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REVIEW ARTICLE

Leaflet repair techniques in mitral valve reconstruction

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Abstract Recently, there has been tremendous development in mitral valve repair, especially in imaging modalities, minimally invasive approaches and surgical techniques. Among various surgical techniques, leaflet techniques have also advanced for treatment of different types of mitral valve diseases. The optimal leaflet technique depends on the involvement of anterior or posterior leaflet, aetiology of the disease and the usage of surgical approach. In degenerative disease for posterior leaflet prolapse, the current trends are from classical quadrangular resection to limited triangular resection. Development of techniques like peeling and pericardial leaflet augmentation has made mitral valve repair feasible in rheumatic heart disease. Similarly, with better understanding of pathophysiology of ischemic mitral regurgitation, the new techniques involving leaflets and subvalvular apparatus have also progressed for more stable and durable repair. In this review, various leaflet repair techniques, which are applicable to various types of functional classification for different aetiology, have been described in detail.

Keywords Mitral valve · Leaflets · Techniques

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Introduction

Mitral valve (MV) repair is the procedure of choice for different mitral valve diseases irrespective of aetiology [1]. Recommendations for MV repair in primary mitral regurgitation were of class 1 level of evidence C in American College of Cardiology/American Heart Association (ACC/AHA) guidelines in 2008 [2]. Subsequent studies proved superiority of repair over replacement which led to more favourable recommendations of class 1 level of evidence B in new guidelines in 2014. According to the latter guidelines, even in rheumatic heart disease (RHD), where compliance to oral anticoagulants is questionable, repair is recommended [3]. Mitral valve reconstruction can be performed by various techniques. In majority of patients, no single technique is sufficient and multiple techniques are required. There has been rapid progress in developments of techniques for repair of mitral valve dysfunction due to various lesions in different aetiologies from French Correction to American Correction and even Indian Correction [4–6].

Leaflet techniques have been primary techniques for mitral valve reconstruction. In this review, the pathophysiology of mitral valve disease and valve analysis are briefly described. Leaflet repair techniques based on valve analysis are described in detail. A comparative analysis of the different techniques is done in the last section of this review.

Pathophysiology

Traditionally, mitral valve pathology has been classified as stenosis, regurgitation and combined stenosis along with regurgitation. Precise description of pathology by anatomical approach proved quite complex and, therefore, it could not become practical regarding MV reconstruction. The functional

classification introduced by Alain Carpentier in 1983 simplified this complex field and became the basis of successful MV repair [4]. Normal mitral valve has fully mobile leaflets and a large coaptation surface with free edge lying below the line of coaptation. Any lesion disturbing this relationship can lead to a valve dysfunction. Accordingly, various types of valve dysfunction were described by Carpentier as shown in (Table 1) and (Fig. 1). It led to adoption of functional approach with an aim to restore normal valve function rather than a normal anatomy. He also introduced a segmental classification (Fig. 2), in which the mitral valve leaflet posterior segments are identified as P1 (anterior scallop), P2 (middle scallop) and P3 (posterior scallop) as viewed by the surgeon though a left atriotomy. The three corresponding segments of the anterior leaflet are termed A1 (anterior part), A2 (middle part) and A3 (posterior part). The remaining two segments are the anterior commissure (Ac) and posterior commissure (Pc) [7].

Valve analysis

Alain Carpentier described a systemic method of intraoperative valve analysis. In the valve analysis, the regions of the mitral valve leaflets are defined surgically through a left atriotomy by taking nerve hooks and lifting each leaflet segment in a systemic manner, starting in clockwise fashion from P1 to Ac, A1, A2, A3, Pc, P3 and P2. P1 serves as reference segment and pliability and motion of the leaflet segments are compared with P1, as the free edge of P1 rarely crosses the annular plane. The causative lesions of valve dysfunction of all the segments are also determined [7].

Nowadays, valve analysis is performed using echocardiography. Valve dysfunction and lesions are determined by valve analysis preoperatively by 2D echocardiography, and currently live 3D transesophageal echocardiography is becoming an alternative to intraoperative valve analysis. Mitral valve analysis by optical tracking represents a unique technologic advance in intraoperative assessment, providing the surgeon with an extended quantitative perception of surgical target. This technology promotes a major philosophical change from an empirical procedure toward a quantitatively predictable modern reconstructive operation [8].

However, intraoperative valve analysis is essential for precise location of leaflet dysfunction and the lesions. It helps the surgeon to use the appropriate reconstruction techniques. Alain Carpentier [7] has defined the following golden rules of successful reconstructive valve surgery:

- Restoration of full leaflet motion
- Optimisation of surface area of coaptation
- Remodelling and stabilisation of annulus

Leaflet repair techniques

Techniques in type I dysfunction (normal leaflet motion)

The main lesion in type I dysfunction is annular dilatation and the technique done is annuloplasty. The other lesions in type I dysfunction are leaflet perforation or leaflet tear in infective endocarditis. The infected lesion is usually excised with a 2-mm margin of healthy tissue and the defect can be closed with fresh autologous pericardial

Table 1 Functional classification showing dysfunctions, corresponding lesions and aetiology

Type	Leaflet motion	Lesions	Aetiology
I	Normal	Annular dilation	Degenerative
			RHD
			Ischemic
		Leaflet perforation	Endocarditis
		Vegetations	Endocarditis
		Leaflet tear	Endocarditis
II	Excessive	Chordal rupture	Degenerative RHD
		Chordal elongation	Degenerative RHD
		Papillary muscle rupture	Ischemic
		Papillary muscle elongation	Degenerative
IIIa	Restricted in diastole	Commissure fusion	RHD
		Leaflet thickening	
		Leaflet fibrosis and calcification chordae thickening and fusion	
		Papillary muscle fusion	
IIIb	Restricted in systole	Ventricular wall dyskinesia	Ischemic
		Dilated cardiomyopathy	Ischemic Idiopathic

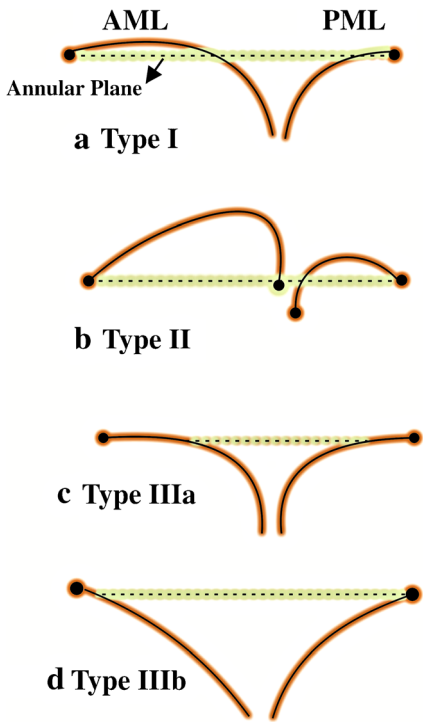

Fig. 1 Functional classification. **a** Type I: normal leaflet motion within annular plane. **b** Type II: excess leaflet motion above annular plane. **c** Type IIIa: restricted leaflet motion in diastole. **d** Type IIIb: restricted leaflet in systole below the annular plane. AML anterior mitral leaflet, PML posterior mitral leaflet

patch. The patch is usually circular and sutures used are 5–0 polypropylene continuous or interrupted sutures [9].

Techniques in type II dysfunction (excess leaflet motion)

Type II dysfunction is further divided in to following subgroups:

1. Posterior leaflet prolapse
2. Anterior leaflet prolapse
3. Bileaflet prolapse
4. Commissural prolapse

The lesions leading to leaflet prolapse are chordae rupture, chordae elongation and deficit chordae. Various procedures for correction of respective leaflet prolapse are described below.

1. Posterior leaflet prolapse

The techniques used for posterior leaflet prolapse are as follows:

(a) *Quadrangular resection and sliding leaflet plasty*

It has been the most common technique used for mitral valve repair in degenerative disease, usually involving P2

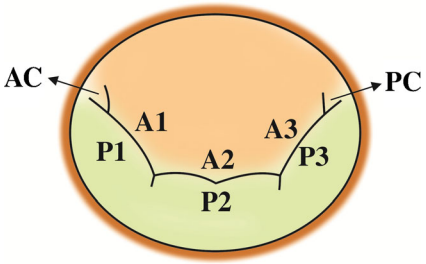

Fig. 2 Segmental anatomy of mitral valve leaflets: AML and PML are divided into six segments A1, A2 and A3 and P1, P2 and P3 along with two commissural segments AC anterior commissure, PC posterior commissure

segment, and has been advocated as the first technique for learners. It is performed when prolapse involves more than one third of the length of the free edge of the segment. The diseased quadrangular segment (either due to chordae rupture or elongation) is excised, and when height of remaining segment is < 20 mm, the annulus is plicated with 2–0 polyester interrupted sutures. The leaflet edges are sutured continuously in two layers with 5–0 polypropylene. If the height of leaflets is more than 20 mm, sliding leaflet plasty is performed either on one or both sides [7].

Eventually, following modifications have been made in this technique:

Cohn et al. attached leaflets together and then leaflets to annulus with three polypropylene sutures without separate annulus plication sutures, making a smooth suture line. The smooth suture line prevents clot formation thus reducing risk of thromboembolism. Further modification of the technique was done by them: performing limited quadrangular resection and then simply folding it over without a major advancement of leaflets. In comparison with cutting away the entire posterior leaflet, this technique is both faster and much safer, although accomplishing the same principle [10]. DiBardino et al. from Cohen group found 10- and 20-year freedom from reoperation rates 90 and 82% in degenerative disease in a series of 1042 in which quadrangular resection and other modifications were performed in 752 patients [11].

Gillinov et al. advanced the P1 and P3 flaps in the centre after detaching from annulus and reduced the heights of segments by taking deep bites while suturing to annulus incorporating excessive tissue into suture line [12]. Between 1985 and 1997, 1072 patients underwent primary isolated mitral valve repair for valvular regurgitation caused by degenerative disease at Cleveland Clinic. They showed 93% freedom from reoperation and durability was greatest after quadrangular resection [13].

We modified this technique by using single 5–0 polypropylene suture in continuous fashion, starting from the upper edges of P1 and P3 and tying it with two knots and approximating the leaflets in two layers. Both arms of sutures are passed into the annulus in the centre, suturing the leaflets to

the annulus up to both commissures. Then both arms are brought in the centre, making it a double layered suture line. Annulus is plicated in the same suture line by taking larger bites in the annulus. Heights of the leaflets can be reduced, if needed, by taking deeper bites in the leaflets (Fig. 3).

Measana et al. plicated the whole of posterior annulus with interrupted annuloplasty sutures after P2 resection and detaching P1 and P3 from annulus. A second row of interrupted annular sutures was used for annuloplasty [14].

(b) *Triangular resection*

Triangular resection is performed by excising the prolapsed segment in triangular fashion, attaching them together in two layers. Triangular resection was advocated by Carpentier for limited prolapse, involving only one third length of the segment [7]. Recently, it is becoming the preferred technique in comparison to quadrangular resection. A quadrangular resection usually requires leaflet detachment from the annulus and annular plication or a sliding plasty to repair the resulting defect. The triangular resection has several distinct benefits over a quadrangular excision. Because degenerative leaflet pathology is usually most predominant at the leading edge, such an extensive resection toward the annulus of otherwise normal tissue is often unnecessary. *Furthermore, a quadrangular resection/sliding plasty requires added steps, as it creates a longer suture line and is more prone to technical failure at the annular level* [15].

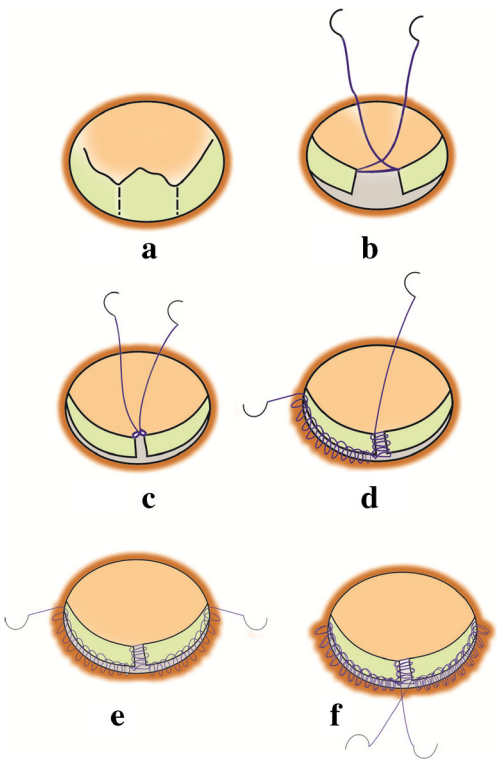

Fig. 3 Quadrangular resection with sliding leaflet plasty. **a** Prolapsed P2 segment line of excision. **b** P2 is excised and P1 and P3 detached from annulus. **c** A double armed 5–0 polypropylene suture approximates P1 and P3. **d** One arm of suture approximates P1 to annulus toward AC. **e** Another end approximates P3 to annulus toward PC. **f** Both sutures run as second layer toward centre and tied resulting in single knot

Several other techniques for posterior prolapse have also been described.

(c) *Butterfly technique*

This technique was described by Asai et al. typically for a P2 prolapse but applicable to P1 and P3 pathology as well. This technique essentially combines a shallow triangular resection with a sliding leaflet annuloplasty; the residual leaflets of which resemble butterfly wings [16]. This repair eliminates the prolapse and prevents systolic anterior motion (SAM) while preserving enough leaflet tissue to avoid a monoleaflet repair. The overall results are excellent. The 3-year estimated survivals free from overall death and reoperation for recurrent mitral regurgitation in the Butterfly group were compared with Quadrangular group. The survivals in the Butterfly group and the Quadrangular group were 97% ± 2 versus 96% ± 3% (P = .89). Reoperations for recurrent mitral regurgitation in these groups were 95% ± 3 versus 96% ± 3% (P = .75) [17].

(d) *Double breasting technique*

It was described by Raman et al., in which flail segment of the middle scallop of the posterior leaflet with torn chordae is excised as a triangular or quadrilateral section with the wider segment along the base of the leaflet. The sliding incisions are made close to the base of adjacent leaflet tissue, preserving the chordal support to the adjacent edges. The two leaflet edges are folded and advanced sideward in opposite directions. The two leaflet edges are sutured to the base of the leaflet, close to the apex of the sliding incision on the annulus [18].

There are several other techniques in which the P2 prolapsed segment is excised in a shape and named accordingly as Fleur de Lys technique [19], hourglass technique [20] and hair cut technique [21].

(e) *Plication techniques and foldoplasties*

After the initial McGoon's plication [7] technique, there have been many other plication and foldoplasty techniques. In these techniques, the diseased segment is retained and leaflet pliability is restricted and, thus, are not preferred.

2. Anterior leaflet prolapse

Unlike posterior prolapse, it is a difficult lesion to repair. The techniques used for anterior leaflet prolapse are as follows:

(a) *Triangular resection*

Triangular resection of the anterior mitral leaflet was originally described by Carpentier but abandoned because of the severe reduction in area (particularly in rheumatic patients). It should be used when prolapse is small (being less than one fifth of the length of free margin of anterior leaflet) and only 10% leaflet area is resected. The defect can be repaired by interrupted or continuous sutures in an inverted fashion (Fig. 4). Many studies have shown that anterior leaflet resection is comparable to other anterior leaflet procedures in degenerative disease [7, 15]. The 5-year results for freedom from cardiac death, reoperation and valve-related complications among the 211 patients with degenerative aetiology were, respectively, 93, 94 and 90% at New York University Medical Center by Galloway et al. [22].

(b) *Leaflet fixation on secondary chordae*

It is applicable only in limited prolapse when there is strong chorda (less than 5 mm away from free edge). These chordae are cut and fixed on margin, mostly in case of rheumatic disease [7].

(c) *Chordal transfer*

The technique was originally described by Carpentier and popularised by Duran [23] and Cosgrove [24]. We have successfully used this technique. In this technique, the lesions were identified as deficit chordae, either ruptured or elongated, of A2 scallop by two silk sutures, which were put medial to normal chordae on anterior leaflet for identification of unsupported portion. The corresponding portion of posterior leaflet usually P2 scallop was also demarcated by two silk sutures. This portion of posterior leaflet along with intact normal chordae was excised like standard quadrangular resection, and it was attached to unsupported anterior leaflet with 4–5 interrupted 4–0 braided sutures. The posterior leaflet was repaired in standard fashion with or without sliding leafletplasty and the procedure was completed with posterior band annuloplasty (Fig. 5) [25]. Although the long-term results have been quite good being 5-year freedom from reoperation after mitral valve repair 96% [26], yet this technique has been criticised, as it disturbs the morphology of normal posterior leaflet and decreases the pliability of both leaflets.

3. Bileaflet prolapse

Depending upon the sites of prolapse, the combinations of techniques used for anterior and posterior leaflet prolapse can be used. Another technique edge-to-edge, devised by Alfieri, is a simple technique which can be very useful in bileaflet prolapse. In this technique, interrupted sutures are used to attach A2 and P2 in midportion or the other respective segments. Alfieri group has published the outcomes of these patients at 17 years. The actuarial survival was 72.4 ± 7.89% and freedom from reoperation was 89.6 ± 2.74% [27]. This approach has been criticised because it dramatically increases stress on both leaflets, resulting in MV stenosis and leaflet tissue fibrosis. It also compromises one of the fundamental principles of MV repair, preserving leaflet mobility [28]. However, this technique has been adopted in percutaneous correction of mitral regurgitation, known as MitraClip system. The MitraClip system (Abbott Laboratories, Abbott Park, IL, USA) reproduces the edge-to-edge technique by attaching both free edges of mitral leaflet with a clip delivered

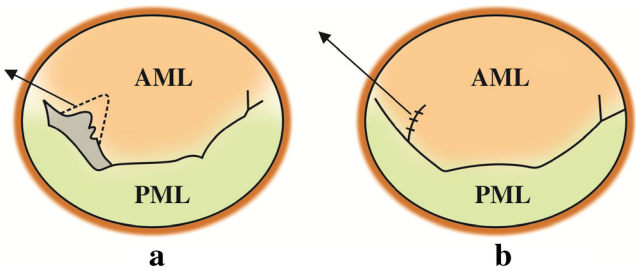

Fig. 4 Triangular resection. **a** Prolapsed segment resected in triangular fashion.**b** Defect is closed by running 5–0 polypropylene suture in two layers

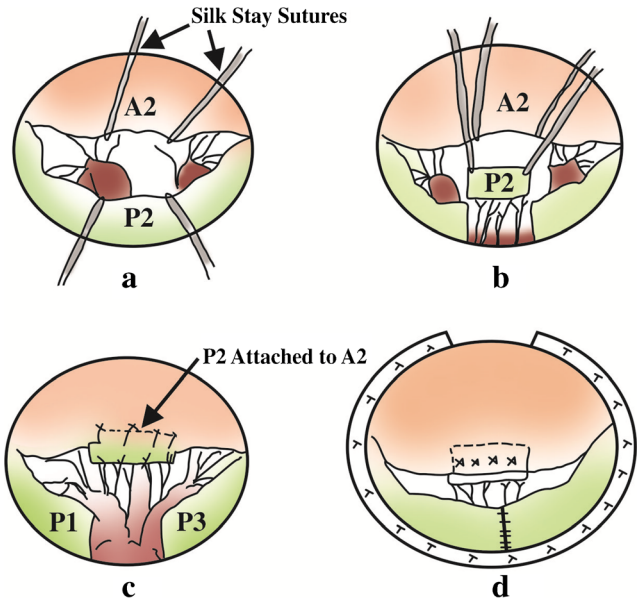

Fig. 5 Chordal transfer technique. **a** Normal P2 segment and prolapsed A2 segment delineated by silk sutures. **b** P2 segment with normal chordae detached from annulus. **c** Detached quadrangular-shaped P2 segment attached to A2 segment. **d** Repaired PML similar to steps c, d, e and f as mentioned in Fig. 3

transvenously. This device has been used in selective high-risk surgical patients [29].

4. Commissural prolapse

The prolapse can be corrected by closing the commissure by continuous inverting sutures [30]. The limited prolapse can be corrected by one or two inverted figure of eight sutures. This technique can be used to correct the commissural prolapse, either as primary one or residual leak, persisting after valve repair and is known as Magic suture [31].

Techniques in type III a dysfunction (restricted leaflet motion in diastole)

Alain Carpentier further divided this classification in to four subgroups:

1. Pliable leaflets
2. Rigid leaflets
3. Minimal subvalvular fusion
4. Severe subvalvular fusion and/or calcification

The criteria for mitral valve repair in this type of dysfunction are the combination of pliable leaflets and minimal subvalvular fusion, whereas there is some feasibility of repair in case of rigid leaflet with minimal subvalvular fusion or pliable leaflets with severe subvalvular fusion [7]. The majority of lesions in type IIIa have rheumatic origin. Most common type of dysfunction in RHD is type IIa/IIIp which is restricted posterior leaflet with relative anterior leaflet prolapse. The leaflets repair techniques are as follows:

(i) *Commissurotomy*

Commissural fusion is corrected by commissurotomy. Commissurotomy was the first technique used in CMV (closed mitral valvotomy) and proved itself as a very useful technique. This technique is the mainstay of treatment of mitral stenosis by percutaneous method known as PBMC (percutaneous balloon mitral commissurotomy) now in suitable morphology, assessed by echocardiography. Open mitral commissurotomy has remained an alternative method when it is not feasible to perform CMV or PBMC. Commissurotomy can be performed in grade I (clearly visible line of fusion) and II (faint line of fusion), but difficult in III (no line of fusion visible) (Fig. 6). It is performed with No 11-knife blade, starting 5 mm away from annulus and then holding the chordae on both sides by nerve hooks, the opening is made and can be extended to separation of two heads of papillary muscle [7]. It is essential to separate the leaflets in exact plane so that chordae are there on both margins. We mark the fusion line with ink marker pen and apply traction sutures on both edges of leaflets to do so (Fig. 7).

(ii) *Cusp thinning*

There is excessive fibrous tissue on leaflets in rheumatic disease. Removal of the fibrous tissue may restore the leaflet pliability. Cusp thinning can be performed by sharp dissection or blunt dissection. In sharp dissection, the fibrous tissue is taken out from both sides of leaflets usually in chips with No 15-knife blade. The disadvantages of sharp dissection are that it can lead to leaflet perforation and bridges of residual fibrous tissue. The blunt technique was devised by Kumar et al. from India popularly known as Peeling [6]. In this technique leaflet edge is grasped with Russian forceps. The plane of fibrous peel is separated from annulus by Debakey forceps and fibrous layer is gradually removed up to margins by blunt dissection. If fibrous tissue is densely adherent to margins, then it is sharply cut by scissor (Fig. 8). The advantages of peeling are minimal residual fibrous tissue and usually no leaflet perforations. Disadvantage of peeling is that it cannot be performed on the under surface of leaflets and requires patient surgical skills with learning curve. This technique has extended the feasibility of MV repair in RHD. Eventually, this useful technique has been followed all over the world [32, 33] and, thus, deserves to be labelled as Indian Correction. We perform cusp thinning on both surfaces using both blunt and sharp dissection methods.

(iii) *Pericardial patch augmentation*

Usually, there is paucity of leaflet tissue due to fibrosis and retraction of leaflets in RHD. Leaflet extension by autologous pericardium was initially described by Shumway et al. [34]. It

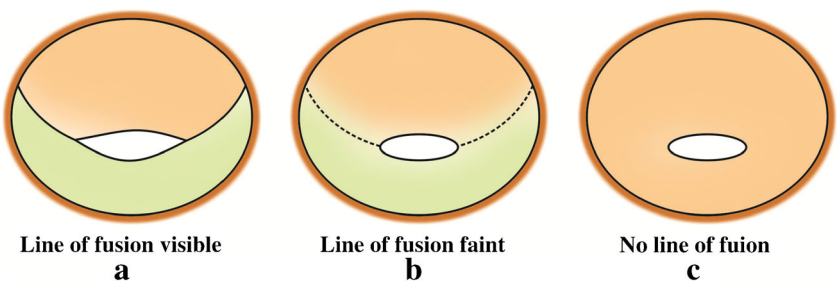

Fig. 6 Grades of commissural fusion. **a** Grade I: clearly visible line of fusion. **b** Grade II: faint line of fusion. **c** Grade III: no line of fusion visible

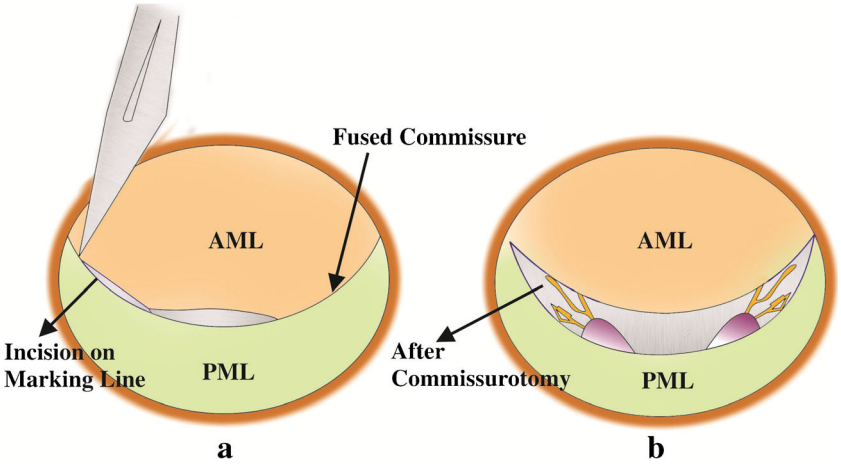

Fig. 7 Commissurotomy technique with no. 11 blade knife. **a** Incision starts 5 mm away from annulus after marking of fusion line. **b** Incision is extended toward opening keeping intact chordae on both leaflets

was tested clinically by Frater et al. 10 years later [35]. The outcomes were disappointing, mainly due to occurrence of retraction and calcification. The other materials such as autologous fascia lata or glutaraldehyde-treated bovine pericardium also were disappointing. But after successful experimental studies on stabilisation of autologous pericardium with 0.6% glutaraldehyde, Alain Carpentier demonstrated better results [36]. Leaflet augmentation with pericardial patch is an apt technique to increase the area of leaflets. Posterior leaflet extension is undertaken when there is severe leaflet retraction, especially when the vertical height is less than 10 mm. Anterior leaflet extension is recommended when the area of the leaflet is smaller than 26 mm [37]. In this technique, the retracted and fibrosed portion of leaflet is excised leaving the margins with intact chordae usually from commissure to commissure. In case of extensive fibrosis, the excision is extended beyond commissures. An appropriate sized oval-shaped glutaraldehyde-treated autologous pericardial patch is cut. The pericardial patch is sutured to the edges of residual leaflets either with interrupted or continuous 5–0 polypropylene sutures from commissure to commissure and even beyond (Figs. 9 and 10). Extension of the patch up to commissure or beyond makes new coaptation surface area by pericardial patch making the neoleaflet mobile. The intermediate and long-term results are quite encouraging [36, 37]. This technique has made feasible mitral valve reconstruction in RHD when adequate area of leaflets is not achievable by other methods. Dillon et al. from Malaysia did leaflet extension with glutaraldehyde-treated autologous pericardium in 62 of 446 rheumatic patients as part of their mitral repair procedure. Leaflet extension was performed in the posterior, anterior, and both leaflets in 77, 13, and 10% of patients. At 5 years postoperatively, the estimated rates of freedom from reoperation and valve failure were 96.8 and 91.6%, respectively [37].

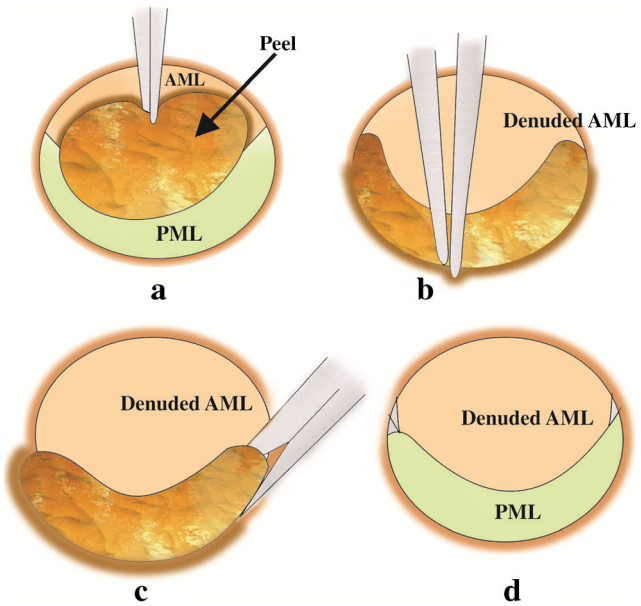

Fig. 8 Technique of peeling for anterior leaflet thinning. The leaflet edge is grasped with Russian forceps. **a** The plane of fibrous peel is separated from annulus by Debakey forceps. **b** Fibrous layer is gradually removed up to margins by blunt dissection. **c** If it is densely adherent to margins, then it is sharply cut by scissor. **d** Denuded AML

Chotivatanapong et al. from Thailand operated 221 rheumatic patients and had 97% survival and 98% freedom from reoperations at 3 years. They used combinations of different techniques including cusp thinning and pericardial patch leaflet extension [32].

We describe here our experience of mitral valve repair in RHD. From January 2007 to July 2015, 238 patients predominantly young females were operated using combination of different reparative techniques including leaflet thinning and pericardial patch leaflet augmentation. The valve dysfunction was type IIp/IIIa in majority of patients. Early mortality was 5.62%. Patients were followed up and were evaluated clinically and by transthoracic echocardiography. Mean follow-up was 6 years. Various outcome parameters were survival 91.59% and freedom from reoperations 95% [38].

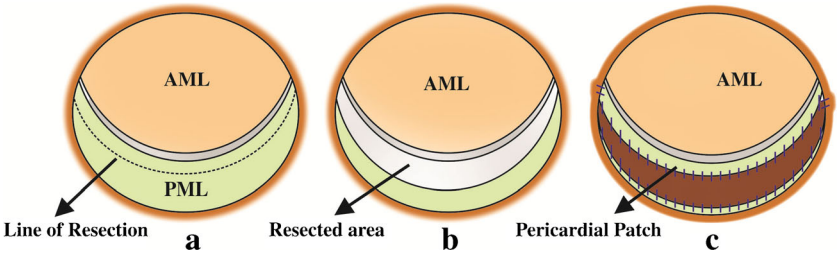

Fig. 9 Technique of PML augmentation by autologous pericardial patch. **a** Line of resection extends up to or beyond commissures on both sides. **b** The fibrosed and retracted portion of the leaflet is excised. **c** An appropriately sized oval-shaped glutaraldehyde-treated autologous pericardial patch is sutured in place extending to or beyond commissures, with 5–0 running or interrupted sutures

Type IIIb dysfunction (restricted leaflet motion in systole)

The main lesions in type IIIb dysfunction are tethering of posterior leaflet in the region of P2 and P3 due to left ventricle dyskinesia and dilatation. The main useful technique is reduction annuloplasty. Anterior and posterior leaflet augmentation with either bovine pericardium or autologous pericardium similar to methods used in IIIa dysfunction has been advocated for correction of severe form of this dysfunction. Posterior leaflet extension with annuloplasty of the mitral valve for severe type IIIb ischemic regurgitation is a safe and effective method that provides good early and intermediate-term results This technique addresses the pathophysiology of tethered leaflets especially in the region of P2 and P3 [39]. In patients suffering from ischemic mitral regurgitation (MR), anterior leaflet augmentation was also found simple and reproducible method of valve repair [40].

Comparison of techniques

There is a controversy whether leaflet resection technique is better than the chordal replacement one. The resection technique is curative because it removes the main pathologic lesion, but its disadvantage is that it is complicated and often requires advanced surgical skills. On the other hand, chordal replacement is not pathologically curative because it leaves behind a redundant leaflet. The three repair techniques (quadrangular resection, triangular resection and neochordoplasty) were compared for correction of posterior leaflet prolapse in the experimental model of acute chordal rupture with otherwise normal leaflet geometry. All these techniques were found hemodynamically comparable. But valve function and leaflet kinematics were significantly better after a nonresection or limited resection [41]. In another in vitro experimental model, three techniques (triangular resection, neochordoplasty and edge-to-edge) were compared for correction of anterior leaflet prolapse. Reduction in MR was achievable with all these techniques. Neochordoplasty and triangular resection proved superior to edge-to-edge repair in eliminating MR [42]. However, the long-term results appear to be equivalent for various techniques in many reports. Functionally, chordal replacement retains greater posterior leaflet motion with a lower trans-mitral pressure gradient than quadrangular resection. Moreover, chordal replacement is simple and yields uniform results. The optimal technique depends on whether the anterior leaflet or posterior one is involved and a mini-thoracotomy/robotic or standard sternotomy approach is used.

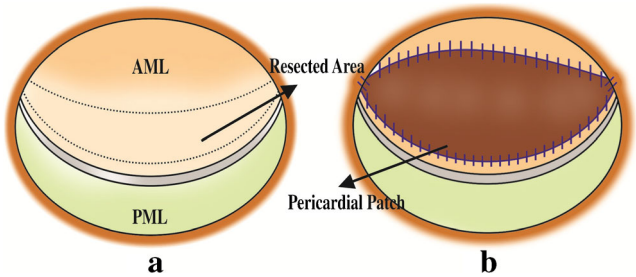

Fig. 10 AML augmentation technique by autologous pericardial patch. **a** The fibrosed and retracted portion of the leaflet is excised. **b** An appropriately sized oval-shaped glutaraldehyde autologous pericardial patch is sutured in place extending to or beyond commissures, with 5–0 running or interrupted sutures

Conclusion

For mitral valve repair, the most superior and reliable technique for the posterior leaflet is resection, using the newer limited resection technique [43]. Current trend for robotic approach is quite encouraging, performing limited posterior triangular resection with artificial chordae to anterior leaflet for complex lesions in degenerative disease [44]. In RHD adoption of cusp thinning and leaflet augmentation with pericardial patch, the feasibility of durable repair has been extended [37]. Similarly, with better understanding of pathophysiology of ischemic mitral regurgitation, the new techniques involving leaflets and subvalvular apparatus have also progressed for more stable and durable repair [39].

Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, formal consent is not required.

Conflict of interest Shamsher Singh Lohchab, Ashok Kumar Chahal, Kuldeep Singh Laller, Divya Arora and Sanjay Johar declare that they have no conflict of interest.

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