Leaflet extension in rheumatic mitral valve reconstruction†

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Abstract

OBJECTIVES: Type IIIa mitral regurgitation (MR) due to rheumatic leaflet restriction often renders valve repair challenging and may predict a less successful repair. However, the utilization of leaflet mobilization and extension with the pericardium to increase the surface of coaptation may achieve satisfactory results. We reviewed our experience with leaflet extension in rheumatic mitral repair with emphasis on the technique and mid-term results.

METHODS: Between 2003 and 2010, 62 of 446 rheumatic patients had leaflet extension with glutaraldehyde-treated autologous pericardium as part of their mitral repair procedure. Their clinical and echocardiographic data were prospectively analysed.

RESULTS: The mean age of the rheumatic patients was 20.2 ± 11.7 years; range 3–60 years. Forty-eight (77.4%) patients had predominant MR, while 22.6% had mixed mitral stenosis and mitral regurgitation (MS/MR). Leaflet extension was performed in the posterior, anterior and both leaflets in 77, 13 and 10% of patients, respectively. Additional repair procedures included neo-chordal replacement, chordal transfer/shortening/fenestration/resection, commissurotomy and papillary muscle splitting. All repairs were stabilized with annuloplasty rings. The follow-up was complete in all patients with a mean follow-up of 36.5 ± 25.6 months. There was no mortality in this series. At the latest follow-up, the MR grade was none/trivial in 64.5 of patients, mild in 22.6, moderate in 6.5, moderately severe in 4.8 and severe in 1.6%. Two patients had redo mitral surgery. At 5 years postoperatively, the estimated rates of freedom from reoperation and valve failure were 96.8 and 91.6%, respectively.

CONCLUSIONS: Repair with leaflet extension in rheumatic disease resulted in good early and mid-term outcomes. A wider utilization of this technique may increase the feasibility and durability of repair in complex rheumatic mitral valve disease.

Keywords: Mitral valve • Valve reconstruction • Valve repair • Rheumatic heart disease • Leaflet extension • Pericardium

INTRODUCTION

Mitral valve (MV) repair is preferred over replacement for its benefits of the preservation of ventricular function, lower operative mortality, superior long-term survival and avoidance of anticoagulation [1–3]. MV repair has been shown to have excellent durability in patients with mitral regurgitation (MR) caused by degenerative disease [4, 5] and is indeed the method of choice in the correction of MR whenever feasible. In contrast, valve reconstruction for rheumatic MR remains controversial as it not only suffers from an inferior feasibility of repair [6], but also the repaired rheumatic valve is less stable with inferior durability when compared with a degenerative MV repair [7]. The Type IIIa MR due to rheumatic leaflet restriction often renders valve repair challenging and may predict a less successful repair [8]. However, the utilization of leaflet mobilization and extension with the pericardium to increase the leaflet area and the surface of coaptation may achieve satisfactory results [9–11]. In this single-centre study, we reviewed our experience of MV repair with leaflet extension in rheumatic disease, with emphasis placed on the description of the technique of leaflet extension and the mid-term durability of the repaired valve.

MATERIALS AND METHODS

Patients

Between January 2003 and December 2010, 62 of 446 (13.9%) rheumatic patients underwent leaflet extension using autologous pericardium treated with 0.6% glutaraldehyde as part of their repair procedure. The data were prospectively collected from the valve repair registry of our institute. Patients who underwent concomitant cardiac surgery for the aorta, cardiac tumour or pericardial diseases, or coronary artery bypass grafting were excluded. However, patients who had undergone concomitant repair or replacement for aortic and tricuspid valvular lesions were not excluded. The mean age for our study group was...
20.2 ± 11.7 years (range 3–60 years). There were 47 females (75.8%) and 15 males (24.2%). Predominant MR was present in 48 (77.4%) patients and mixed stenotic and regurgitant lesions in 14 (22.6%). Atrial fibrillation was present in 14 (22.6%) patients. Shortness of breath on exertion was the predominant symptom, and 48 (77.4%) patients were in New York Heart Association (NYHA) functional Class II and higher (Table 1). This study received the approval of the ethics committee/institutional review board of our institution.

Preoperative assessment

Two-dimensional (2D) echocardiography and Doppler colour flow imaging were performed on all patients using a Hewlett-Packard Sonos 2500 or Philips IE 33 equipped with a 2.5–3.5-MHz transducer. Preoperative echocardiography was performed on all patients within 3 months before surgery. The morphology of the valve was documented to further substantiate the diagnosis of rheumatic MV disease with leaflet restriction. Of the 62 patients, 42 (67.7%) were further classified into Type III (leaflet restriction) and 20 (32.3%) into Type Ila/Illp (a combination of prolapse of the anterior leaflet with retraction of the posterior leaflet), as described by Chauvaud et al. [10]. The degree of severity of MR was quantified by the regurgitant fraction (RF) obtained by 2D echocardiography with Doppler, and graded as mild (1+ MR, RF <15%), moderate (2+ MR, RF 15–30%), moderately severe (3+ MR, RF 35–50%) and severe (4+ MR, RF >50%). This quantification was supplemented by using the simplified proximal isovelocity surface area (PISA) method to determine the severity based on the regurgitant volume and the effective regurgitant orifice area. The classification of the severity of rheumatic mitral stenosis primarily relied on the MV area assessed by 2D echocardiogram, using the planimetry and/or pressure half-time methods.

Mitral stenosis was graded as mild (valve area >1.5 cm²), moderate (1.0–1.5 cm²) or severe (<1.0 cm²). In addition, all patients also had intraoperative transoesophageal echocardiography (TEE) through the use of Hewlett-Packard Sonos 2500 or Philips IE 33. Coronary angiography was performed in patients above 40 years old.

Surgical procedures

A median sternotomy approach and conventional ascending aorta and bicaval cannulation were used for all patients. Moderately hypothermic (28–32°C) cardiopulmonary bypass was performed, and myocardial protection was achieved with cold-blood cardioplegia. The MV was approached through a left atrial incision parallel to the interatrial groove. After careful analysis of the MV leaflets and subvalvular apparatus, the reconstruction procedure was planned. The repair techniques were based on Carpentier reconstruction principles [12], although there were some modifications tailored to the individual patient. We usually perform a step-wise repair to mobilize the restricted mitral leaflet. The initial step was to free the fused commissures and subvalvular apparatus by a commissurotomy, and splitting of the fused chords and papillary muscles. Shortened secondary chords are often cut to further free the leaflets. In some cases, even restricted primary chords were resected and, in these instances, they were substituted with artificial chords. The leaflets themselves were made more pliable by peeling off the inflammatory fibrotic layer (leaflet shaving, leaflet peeling or cusp thinning) and decalcification. Next, when the leaflet and subvalvular mobilization were not enough to compensate for tissue retraction and leaflet hypoplasia, leaflet extension or augmentation techniques were adopted to increase the surface area of the leaflet, providing increased mobility and surface for leaflet coaptation. The leaflet extension technique further allows for the insertion of a larger annuloplasty ring, thereby reducing the risk of stenosis [10, 12]. For the Type Ila/Illp lesion, the prolapsed anterior leaflet was primarily re-supported by the use of polytetrafluoroethylene (PTFE) artificial chordal replacement and occasionally by the transfer of adjacent secondary chords. All mitral reconstructions were completed by the placement of an annuloplasty ring. Following repair, MV competency was assessed by injecting cold saline with a bulb syringe into the left ventricle directly through the MV. Intraoperative TE was routinely used to objectively assess the repair following termination of cardiopulmonary bypass.

The commonest concomitant procedure performed was tricuspid annuloplasty in 21 (33.9%) patients, aortic valve replacement in 8 (12.9%) and the modified Cox-maze III procedure in 7 (11.3%).

The leaflet extension procedure

The leaflet extension technique is further described in detail. An autologous pericardial patch was harvested at the beginning of the operation before the injection of heparin, cleared of fatty tissue, trimmed and soaked in 0.6% gluteraldehyde-buffered solution at room temperature for 5–10 min and then rinsed with normal saline solution for 15 min in three separate baths. Annuloplasty sutures were applied around the posterior circumferance of the mitral annulus. This initial step improves valve

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Data presented as mean ± standard deviation or median for continuous variables and number of patients, with percentages in parentheses for categorical variables.
exposure for accurate analysis and in addition avoids pericardial patch dehiscence due to needle-hole perforation if the larger annuloplasty sutures were to be inserted after the patch had been sewn into place. An anterior leaflet extension was performed when it was determined that the area of the leaflet was smaller than the 26-mm annuloplasty sizer, which is the smallest adult prosthetic ring. Alternatively, leaflet augmentation was also undertaken when the vertical height of the anterior leaflet was <26 mm as this was associated with the failure of repair [13]. An incision was carried out on the anterior leaflet 2 mm away from the annulus and extended to both commissures. The size of the pericardial patch was made so that the newly augmented leaflet could fit the size of at least a 28-mm annuloplasty template. For smaller children, the size of the patch was determined to allow the new anterior leaflet to generously meet the opposing posterior leaflet so as to provide adequate coaptation. The width of the pericardial patch was also made to be of generous size covering the defect created from commissure to commissure. The posterior leaflet extension was undertaken when it was determined to be retracted and/or when the leaflet tissue was insufficient. The patch usually had an ovoid shape, and the height and the width of the patch were designed to create a curtain-like posterior leaflet to allow for free and generous coaptation against the anterior leaflet (Figs. 1 and 2). The reconstructed posterior leaflet usually had a height of about 15–20 mm and a breadth that spanned from commissure to commissure. An effort was made to maintain the height ratio of the repaired anterior and posterior leaflet to 2/3 and 1/3, respectively. The patch was sutured using two continuous 5/0 non-absorbable monofilament sutures (polypropylene) with fixations at three or four points to prevent a purse-string effect. The patch was oriented so that the smooth surface of the pericardium faces the left atrial side to reduce the potential of thrombogenesis. In this series, 77% of patients had posterior leaflet extension and 13% had anterior leaflet extension, while 10% had both leaflets extended. For the Type Ila/IIlp lesion, following extension of the retracted posterior leaflet, the prolapsed anterior leaflet was primarily re-supported by the use of PTFE artificial chordal replacement (Fig. 2).

Postoperative management

The patients who underwent implantation of prosthetic annuloplasty rings were routinely administered warfarin for

Figure 1: Extension of the posterior mitral leaflet with glutaraldehyde-treated autologous pericardium. Note that the patch is made generously wide to extend from commissure to commissure.

Figure 2: Type Ila/IIlp lesion of the MV treated with pericardial patch extension of the retracted posterior leaflet and PTFE neo-chordal replacement to support the prolapsed anterior leaflet.
anticoagulation for 6 weeks postoperatively, with a target international normalized ratio (INR) of 2.0–3.0, and this was continued indefinitely for those who had atrial fibrillation. All patients were given oral penicillin as secondary prophylaxis against rheumatic fever for 10 years or until 40 years of age (whichever was longer) as is currently recommended [14].

Follow-up

Data on follow-up were obtained up to March 2012 and were collected during the visits to the outpatient clinic or by telephone interviews. The data were 100% complete. The mean follow-up was 36.5 ± 25.6 months, and the maximum was 96 months. Operative mortality was defined as death within 30 days of surgery or in-hospital death. The end points of the study were defined as the composite of operative mortality, late death, reoperation and valve failure. Valve failure was defined as recurrent significant regurgitation more than moderate MR (2+ MR) and/or reoperation. All survivors were evaluated with echocardiography before discharge, at 3 months, 6 months and annually after surgery.

Statistical analysis

Data were presented as frequencies and percentages for categorical variables, and medians or means with standard deviations for continuous variables. In categorical variables, data were compared using χ² or Fisher’s exact tests. In continuous variables, Student’s t-test or Mann-Whitney U-test were carried out to compare the association between groups. Late survival and time-dependent morbidity were evaluated with the Kaplan–Meier method and log-rank test. A P-value <0.05 was considered to indicate significance. Statistical tests were performed using SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

General outcomes

The patients in the study group with leaflet extension were young, with a mean age of 20.2 ± 11.7 years. The mean size of annuloplasty rings was 28 ± 2 mm and the median size was 28 mm (Table 1). The annuloplasty rings used in the study group were Carpentier Edwards Physio in 41 (66.1%) patients, Carpentier Edwards Classic in 2 (3.2%), Cosgrove Edwards band in 15 (24.2%) and the biodegradable Kalangos Bioring in 4 (6.5%). The flexible bands and biodegradable rings were used in children to allow for potential annular growth corresponding to somatic growth.

Early outcomes

There were no hospital deaths or major postoperative morbidity. Minor complications included re-exploration for bleeding in 2 (3.2%) patients and pericardial effusion in 6 (9.7%).

Late outcomes

Follow-up was complete in all patients. The mean follow-up for the leaflet extension group was 36.5 ± 25.6 months. There were no late deaths reported in both groups. None of the patients experienced thromboembolism, bleeding related to anticoagulation or endocarditis. At the latest follow-up, all except one patient were in NYHA functional Class I.
Recurrent mitral regurgitation, reoperation and valve failure

At the latest follow-up, the MR grade was none/trivial in 64.5 of patients, mild in 22.6, moderate in 6.5, moderately severe in 4.8 and severe in 1.6% (Fig. 3). Two (3.2%) patients had redo MV surgery. The reasons for redo surgery were recurrent MR from inadequate initial repair in one patient and progression of rheumatic disease with mitral stenosis in the other patient. In the latter patient, somatic growth also accounted for a relative ring size mismatch contributing to the mitral stenosis. At redo surgery, MV replacement was performed in 1 patient and a re-repair was performed in the other patient. At 5 years post-operatively, the estimated rate of freedom from reoperation was 96.8% ±3.2 years (Fig. 4) and from valve failure was 91.6% ±4.9 years on Kaplan–Meier analysis (Fig. 5).
Rheumatic heart disease is the commonest aetiology of valve disease that affects the younger generation in the developing nations [15, 16]. The rheumatic process affects the MV in up to 50% of cases and results in MR, MS or both [11]. Replacement of the diseased MV with a prosthetic is associated with suboptimal preservation of ventricular function, anticoagulation-related complications and reduced survival [1-3]. Furthermore, poor compliance with anticoagulation, somatic growth, accelerated bioprosthetic degeneration and pregnancy remain important issues in young patients, particularly in developing countries. MV repair is well recognized as the procedure of choice for patients with degenerative MR. However, valve repair in rheumatic MV disease patients remains controversial because several studies have demonstrated inferior feasibility and durability of reconstruction in rheumatic patients [6, 7]. Chauvaud et al. [9, 10], on the other hand, had demonstrated good long-term results with repairing diseased rheumatic MVs using Carpentier's reconstruction techniques.

The diseased rheumatic valve poses a challenge to successful repair due to the young age of the patient, the possibility of continuing rheumatic inflammatory process and the complex nature of the pathology frequently requiring numerous repair techniques in a single patient, adding to the technical difficulty. The dysfunction that is peculiar to rheumatic disease is the Carpentier's Type III leaflet restriction, which is the commonest dysfunction in rheumatic mitral disease with involvement of up to 60% of cases [10]. When present, leaflet restriction due to rheumatic disease predicts a low possibility of a successful repair with the feasibility rate as low as 20-36%, depending on the number of leaflets involved [8]. The most challenging lesions to repair are those that had induced fibrotic retraction of the leaflets and the subvalvular apparatus. The free edge of the rheumatic leaflet is almost always thickened, but the fibrosis may affect the entire leaflet causing transverse or vertical retraction, rendering the leaflet less pliable and less amenable to repair. In the French correction, Carpentier had outlined the basic principles of mitral reconstruction [12], emphasizing that restoration of normal leaflet motion is central to successful repair. Several strategies to correct leaflet restriction have been described. These include mobilizing the fused commissures, chords and papillary muscles [10], cusp thinning [17], leaflet extension [9] and usage of an undersized annuloplasty ring. In our series of patients, we describe the use of autologous pericardium to treat Type III rheumatic MV disease. Leaflet extension or partial replacement with glutaraldehyde-treated autologous pericardium is useful when leaflet retraction, leaflet hypoplasia or leaflet perforation is present. The use of autologous pericardium was first described by Chauvaud et al. [9] two decades ago. Its ready availability, ease of handling and its pliability make it an obvious choice to correct leaflet defects. When compared with commercial bovine pericardium, autologous pericardium is non-antigenic, avoids the risk of xenograft viral transmission and does not add to the cost. The autologous pericardium was treated with 0.6% glutaraldehyde-buffered solution for 5–10 min. The glutaraldehyde solution makes the pericardium stiffer, rendering it easier to handle. The 5–10 min of glutaraldehyde pretreatment is important as untreated pericardium suffers from acute tissue shrinkage and contracture, whereas prolonged treatment could cause late fibrosis and excessive calcification.

It remains somewhat debatable whether the anterior or the posterior leaflet should be extended in restrictive rheumatic disease. Many studies have reported the extension of the anterior leaflet as the primary repair procedure with good results, explaining the benefits as including the correction of MR with the ability to insert a larger prosthetic ring to prevent significant mitral stenosis [18-20]. More recent publications have focused on patch extension of the posterior leaflet instead [21-24], as it would also seem logical, as according to Carpentier, the most frequent mechanism in rheumatic MR is the retraction of the posterior leaflet (Type III) due to progressive fibrosis of the leaflet and subvalvular apparatus [12]. Posterior leaflet extension was undertaken in our patients when it was determined to be retracted and/or when the leaflet tissue was insufficient. The patch usually had an ovoid shape, and the height and the width of the patch were designed to create a curtain-like posterior leaflet to allow for free and generous coaptation against the anterior leaflet (Figs. 1 and 2). The extended posterior leaflet also allows for the possibility of oversizing (usually one size) of the prosthetic ring. A conscious effort is, however, taken to avoid excessive height of the extended posterior leaflet and the use of an undersized prosthetic ring to prevent systolic anterior motion (SAM) causing left ventricular outflow tract obstruction. Having said that, we have not encountered SAM following rheumatic MV repair in our practice nor have there been any such reported cases in the literature. This is probably due to the fact that the rheumatic leaflets are rather fibrotic, short and stiff, less pliable than normal, thus not displaying the propensity of the bulky myxomatous leaflets in degenerative disease to cause SAM.

Regardless of whether it is the anterior or the posterior leaflet that is extended, it is important for the width of the pericardial patch to be of a generous size covering the defect created from commissure to commissure. This is to ensure complete mobilization of the entire retracted leaflet, an enlarged leaflet surface area and sufficient surface of coaptation between the opposing leaflet edges. An added benefit of the leaflet extension technique is that it permits an excellent view into the left ventricle and the subvalvular apparatus via the surgically created defect, allowing the surgeon access to mobilize the fibrotic, fused or calcified tissue contributing to the leaflet restriction. The use of a prosthetic annuloplasty ring is essential for correcting rheumatic MR as it restores the size and shape of the deformed annulus and reinforces the repair by taking tension off the leaflets and the chords. All our patients had prosthetic annuloplasty rings implanted. Despite a relatively young study population, we were able to implant adequate adult size annuloplasty rings where the mean and median sizes of rings were 28 ± 2 and 28 mm, respectively (Table 1). This observation reinforces the important benefit of the patch extension technique that allows for the implantation of larger size annuloplastic rings, regardless of whether the anterior or the posterior leaflet was extended. Patch extension increases the surface area and length of leaflet coaptation, and thus obviates the reliance on implanting an undersized ring to achieve good coaptation and valve competence. Furthermore, by aggressive mobilization of the restricted or ‘trapped’ rheumatic leaflet and subvalvular apparatus, the annulus is often released or ‘freed’ to accommodate a larger-sized ring.

There has been scant information in the literature with regard to the durability of autologous-treated pericardium in rheumatic MV repair. Chauvaud et al. [9] observed a rate of freedom from reoperation of 70% at 6 years, while Omeruglu et al. [21] reported a reoperation-free life expectancy rate of 85% at 7.5 years. In our series, the actuarial rates of freedom from
reoperation and valve failure at 5 years were 96.8 and 91.6%, respectively (Figs. 4 and 5), with particular importance placed upon the freedom from valve failure, which we believe is a more robust and sensitive indicator of long-term durability as the performance of the repaired valve is also taken into consideration. The long-term fate of the pericardium is largely unknown. We had 2 patients in our leaflet extension series who had reoperation; one for early failure from inadequate primary repair and another after 7 years for mitral stenosis as the patient had progression of rheumatic disease plus a ring size mismatch from somatic growth. In the latter patient, the integrity of the posterior pericardial patch seemed preserved with no signs of fibrosis, contracture or calcification and in fact appeared indistinguishable from the native anterior leaflet (Fig. 6).

In conclusion, leaflet extension is feasible for rheumatic MV and complements the armamentarium of Carpentier’s valve reconstruction methods. The technique is reproducible and offers encouraging early and mid-term outcomes. The longer follow-up will establish the potential durability of this technique. A wider utilization of this technique may increase the success rates of repair in complex rheumatic MV disease especially in children and young adults.

LIMITATIONS

This study was subject to the limitations inherent in observational data collected prospectively from our MV repair registry. The non-randomized design may have affected the results because of the presence of unmeasured confounding factors and procedure bias or detection bias. The variations in results depend on the attending surgeon’s discretion on different techniques and level of acceptance of the results of repair.

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Conflict of interest: none declared.

REFERENCES

APPENDIX. CONFERENCE DISCUSSION

Dr S. Livesey (Southampton, UK): Your presentation was really a ‘how-to-do-it’ of leaflet extension; I think there will be very few questions left after that. Can I ask you, first of all, to elaborate on how you decide between whether or not to extend the anterior leaflet or the posterior leaflet. And when you have done that, could you tell us whether or not you’ve noticed any difference in longevity between anterior extension and posterior extension.

Dr Dillon: I’ll answer the second one first. The groups of patients were small and were predominantly posterior. We chose to extend the posterior because inherently when we looked at the echo intraoperatively, the posterior leaflet seemed retracted in most of the cases as opposed to the anterior leaflet. This was seen in more than three-quarters of our patients.

Secondly, as to how to decide on the anterior leaflet extension, there are two methods that we used. The first refers to Dr. Kumar’s paper that measured the height of the anterior leaflet, where a cut-off of 26 mm was taken; if the height is 26 mm or less, if you do not extend the leaflet, then it predicts a poorer repair result. In the second method, we also use an adult ring annuloplasty sizer. If one sizes it more than 26 mm, I think that it should be able to get a good result with that dimension without leaflet extension.

Dr Livesey: And you’re not aware, for example, that anterior leaflet repair has a worse longevity than posterior leaflet repair?

Dr Dillon: Yes, I’m aware of that in degenerative disease; however, I’m not aware of any comparison in rheumatic disease.

Dr Livesey: Secondly, I note from the manuscript that in a quarter of your repairs you’ve used a flexible band rather than a semi-rigid ring. Does that have any impact on the longevity of the repair here?

Dr Dillon: We would prefer to use a semi-rigid or rigid ring. The patients that had a flexible ring or band were children; the idea of that was to allow for any potential growth of the annulus. I think the current thinking is that for a fibrotic rheumatic annulus, one would use a rigid or semi-rigid ring. I have not compared the results between these two rings because the population is small.

Dr K. Sarkar (Calcutta, India): In our part of the world, we still get a lot of mitral valves where closed procedures have previously been performed. So I would like to know what your experience has been: have any of your patients had closed procedures done in the past? Secondly, I just want to clarify how the freedom from reoperation was different from the valve failure rates? Because those statistics weren’t very clear to me.

Dr K. Khargi (The Hague, Netherlands): I have a follow-up question on the technical details of the extension of the anterior leaflet. Can you elaborate in a little more detail precisely how you do it?

Dr Dillon: The anterior leaflet, yes, we would do it in a similar way to the posterior leaflet. We will make an incision 2 mm from the annulus. We then extend the incision from commissure to commissure. As to the sizing of the patch, there are two methods that can be used. One, you can have a nerve hook to pull at the primary chords, pulling down against the posterior leaflet, and the defect itself gives you the size of the patch. Secondly, if you’d want to use a sizer, we like to use a size 28 mm at least in an adult to make sure that they have the good long-term results. And the patch is then sized to a size 28 template, so you could use either one of these two methods.

In two papers published in this issue of the Journal [1, 2] and presented at the last EACTS Annual Meeting, the group from the National Heart Institute of Kuala Lumpur, Malaysia, discuss their long-term experience of repair for rheumatic mitral valve regurgitation, with the aim of identifying predictors of durability and of comparing them with repairs for degenerative mitral