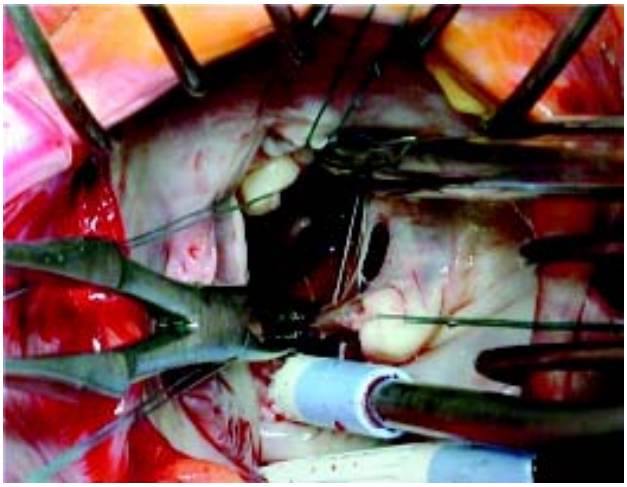

Fig. 2 - Surgical technique of repositioning the papillary muscle. Identifying and separating the papillary muscle heads

Fig. 3 - Surgical technique of papillary muscle repositioning. The 'U-shape' suture is sutured in the fibrous segment of the anterior head and anchored to the posterior head

2) The anterior PMR was performed as follows: The anterior head of the papillary muscle, composed of chordae tendineae that go to A1/A2 was identified and separated from the posterior head. Then, a 'U-shaped' suture was performed at the highest fibrotic end of the anterior head. The suture was anchored downwards, in the posterior head of the papillary muscle, carrying the free edge of A1/A2 towards the ventricle wall.

With the exception of three patients, all received Carpentier Edwards rigid ring prosthesis. The correct measurements of the sizes of the rings were performed in the conventional way. The surface of the ring must be at least similar to the surface of the anterior leaflet [1]. The distance between the anterior and posterior commissures must also be respected. The fibrous trigone can not be plicated. The mean size of the mitral ring was 32.4 ± 1.5 mm. Most of the rings were 32 mm and no patients received rings smaller than 28 mm. A combination of different techniques was necessary in some cases. Table 4 summarizes all the techniques used in this series of patients. Patients with coronary diseases had the distal, as well as the proximal anastomoses, performed after valve repair. When necessary, correction of the aortic and tricuspid valves was performed after the repair of the mitral valve. Tricuspid annuloplasty was only performed when the diameter of the ring was greater than twice the normal size (= 70 mm) irrespective of the degree of regurgitation [12]. The mean size of the tricuspid ring was 33.5 ± 0.8. The mean time of aortic clamping and cardiopulmonary bypass were 98.2 ± 22.7 min and 124 ± 27.7 min, respectively.

Table 4. Surgical procedures

Anterior leaflet		Posterior leaflet	
RPPM	111	Quadrangular resection	85
RAPM	38	Sliding plasty	59
Leaflet resection	17	Preservation of the posterior leaflet	8
Shortening of the posterior chordae tendineae	4	Substitution of chordae tendineae	6
Shortening of the anterior chordae tendineae	35	Mobilization of the leaflet	1
Transference of the chordae tendineae	13	Pericardial patch	2
Substitution of chordae tendineae	3	annular decalcification	16
Sliding plasty	14	Annuloplasty with ring	117
Pericardial patch	2		

RAPM: Repositioning of the anterior papillary muscle; RPPM: Repositioning of the posterior papillary muscle

Follow-up and description of the data

Intraoperative transesophageal echocardiographic examinations were performed with all patients. Clinical and echocardiographic examinations were performed for all

patients before being discharged from hospital, 1 month after the surgery and annually. In the echocardiogram, the mitral regurgitation was classified as 1 to 4. The mean time of follow-up was 6.3 ± 0.4 years, the median time of follow-up was 5.9 years (from 0.1 to 15.6 years). Our study complied with all the ethical norms in force in the United Kingdom.

Statistical analysis

Descriptions of continuous variables are expressed as means ± standard deviations or means with the highest and lowest values. Variable categories were presented as absolute numbers of patients and percentages. The statistical significance of comparison between two or several groups was achieved using the Log Rank test. Survival was calculated using the Kaplan Meier method. P-values of less than 0.05 were considered statistically significant. The analyses were performed using SPSS software (version 11.5.1, SPSS Inc).

RESULTS

Immediate results

Postoperative mortality and morbidity

There were no in-hospital deaths. Eight patients (6.5%) needed reoperations during hospitalization: seven pericardial drains for hemopericardium and a reoperation for mediastinitis. One patient suffered from a stroke. No cases of systolic anterior movement of the anterior valve, of hemolysis or infectious endocarditis were identified. There was no failure of the mitral valve nor reoperations for valve incompetence.

Postoperative echocardiographic results

The transthoracic echocardiogram at hospital discharge showed that there was no insufficiency in 98 (81.7%) patients, minimal regurgitation in eight (6.5%) patients and slight regurgitation in 12 (10%). The mean mitral regurgitation was 0.16 ± 0.16 and the mean diastolic pressure gradient across the mitral valve was 3.39 ± 1.15 mmHg.

Conduction and postoperative rhythm

Ten (8.3%) patients had total atrioventricular blocks requiring definitive pacemaker implantation. Eighty (66.5%) patients had sinus rhythm, 30 (25%) atrial fibrillation, four (3.5%) junctional rhythm and six (5%) patients had ventricular rhythm.

Long-term results

Eighty-seven patients are in the NYHA Functional Class I (72.5%), 15 patients in Class II (12.5%) and three patients in Class III (2.5%). During the transthoracic echocardiography follow-up, 89 patients (74.2%) did not have insufficiency or had minimal insufficiency. Eight patients (6.7%) presented with slight insufficiency while nine (7.5%) had moderate insufficiency. There were 14 late deaths (11.7%), including seven (5.8%) due to heart disease. Considering only the deaths due to heart disease, the accumulated survival rates at 1, 5, 10 and 15 years were 98.3%, 97.2%, 94.1% and 81.4%, respectively (Figure 4). The causes of deaths linked to the heart were: heart failure (four), pulmonary embolism (one), pulmonary edema (one) and cerebral hemorrhage after mitral valve replacement (one). The other cases of deaths were: strokes (four), septicemia (one), mesenteric infarction (one) and pneumonia (one). Reoperation was necessary for two patients (1.7%) to replace the mitral valve due to failure of the repair 1 and 5 years after the initial procedure. These two patients died three and 6 years after valve replacement. The accumulated survival rates free of reoperation involving the mitral valve

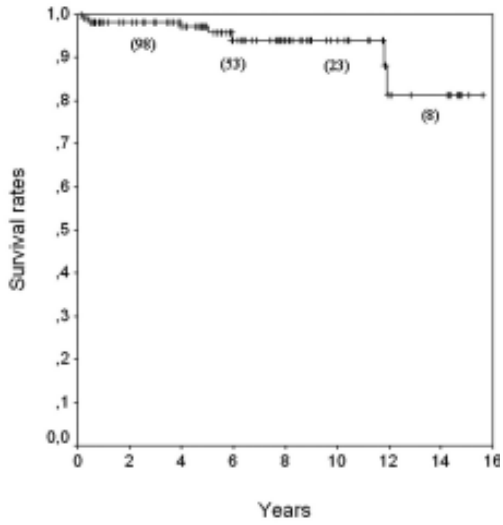

Fig. 4 - Actuarial survival curve including only deaths due to heart disease. ( ) Subjects at risk

over 1, 5, 10 and 15 years are 97.4%, 97.4%, 92.8% and 86.7%, respectively (Figure 5). Age (p-value = 0.14), gender (p-value = 0.43), diabetes (p-value = 0.63), chronic renal insufficiency (p-value = 0.59), etiology (dystrophy or Barlow) (p-value = 0.45), prolapse of the associated FP (p=0.10), previous rhythm (p=0.06), concomitant surgical procedures (p=0.87) were not statistically predictive factors for death. Thus, prolapse of the associated PL (p=0.51), posterior commissural prolapse (p=0.66), anterior commissural prolapse (p=0.92), annular decalcification (p=0.59), chordae tendineae replacement (p=0.79) are predictive factors for reoperation.

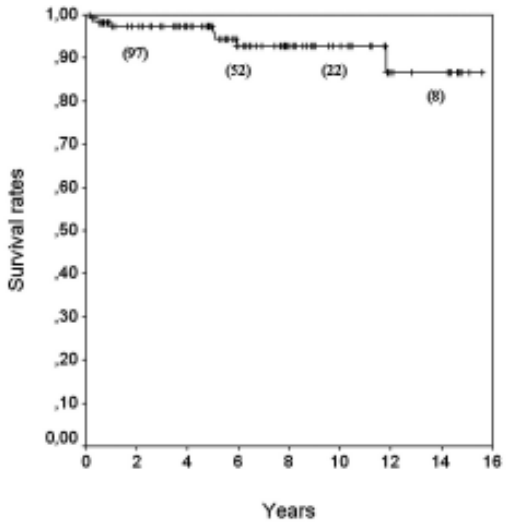

Fig. 5 - Actuarial survival curve free of reoperation.
( ) Subjects at risk

COMMENTS

Excellent results have been obtained with mitral valve repair avoiding the inconveniences of replacement using prostheses. Indeed, mitral valve repair is durable and presents a very low rate of valvular events [13-16], thus should be the first-line procedure for the treatment of insufficiency of degenerated mitral valves. Repair of the posterior leaflet is the commonest procedure in mitral valve repair [1, 3, 4, and 17]. Quadrangular resection associated with or not "sliding" repairs is the normal technique for this indication. Annuloplasty with a prosthetic ring to reestablish the format of the mitral valve orifice, in all chronic diseases of the aforementioned cases, is accepted by the majority of surgeons [11]. The tendency is to implant the largest ring possible, as implantation of the ring is not used to restrict the mitral valve surface, but to reshape the orifice [11].

However, there is still some uneasiness in respect to AL prolapse and so it is a surgical challenge. There is no consensus about how AL prolapse should be repaired and there are even publications questioning the necessity of repair of this leaflet [18]. It seems to be important to stress that anterior leaflet "billowing" and anterior leaflet prolapse are not identical. Billowing can be observed in more than 70% of the population with no degree of regurgitation and, obviously, billowing does not require correction. On the other hand, if regurgitation is present, there is a necessity to repair the leaflet. It appears that 2 mm of prolapsed AL can be repaired with annuloplasty by means of the implantation of a prosthetic ring, reducing the mitral-aortic angle and pulling the free edge of the AL downwards. However, the prolapse is frequently greater than 2 mm and must therefore receive specific treatment. In all our cases the AL prolapse was greater than 2 mm.

We believe the AL repair can be as easy as and as safe as PL repair. The first step is to have a good knowledge of the subvalvar apparatus, especially of the papillary muscles and their components. In our series, isolated PMR was the easiest technique to repair AL prolapse no matter what the site of the injury was: Al, A2 or A3 with muscle repositioning always being the first objective. PMR can only treat elongated chordae tendineae. When the anterior head is not really individualized it is possible to create a fissure inside the papillary muscle between the anterior and posterior bundles. It is important to remember that the shortening must always be a little shorter than necessary to avoid restriction in the movement of the AL. In some cases, a combination of techniques is necessary to achieve total correction of the regurgitation. Limitations can be observed when the chords are very long. On some occasions the repair is completed with plicature of the chordae tendineae where they are fixed to the leaflet. In cases of associated injuries, such as elongated chordae and the rupture of chordae tendineae, chordal transference has also been associated.

We believe there are several reasons to accept PMR as the first-line method:

- Transference (PL to AL) is an excellent method, but can be limited by the number of available chordae tendineae to treat an extensive area of prolapsed anterior leaflet.
- The shortening of chordae tendineae is not a direct method to reduce elongated chords, because the effectiveness of the shortening represents half the length buried inside a fissure created in the papillary muscle. Consequently, shortening of the chords requires experience in repairing the mitral valve. On the other hand, PMR is shortening directly related to repositioning and location within the ventricular chamber and has a relationship similar to the length of the prolapse to be corrected. Thus, we believe that this technique is easy and safe.
- Moreover, much care is required to avoid the sutures coming into contact with the manipulated chordae tendineae because this can lead to rupture over time. Probably due to this technical detail, some researches, including Gillinov et al. [19], report the failure of mitral valve repair in 22% of the cases using the chordal shortening technique, which increases to 36% in degenerative disease cases [20]. But, this complication was not identified in our personal experience of more than 400 mitral valve repairs. The failure rate explains the necessity of research for alternative techniques.
- PMR can be more useful in cases of paramedian and para-commissural prolapse posterior of the AL. In many patients the chordae tendineae are accustomed to grow from

the tip of the papillary muscle. Thus, burying is impossible when there are several chords, as rarely more than two chords can be buried in the same fissure. In this circumstance, PMR offers a safe and elegant alternative. The basic principle of this technique is to separate the anterior head of the posterior papillary muscle, pulling it separately and positioning it below the ventricle. Some chords independently of others.

- When paramedian prolapse of the AL occurs, very frequently the posterior commissural area is not involved. In these cases, the separation from the anterior head corrects the local prolapse, without interfering with the adjacent structures of the leaflet.
- In many situations, the repositioning requires only one monofilament 4.0 thread suture tied in the fibrotic area of the head of the papillary muscle. This is the simplest and quickest technique to repair the prolapse of the AL.
- When the AL prolapse occurs near to the anterior papillary muscle, PMR is also viable. In many cases, there are only two components, anterior and posterior. Additionally, posterior PMR can be easily associated with anterior PMR. Hence, any prolapsed area of the anterior leaflet can be successfully treated using this technique.
- Posterior commissural prolapse still remains among the most challenging injuries to be repaired. In our series we had 16 patients (13.3%) with this type of injury associated with AL prolapse. Separating the anterior and posterior heads of the intermediate component, we were able to shorten to different degrees the commissural bundle and the para-medial bundle. Recently, Aubert et al. [21] described good long-term results in the commissural prolapse repair, but in 50% of the cases they closed the commissure. With PMR we never needed to occlude the commissure, the simple repositioning of the intermediate head of the posterior papillary muscle makes repair of the commissural prolapse possible.

We firmly believe that PMR gives better results than other techniques used previously, as no reoperations for recurrent prolapse of the AL were seen in our previous study over 10 years [10]. Enriquez Sarano demonstrated, in his study that for 80- and 90-year-olds the risk of reoperation for AL falls from 25% to 10% [5]. There were also differences in results between AL and PL. Our study shows that it is possible to avoid these differences and to decrease the necessity of reoperations for recurrent mitral regurgitation. We believe that PMR does not require a long learning curve, as it is a quick technique, which saves time for other procedures, with the aim of treating the AL prolapse completely. David et al. [13] stated that the prolapse of multiple segments of both leaflets would be better managed by valve replacement rather than by repair, until new reconstruction techniques, such as the complete shortening of the papillary muscle trunk, give satisfactory results. Although we are not proposing total displacement of the papillary muscle, we believe that partial dislocation of the papillary muscle can prove to be a safe, long-lasting and reproducible technique to repair the most complex injuries of the anterior leaflet, including Barlow's disease with or without commissural prolapse and extensive involvement of the valve tissue.

CONCLUSION

In our experience, repositioning of the anterior and posterior papillary muscles are the best methods to treat anterior leaflet prolapse, no matter where the injury is located, giving excellent clinical and echocardiographic results over the long term. We recommend this technique as the gold standard treatment in all cases.

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