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Mitral Valve Repair in Degenerative Mitral Regurgitation: State of the Art

Michele De Bonis[a,*], *Ottavio Alfieri*[a], *Malcolm Dalrymple-Hay*[b], *Benedetto Del Forno*[a], *Filip Dulguerov*[c], *Gilles Dreyfus*[c]

[a]"Vita-Salute" San Raffaele University, Department of Cardiac Surgery, IRCCS San Raffaele Hospital, Milan, Italy
[b]Plymouth Hospitals NHS Trust, Department of Cardiac Surgery, Derriford Hospital, Plymouth, United Kingdom
[c]Cardiothoracic Center of Monaco, Monte Carlo, Monaco

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ABSTRACT

In industrialized countries, the most common etiology of mitral regurgitation (MR) is degenerative mitral valve (MV) disease. The natural history of severe degenerative MR is poor. However, its appropriate and timely correction is associated with a life expectancy similar to that of the normal population. Surgical MV repair is the gold standard treatment. This review will focus on the most recent evidence with a specific emphasis on surgical indications, timing of treatment, contemporary surgical techniques, Heart Teams and Centers of Excellence.

Contents

Statement of Conflict of Interest: see page 392.

* Address reprint requests to: Michele De Bonis, MD, FESC, FAHA, "Vita-Salute" San Raffaele University, Department of Cardiac Surgery, San Raffaele Hospital, Via Olgettina 60, 20132 Milan, Italy.
E-mail address: debonis.michele@hsr.it (M. De Bonis).

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Abbreviations and Acronyms

2D = Two-dimensional

3D = Three-dimensional

CE = Centers of excellence

DMR = degenerative mitral regurgitation

LA = Left atrium or atrial

LV = left ventricular

LVEF = Left ventricular ejection fraction

LVESD = Left ventricular end-systolic diameter

MR = mitral regurgitation

MV = mitral valve

PTFE = Polytetrafluoroethylene

RT3D-TEE = Real-time three dimensional trans esophageal echocardiography

SAM = systolic anterior motion

TEE = transesophageal echocardiography

TTE = transthoracic echocardiography

Mitral regurgitation (MR) is the second most frequent valvular heart disease after aortic stenosis in hospitalized patients and is most common in the general population.[1] In industrialized countries, the most common etiology of organic MR is degenerative mitral valve (MV) disease (either myxomatous degeneration or fibroelastic deficiency), leading to MV prolapse. The natural history of severe degenerative MR (DMR) is poor. Indeed, after an initial prolonged asymptomatic period, severe DMR enters a symptomatic phase accompanied by left ventricular (LV) decompensation and adverse outcome. MV repair is the gold standard treatment for DMR, its appropriate and timely correction is associated with a return to a life expectancy similar to that of the normal population.

Reliable and reproducible MV repair techniques have been developed and popularized by Carpentier and have confirmed their durability at long-term follow up. In recent years new surgical techniques have been adopted along with minimally invasive approaches and several trans-catheter methods have emerged as possible therapeutic options in particular circumstances. Finally, new imaging modalities and the concepts of Heart Team and Center of Excellence (CE) for MV repair have been introduced and a multidisciplinary approach in the evaluation and treatment of those patients is becoming a reality in many institutions.

The state of the art of the management of patients affected by DMR will be addressed in this review.

Indications and timing for correction of DMR

Criteria for appropriate management of patients with DMR are given in the published American and European guidelines.[2,3] According to European Society of Cardiology/European Association of Cardiothoracic Surgery guidelines recently release,[3] MV repair is indicated in patients with symptoms and/or signs of LV dysfunction (LV ejection fraction or LVEF $\leq$ 60% and/or LV end-systolic diameter or LVESD $\geq$ 45 mm). If LV function is preserved, surgery should be considered in asymptomatic patients with atrial fibrillation related to MR or pulmonary hypertension (Pulmonary artery systolic pressure >50 mm Hg at rest). Surgery should be considered in asymptomatic patients in sinus rhythm with preserved LVEF ($\geq$60%) and LVESD 40–44 mm, when a durable repair is likely at low risk, and in presence of a flail leaflet or significant left atrial (LA) dilatation (volume index $\geq$60 ml/m^2 BSA). In the other asymptomatic patients, who have no other indication for surgery, the most appropriate management remains controversial as there are no randomized trials to support any particular strategy. However, according to both American and European Guidelines, surgery should be proposed in asymptomatic patients with severe MR if risk is low and repair is likely and performed in a heart valve CE. A reference center is defined by the American College of Cardiology and American Heart Association Guidelines as a center with a mortality of <1% after MV repair, a repair rate without residual MR of >95% and >90% of patients discharged from hospital without any major complications. All these conditions should be fulfilled without any selection of patients based on lesion complexity.

Alternatively, severe MR can be followed with a careful monitoring approach with frequent clinical follow-up. This approach seems particularly indicated in elderly patients with relevant comorbidities and/or complex valve lesions who may have an operative risk which outweighs the advantages of correcting MR. Those patients should be closely followed in order to safely postpone surgery.[4]

In patients with severe LV dysfunction, a durable surgical repair can still improve symptoms, although the effect on survival is largely unknown. In this situation, the decision of whether to operate will take into account the response to medical therapy, surgical risk, and the likelihood of successful valve repair. Finally, a percutaneous edge-to-edge procedure may be considered in patients with symptomatic severe primary MR who fulfill the echo criteria of eligibility, are judged inoperable or at high surgical risk by the heart team.

Echocardiography: the essential diagnostic tool for MV repair

Echocardiography can provide all the relevant information for decision-making with regard to the treatment of MR: parameters include the severity of MR, its consequences on LV size and function, the LA and pulmonary circulation. Tricuspid regurgitation (TR), annular size and RV function are additional important parameters. Two-dimensional (2D) multiple-plane echo images

and Doppler analysis, using transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) approaches, provide a reliable evaluation of the type of lesion and mechanism according to the Carpentier classification and give important information concerning the likelihood of repair (Fig 1). Real Time Three-dimensional (3D) TEE (RT3D-TEE) has significantly enhanced the diagnostic capability of ultrasound beyond 2D imaging, providing a comprehensive and real-time dynamic MV anatomical view and additional details for the evaluation of patients with MR (Fig 2).[5] In terms of tissue characterization of MV apparatus, excessively mobile and redundant leaflets with systolic thinning are a marker of myxomatous degeneration, whereas thin leaflets and chordae tendinee are the characteristic findings of fibroelastic deficiency. The extreme and diffuse myxomatous degeneration of MV apparatus typically indicate Barlow disease. Calcium can be detected by 2-D echocardiography, but precise information over the distribution of calcium in the leaflets and in the annulus can better be provided by RT3D-TEE. The location and the amount of calcium can strongly affect the repairability of the valve. In Table 1 the type of MV lesions based on echo diagnosis are listed along with the difficulty of repair and the likelihood of valve replacement. Besides the preoperative assessment, intraoperative TEE, preferably with the help of 3D technology, is crucial to demonstrate the absence of residual MR, a good length of coaptation and exclude the presence of significant leak and/or systolic anterior motion possibly requiring further correction.

Before discharge from hospital an echocardiography should always be performed to confirm the adequacy of the repair.

Finally, echocardiography can identify MVs which are anatomically suitable for transcatheter repair in patients who are considered inoperable or at high surgical risk by the Institutional Heart Team.

Heart team and heart valve centers

Although >95% of primary MR lesions can currently be successfully repaired in expert centers, the repair rate remains highly variable depending on center and surgeon's experience.[6] For that reason, current guidelines propose that such surgery should only be undertaken in high volume specialist units, so called "Heart Valve CE" which should offer all available options for diagnosis and management of patients with valve disease. The goal of a structured heart valve center should be the delivery of better quality of care through large volumes of repair procedures (center and surgeon), advanced imaging techniques and transparency regarding outcomes. The relationship between case volume and outcomes for surgery in MV repair is complex but cannot be denied.[6] Current data are not sufficient to establish the precise numbers of procedures per surgeon or center required to provide high-quality of care. However, a volume of 25 repairs per year per surgeon and 50 repairs per year per hospital has been proposed as a likely minimum cut-off value to achieve that goal.[7] Indeed, an annual surgeon volume of <25 operations has been associated with lower repair rate, increased 1-year mortality and higher incidence of reoperation.[8]

Moreover, MV repair surgery requires a significant learning curve demonstrably linked to the volume of the procedures performed in the center. Interestingly, an improved MV repair rate has been observed in low-volume surgeon working in high-volume center or in which there is a surgeon performing >50 procedures per year.[8]

In addition to a focused surgeon, one or more cardiologists and anaesthesiologists interested in MV disease should be part of a dedicated multidisciplinary multi valve team.

Advanced imaging and, in particular, high-quality TTE and TEE, including 3D technology must be routinely available for preoperative, intraoperative and postoperative evaluation.

Results in a MV repair center should be reported with the goal of achieving <1% mortality for isolated repair, a near 100% repair rate and <5% repair failure at 5 years follow-up. A reference center for MV repair should be scientifically productive, involved in research and innovative techniques.

Finally, heart valve CEs should pursue adherence to international guidelines, timely referral of patients, evaluation and improvement of patient outcomes, specialization of training, continuing education and active participation in regional or national outcome registries.

Surgical techniques of MV repair in DMR

Surgical access, valve exposure and evaluation

MV surgery is usually performed through a full median sternotomy, although the right lateral minithoracotomy and partial sternotomy, are currently used in many centers. In addition a totally endoscopic approach, with or without robotic assistance, has significantly advanced in the last years. Particularly in the United States, following two clinical trials, the Federal Drug Administration approved the Da Vinci Surgical System in 2002 for intra-cardiac surgery. This device has undergone three iterations and at present it is the only robotic device approved for MV surgery. Several centers have adopted its use as part of their routine MV repair armamentarium.

Extracorporeal circulation with direct aortic and bi-caval cannulation is used for full sternotomy. Peripheral cannulation of the femoral vessels (artery and vein) is usually adopted for minithoracotomy and endoscopic or robotic approaches. An appropriate exposure of the MV plays a key role during surgery. The exposure of the MV is usually done by a direct

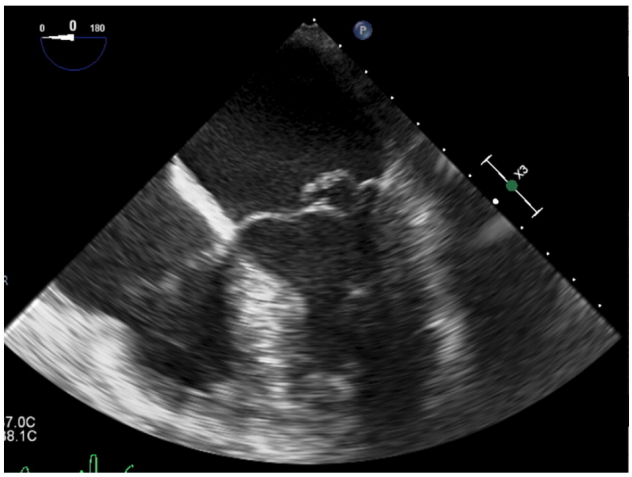

Fig 1 – Myxomatous mitral valve with posterior leaflet prolapse (Two-dimensional TEE).

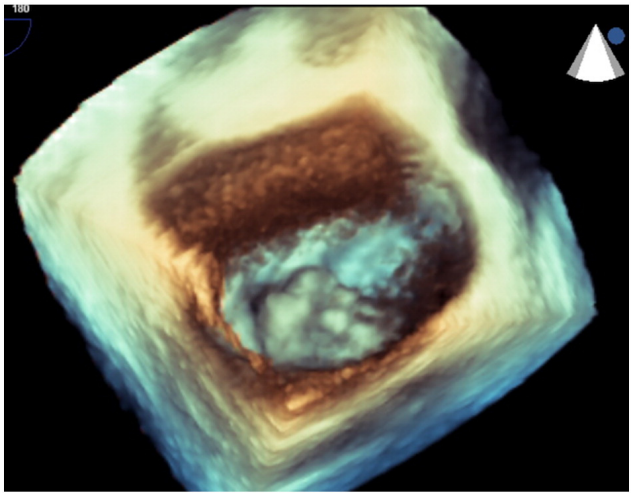

Fig 2 – Myxomatous mitral valve with posterior leaflet prolapse (Real-Time 3D TEE).

left atriotomy through Waterstones groove. Alternatively, a trans-septal incision (though the right atrium, when intervention on the tricuspid valve is also necessary) or superior approach (roof of LA) may be adopted.

An intraoperative assessment and valve analysis is performed. The first discrimination is between myxomatous degeneration or fibroelastic deficiency of the MV apparatus taking into consideration that a large number of intermediate degrees of these pathologies can be found between their two most extreme forms. By using hooks, the mitral leaflets are gently pulled in order to evaluate their mobility and to identify chordal rupture or elongation. The scallop P1 is usually not prolapsing in the vast majority of the patients and is commonly used as reference marker to test the presence and degree of prolapse of all the other anterior and posterior leaflets scallops. The annulus is checked for dilatation and calcification and the subvalvular apparatus is also assessed. Finally, the commissural regions are carefully checked for fusion or prolapse.

According to the classical surgical classification of mitral leaflet pathology initially described by Carpentier the mechanisms of MR are described as:

Type I: Normal Leaflet Motion (Annular dilation, Leaflet perforation);
Type II: Leaflet Prolapse (Chordal Rupture/Elongation, Papillary muscle rupture/elongation)
Type III: Restricted Leaflet Motion
Type IIIa: During diastole
Type IIIb: During systole

In degenerative MV disease, prolapse lesions (type II) are usually present, from a single scallop involvement (most commonly P2) to multi-segment prolapse, up to Barlow's disease.

Surgical techniques

The techniques of repair first described by Carpentier remain largely adopted in the contemporary worldwide practice and have proved to be effective and durable at very long-term. All these approaches are based on three major targets for MV repair: a) restitution of physiological leaflet motion, b) establishment of an adequate line of leaflet coaptation and c) stabilization of the annulus while maintaining an adequate size of the mitral orifice.

Over the years newer procedures have been added to those fundamental methods of repair including the use of artificial chordae and the edge-to-edge technique. Nowadays >95% of degenerative lesions can be repaired successfully in expert centers using contemporary techniques.

Table 1 – Echocardiographic classification of complexity of mitral lesions in degenerative MV disease and surgical expertise required for a successful repair.

Echocardiographic
Valve lesion complexity
Simple lesions
(high probability of successful and durable repair)
– Posterior Leaflet prolapse/flail
– *Isolated mid scallop involvement (P2) with/without redundant tissue (leaflet height ≥ 15 mm)*
– Annular dilation
– Leaflet perforation
Complex lesions
(likelihood of successful and durable repair depending on experienced surgical team matching)
– Complex posterior leaflet lesions
– Anterior prolapse/flail
– Bileaflet prolapse/flail
– Commissural prolapse/flail
– Combined lesions
Lesions at high risk of unsuccessful repair
– Prolapse and extensive annular calcification
– Prolapse with hypoplasia of opposite leaflet
– Extreme fibroelastic deficiency

Posterior leaflet prolapse

Triangular/quadrangular resection

Prolapse of the middle scallop (P2) of the posterior leaflet represents the most frequent cause of MR in degenerative MV disease. In presence of a small prolapse of flail, triangular resection may be used to repair the posterior leaflet. If the prolapse is relatively large, a quadrangular resection of the prolapsing segment followed by annular plication of the base of the resected segment and approximation of the posterior leaflet can be used. To avoid the plication of the annulus with potential kinking of the circumflex artery, a quadrangular resection with sliding or folding plasty can be adopted where extensive excision has been performed, this also decreases the height of the posterior leaflet. The sliding and folding plasty are particularly indicated when the valve tissue is too redundant in order to decrease the risk of postoperative systolic anterior motion (SAM) of the anterior leaflet.

Table 2 – Outcomes of mitral valve repair.

	N. pts	Mean Age (years)	Leaflet Involved	Mean/ Median Follow-up (years)	30-Days Mortality	Overall Survival	Freedom From/CI REDO	Freedom From/CI MR ≥ 3
Tabata M 2014[17]	700	54 ± 14.9	AL, PL, BL	6.6 ± 4.6	1.3%	85.9% at 12 years	88.7% at 12 years	72.3% at 12 years
Yaffee DW 2014[18]	1612	–	AL, PL, BL	–	1.3%	77% (PB) 83% (CR) at 8 years	95% (PB) 92% (CR) at 8 years	91% (PB) 92% (CR) at 8 years
Suri RM 2016[11]	1218	64 ± 13	AL, PL, BL	11.5 [9.2–13.6]	–	–	6.9 ± 1% at 15 years	13.3 ± 1.2% at 15 years
Braumberger E 2001[19]	162	56 ± 10	AL, PL, BL	17 [1–29]	1.9%	48% at 20 years	96.9% (PL) 86.2% (AL) 82.6% (BL) at 20 years	–
David TE 2013[20]	606	56 ± 13.3	AL, PL, BL	10 ± 4.5	0.8%	66.8 ± 3.3% at 18 years	90.2 ± 2.4% at 18 years	67.5 ± 4.2% at 18 years
De Bonis M 2014[21]	139	54 ± 14.4	AL	11.5 ± 3.7	0	72.4 ± 7.9% at 17 years	89.6 ± 2.7 at 17 years	80.2 ± 5.9% at 17 years
Coutinho GF 2016[22]	475	58 ± 15.1	AL, BL	7.9 [3.6–11.5]	1.2%	61 ± 3.7% at 15 years	88 ± 2.7 at 20 years	–
Di Bardino DJ 2010[23]	1042	59 ± 13	AL, PL, BL	–	0.6%	62% at 20 years	82% at 20 years	–
Seeburger J 2008[24]	1339	60 ± 12.7	AL, PL, BL	2.34 ± 2	2.4%	82.6% at 5 years	96.3% at 5 years	–

CI: cumulative incidence. AL: anterior Leaflet. PL: posterior leaflet. BL: both leaflets. PB: posterior band. CR: complete ring.

Artificial chordae implantation

Chordal replacement with a polytetrafluorethylene (PTFE) suture is currently a popular technique for the treatment of diseased chordae ("respect rather than resect" approach). PTFE neochordae can be implanted in either anterior or posterior papillary muscles, respecting the policy of not crossing the midline or native chordae, to prevent excess traction. A variety of different techniques have been reported to establish the correct size of PTFE neochordae. In many instances the abnormal redundant leaflet tissue is displaced into the ventricle to maintain a good coaptation surface between leaflets and avoid SAM. Modified artificial chordae with a premeasured loop have been introduced several years ago and widely adopted to facilitate the use of a "respect" approach, particularly through a minithoracotomy approach.

Anterior leaflet prolapse

Repair of anterior leaflet prolapse is more complex than posterior leaflet repair. Various techniques may be used.

Chordal transfer

Chordal transfer involves the selection of a normal looking secondary chord which is detached from its insertion on its leaflet, and reattached to the margin of the anterior leaflet with 5/0 prolene. Although this is a reliable repair method using normal tissue, the technique is limited by the number of normal chordae available in valves affected by extensive disease.

Chordal transposition

Native chordae from the posterior leaflet can be transferred to the anterior leaflet to repair a prolapsing segment from an elongated or torn chord. The chosen chord from the posterior leaflet is resected with a portion of the above leaflet tissue and transposed on the anterior one.

The advantage of chordal transposition compared to the use of artificial chordae is that the former already have the correct length. On the other hand, a major disadvantage is the fact that a valve segment not affected by the pathology needs to be resected in order to transpose the chordae tendineae of the posterior leaflet.

Papillary muscle repositioning

This technique consists in separating the anterior head of the papillary muscle from the other heads and taking it down into the LV. This is achieved by putting a stitch in the fibrous segment of the anterior head and tying it to the fibrous segment of the posterior head. Since the chordae arising from the anterior head are anchored to the anterior leaflet, by shortening its length it is possible to correct anterior leaflet prolapse in a very effective and durable way.

Implantation of artificial chordae

The use of artificial chordae tendineae (neochordae) is a now widely used technique to treat anterior leaflet prolapse. Artificial chordae are fastened to the fibrous portion of the papillary muscle on one end and to the free margin of the prolapsing portion of the anterior leaflet on the other. The main technical difficulty lies in determining the proper length of the neochordae. In case of isolated prolapse of the anterior leaflet, the best way to determine the correct length is to use the height of the non-prolapsing posterior leaflet as a reference. In the case of bileaflet prolapse or prolapse of several segments, the point of reference to be used is the lateral commissure, unless it is affected by the degenerative process. Modified artificial chordae with a premeasured loop have also been introduced to facilitate the choice of the proper length.

Edge-to-edge technique

Segmental prolapse of the anterior MV leaflet, involving only one scallop, can be effectively treated also with the edge-to-edge technique (E-to-E). The matching edges of both leaflets are sutured together at the site of MR. If the prolapse involves the central scallop of the anterior leaflet (A2), this correction generates a double orifice valve. By contrast, when the prolapse involves either the lateral (A1) or medial (A3) scallops of the anterior leaflet, the edge-to-edge suture leads to a single orifice valve with a relatively smaller area. Although this approach allows a "functional" rather than an "anatomical" repair, long-term results have confirmed that its effectiveness and durability are not inferior to conventional "anatomical repairs". Due to its simplicity, this technique is very attractive particularly when a short cross-clamp time is important because of comorbidities, low LVEF or multiple concomitant procedures.

Bileaflet prolapse

Bileaflet prolapse is typically encountered in the context of a global myxomatous degeneration of the MV (Barlow's disease). A combination of the surgical techniques previously described are usually used to treat the prolapse of the posterior (resection, artificial chordae) and of the anterior (artificial chordae, papillary muscle repositioning) leaflets. Alternatively, the edge-to-edge repair finds one of its best indications in this difficult setting.

Prosthetic annular ring

In surgical MV repair, annuloplasty plays a very important role and is routinely carried out by means of a prosthetic ring or band. The aim of annuloplasty is to restore the normal ratio between annular diameters, regain normal annular shape, prevent further dilatation and increase the coaptation surface of the leaflets which is important for repair durability. Lack of annuloplasty has been associated with reduced durability of surgical repair.[9–11] Currently annuloplasty is avoided in selected patients undergoing trans-catheter mitral repair procedures but the long-term durability of these ringless approaches remains unknown.

The final repair is assessed initially by visual inspection. A uniform coaptation line close and parallel to the posterior annulus and the absence of regurgitation at the "water test" are usually predictive of a good result. At the intraoperative TEE performed after weaning from cardiopulmonary bypass it is very important that there is no (or only trivial) residual MR, a good length of leaflets' coaptation together with sufficient valve area and no iatrogenic stenosis.

Controversial issue: resect or not

Even though posterior leaflet prolapse is supposed to be a straightforward lesion with simple treatment and very good long-term results, in the real world it can be more complex. Indeed, isolated P2 lesion with a single ruptured chord is quite rare being observed in about 20–25% of the cases, while in the remaining 75% of the patients the lesions are more complex. There is often excess of tissue in height and width, the involvement of another scallop such as P3 (or the posterior commissure) is not rare and, therefore, the surgical strategy needs to be more refined. The initial approach proposed by Carpentier was to resect all the diseased tissue. This strategy has been progressively abandoned initially in favor of the triangular resection, leaving the annulus intact, and, more recently, by using a non-resection strategy. In between non-resecting and resecting when necessary, the debate is still ongoing and it does not seem that there is any clear difference in term of results, at least being published. Obviously even those who tend to say that they do not resect, they indeed do resect in about 35% of the cases, and therefore resection should not be considered as a failure. Resection has to be limited, adequate, and following a strict rationale.

Results of surgery

Despite the absence of randomized trials, when compared with MV replacement, repair has a lower perioperative mortality, improved survival and lower long-term morbidity, including less thromboembolism (stroke), bleeding and endocarditis.[12] In high volume centers, hospital mortality after isolated MV repair for DMR is <1%.[13,14] The overall experience of an individual surgeon does have a major impact on the hospital outcome, since lowest mortality and morbidity are usually reached after a total of 300 MV surgeries.[15]

Overall survival and quality of life are comparable to that of the general population of the same age but only if the procedure is performed before the onset of symptoms and LV dysfunction.[16] In contrast life expectancy is reduced if the procedure is carried out in patients with symptoms of congestive heart failure and in presence of reduced LVEF.[16]

The durability of MV repair is strictly related to the mechanism of MR, the techniques of repair and the experience of the center. The presence of residual MR greater than mild immediately after surgery is a strong predictor of repair failure. Most early failures are the result of technical issues while late failures primarily relate to progression of the degenerative disease with the occurrence of new leaflet prolapse/flail and, less commonly, leaflet retraction or infection. In many studies the long-term durability of mitral repair is assessed by using the freedom from reoperation. However, as shown in Table 2,[11,17–24] freedom from reoperation is not an accurate measurement of durability of MV repair, because the reoperation rate underscores the recurrence rate of MR which represents the true endpoint and is assessed by TTE/TEE. In most of the published series, the best results at long-term have been obtained in patients with isolated prolapse of the posterior leaflet. Less favourable outcomes, on the other hand, have been reported in patients with MR due to anterior leaflet and bileaflet prolapse in whom the risk of recurrence of moderate or severe MR after repair is 1–2% per year.[17–24] Although surgical expertise in MV repair is growing worldwide, extensive valve prolapse and annular calcification are some of the conditions which significantly decrease the likelihood of repair. Under those and other similar circumstances, like prolapse with hypoplasia of the opposite leaflet or extreme fibroelastic deficiency, surgery should better be performed in experienced centers with high repair rates and low operative mortality and morbidity.

Current role of the transcatheter methods in high surgical risk patients

A large number of patients with MR are still not referred for surgery being considered inoperable or a high surgical risk

because of age or comorbidities.[25] Transcatheter MV repair techniques have been developed as an alternative to treat those patients through a transseptal or transapical approach. In all high-risk patients with MR, a multidisciplinary Heart Team should evaluate the pros and cons of surgical, percutaneous and conservative approaches, and assess the risk/benefit ratio of each option by taking into consideration important comorbidities and individual life expectancy. Established risk scores (e.g. Society of Thoracic Surgery, Euroscore) should be used and several other factors (such as frailty) should be carefully evaluated as recommended by the VARC-2 consensus document[26] in order to tailor the approach to the individual patient. Finally, the possible futility of any intervention in very high-risk subjects must also be considered.

When adopting trans-catheter solutions, important lessons learned from decades of surgical experience should not be forgotten. In particular, large surgical series have demonstrated that, in presence of prolapse, the repair procedure should target both the leaflets and the annulus in almost all patients to achieve durable long-term results. The omission of ring annuloplasty, for instance, has been associated with poor long-term outcomes.[9–11] Therefore, in order to achieve long-term outcomes comparable to surgery, transcatheter repair therapy will need to encompass approaches that either overcome the limitations of singular methods by very careful patient selection or use multiple techniques.

Among the transcatheter procedures, currently only the edge-to-edge MV repair is widely adopted and experience with transcatheter annuloplasty is still limited. The applicability of the percutaneous edge-to-edge repair is limited because precise echocardiographic criteria have to be respected to make a patient eligible and the acute achievement of an optimal outcome, as defined by the MVARC criteria, remains difficult to predict.[27] The procedure is generally safe and can improve symptoms and provide reverse LV remodeling. However efficacy is suboptimal and the majority of patients are left with residual or recurrent MR $\geq$ 2/4 at 1 and 4 years.[28,29] When compared with surgical treatment, percutaneous E-to-E repair is associated with a higher rate of MR requiring repeat surgery and MR grades 3–4 at 1 and 4 years.[28,29] Current guidelines recommend that percutaneous edge-to-edge procedure may be considered in patients with symptomatic severe primary MR who fulfill the echocardiographic criteria of eligibility and are judged inoperable or at high surgical risk by the Heart Team, avoiding futility. At the present time, patients who can be offered mitral valve surgery with an acceptable risk should not be considered for the MitraClip procedure.

Trans-apical artificial chordae implantation

Trans-apical beating heart MV repair with expanded PTEE (ePTFE) chordal implantation represents an innovative operation to treat DMR due to leaflet prolapse. The procedure is performed through a small anterolateral left thoracotomy at the level of the fourth or fifth intercostal space to access the cardiac apex. Without the use of cardiopulmonary bypass it allows dynamic echo-guided adjustment of the ePTFE chord length in normal filling conditions of the heart. Currently two devices are available for this approach: the Neochordae DS1000[30,31] and the Harpoon system.[32] The Neochordae device allows the physician to grasp and pierce the leaflet, and then to pull a ePTFE chord through the prolapsing segment. After that, the ePTFE suture is tied with a girth hitch knot to re-suspend the prolapsing leaflet under normal filling conditions. The Harpoon device differs from the first one in the mechanism for fixation of ePTFE sutures on the diseased MV leaflet: the prolapsing segment is perforated from the ventricular side with a specially designed 21-gauge needle wrapped with 50 coils of ePTFE in a preformed knot configuration. At this point, a knot is formed on the atrial surface of the leaflet, fixing the associated pair of ePTFE artificial chords. Finally, like with NeoChord device, the chords are exteriorized at the level of the cardiac apex and then are titrated to an optimal length, defined as maximal coaptation on echocardiography and absent MR on color Doppler interrogation. Each pair is then tied on a single pledget to complete the procedure. Patient selection represents the key point for this technique.

Most of the patients who have been treated so far with Neochordae whose results were shown to be stable at early follow-up were almost exclusively patients with isolated posterior leaflet prolapse.[33] The intent, with transapical artificial chordae implantation, is to treat MR due to prolapsing lesions very early in the history of the disease, in presence of no or only initial annular dilatation and limited left ventricular remodeling. This “micro-invasive” off-pump approach, however, requires further studies and longer follow-up before its role can be clearly established.

Conclusion

Surgical MV repair is the standard of care in the management of patients with severe DMR. Surgical outcomes depend on pre-operative status, mechanism of MR, technique of repair and experience of the center and surgeon. Patients should be referred to experienced centers with a multidisciplinary heart team to maximize the likelihood of a durable repair. Timing of surgical referral is crucial. If the procedure is carried out timely and effectively, the operative risk is very low and life expectancy is the same as that of the sex-age matched population. In high-risk patients, the choice among surgical, percutaneous and conservative approaches can be difficult since definitions of “high surgical risk” and “inoperable patient” remain elusive being significantly influenced by surgeon and center experience. In this setting, tailoring the approach to the individual patient while avoiding futility remains challenging. Being able to perform such a complex decision-making process at the highest level will be one of the most important criteria to define a true “CE” in MV repair.

Statement of conflict of interest

None of the authors have any conflicts of interests with regard to this publication.

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