Degenerative Mitral Valve Repair: From Etiology, Pathology, Surgical Strategy to Durability

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To the Editor: Degenerative mitral valve disease is a common disorder afflicting 2–3% of the general population and nearly half of them are elderly.[1] Plenty of studies have confirmed that mitral repair would result in better outcomes than mitral replacement for degenerative valve disease.[2] In order to illustrate the relation of etiology, pathology, valvular dysfunction, surgical strategy, and midterm durability of mitral valve repair for degenerative valve disease, we retrospectively analyzed the data of a single center. In the consecutive cohort, all of operations were performed by a skillful surgeon (G. D.) based on 100% repair criteria.

We retrospectively analyzed 252 consecutive patients with degenerative mitral valve disease who underwent mitral repair in the Cardio-Thoracic Center of Monaco between January 2010 and December 2016.

Etiology of all patients was documented as degenerative disease. Patients undergoing concomitant aortic valve replacement and those who had previous myocardial infarction, angina pectoris, or endocarditis were excluded. The median age of patients was 68 years, and 30.6% of patients were female. The baseline data are presented in Supplementary Table 1.

Degenerative mitral valve disease was defined as a disease including fibroelastic deficiency (FED) and Barlow's disease (BD) diagnosed by transesophageal echocardiographer and surgeon intraoperatively and/or confirmed by pathologist postoperatively.

All operations were performed by the same surgeon (G. D.). All cases were completed through conventional sternotomy approaches. Operations were performed under cardiopulmonary bypass during mild hypothermia (32°C), and myocardial protection was achieved with cold crystalloid cardioplegia and topical cooling.

Valvular lesions were assessed by means of transthoracic echocardiography preoperatively and then confirmed by transesophageal echocardiography intraoperatively. Finally, it was analyzed by the surgeon intraoperatively. The lesions of the mitral valve observed during the systematic intraoperative assessment are summarized in Supplementary Tables 2 and 3. Before repairing, a careful surgical analysis of the valve is important not only to localize the prolapsed area but also to analyze whole leaflet, annulus, and subvalvular apparatus. If excessive tissue presents leaflet irregular with bulging deformations, a limited resection based on "resect with respect" principle should be carried out, to obtain regular and smooth leaflet. Usually, a limited prolapse was treated by triangular resection. Other alternative techniques, such as artificial chordae, chordal transfer, decalcification, papillary muscle (PPM) repositioning,[3] and sliding plasty, were also used to achieve one basic goal of restoring a smooth and correct-sized leaflet and creating the best coaptation area in the inflow of the left ventricle. The ratios of chordal transfer versus artificial chordae were 70% versus 30%. Considering the problems of proper determination of their length, the risk of calcification, and rupture of artificial chordae, only when there were no strong secondary chordae or in case of FED, we used neochordae. In some instances, we used both. Water test is crucial as it can show us reliable repair and closure line without any sutures or ring. All but 6 patients received a Carpentier-Edwards Physio II rigid prosthetic ring. The size of the mitral ring was 32.9 mm ± 7.0 mm. If tricuspid valve correction was needed, it was performed after the mitral valve repair.

A combination of several techniques was used to achieve real anatomical repair and restore the structure and function of mitral valve. During operation, we followed the principle of respecting healthy tissue and resecting excessive or unhealthy tissue without deforming the precise valvular configuration. The percentages of all surgical techniques used in this series are summarized in Figure 1. Coronary artery revascularization in case need to be done was performed after the valve repair. Cross-clamping time was 106.2 ± 36.1 min and cardiopulmonary bypass time was 126.0 ± 45.7 min.

Clinical variables were prospectively entered into databases including patient demographics and risk factors, operative information, and postoperative outcomes. Additional information

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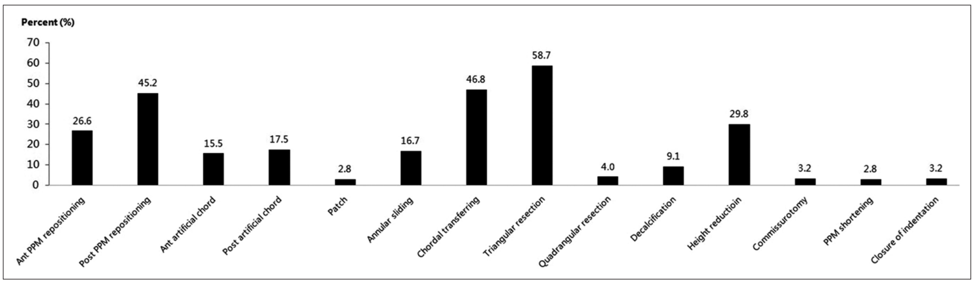

Figure 1: Percentage of surgical techniques in mitral repair. PPM: Papillary muscle.

was obtained from patient charts when necessary. The mean length of follow-up was 37 months (range: 1–95 months) and 98.4% of patients were successfully followed up.

Intraoperative transesophageal echocardiograms were obtained for all patients. Clinical and echocardiographic examinations were performed on all patients preoperatively, before hospital discharge, at 1 year, and then every year by the same cardiologist from our echo laboratory. On echocardiography, mitral valve regurgitation was graded from 0 to 4.

Continuous variables are presented as mean ± standard deviation and discrete variables were expressed by frequency percentages. Baseline characteristics considered clinically important were included. Comparative analysis of different groups was done based on Chi-square test. If variables were not normally distributed, nonparametric tests were used. Bivariate correlation between lesions and surgical techniques was calculated with Chi-square test. $P > 0.05$ indicates retention calibration of the model. The statistical analysis was performed using SPSS for Windows, version 17.0 (SPSS, Inc., Chicago, IL, USA).

One hundred percent repaired rate was achieved in all patients. There was no systolic anterior motion (SAM) echocardiographically or hemodynamically. There was a second pump run for significant mitral regurgitation (MR), which was repaired successfully by that. Three cases of coronary artery bypass grafts, 5 cases of ablative Maze, 4 cases of aortic valve replacement, 1 case of David, 2 cases of left atrial appendage closure, and 1 case of left atrial reduction were performed concomitantly. Two patients underwent extracorporeal membrane oxygenation support postoperatively. There were 3 operative deaths (1.2%) totally. Deaths were caused by multiple organ function failure, cardiopulmonary function failure, and ventricular failure, respectively.

Postoperatively, MR grade reduced dramatically (80.7% of patients presented no regurgitation, 16.0% of patients presented Grade 1+ MR, and 3.3% of patients presented Grade 2+ MR). No patient presented MR over Grade 2+ and the results remained stable at 1 year and midterm follow-up. Only 0.9% of patients suffered recurrent MR over Grade 3+ [Supplementary Figure 1]. However, there was no reoperation for recurrent residual MR.

No difference of operative and postoperative results was found between the FED and BD groups.

In this series, compared with FED, BD presented higher incidence of excess P2 height and elongated chordae and lower risk of chordal rupture [Supplementary Table 2]. In the case of mitral prolapse, P2 was the most vulnerable segment in both groups. Compared with FED, BD tended to present prolapse in A2, A3, P1, P3, anterior commissure, and posterior commissure. Posterior commissural prolapse was presented in 41.3% of cases in BD [Supplementary Table 3]. It is considered difficult to treat as the commissure is not well defined and often adjacent structures such as A3 and P3 are involved. The posterior commissure is the anatomical structure initiating coaptation; thus, if ignored, it can lead to recurrent/residual MR. With the trend of simplification of mitral valve repair, a regurgitant posterior commissure is often either simply sutured or neglected. We used PPM repositioning as an alternative surgical option in order to obtain a durable mitral valve repair. The posterior commissure has no surrounding support and is a weak point of the mitral valve apparatus. Results of direct suture or artificial chordae are not known.

As for excess height, we transect the redundant leaflet, but others bury the leaflet with the principle of respecting the leaflet and then pull the free edge into the ventricle with Gore-Tex suture line, but it is always difficult to determinate how much leaflet should be pulled down. Anyway if you made a mistake, you would get a SAM. We rarely have had a SAM as we often resect high leaflet. In the great majority of cases, the leaflet height is between 10 mm and 15 mm. If the height of any segment is up to or greater than 20 mm, the height of this segment should be reduced to avoid SAM. Some do triangular resection and folding as Mayo Clinic did.[4] Triangular resection was the most commonly used technique [Figure 1]. It is not only admitted as a simple, easy-to-follow technique but also results in satisfying long-term outcomes. Usually, we address prolapse separately with native chordal transfer or Gore-Tex chordate. Nevertheless, some treat both height and width together with isolated triangular resection but often need to add folding or restrict free edge chordae to bury the excess remaining height. So if you can remove what should be removed, that's where expertise, judgment, and experience come into place. Remember the principle is resection should be enough but avoid tension.

Water test is an important method to identify the repair result and should be undertaken without any sutures or ring. The closure line will present after left ventricle was full swelled. Basically, it should be evenly distributed at least 2/3–1/3 or even better 3/4–1/4. P2 is not higher than P1 and P3. In brief, the surgical principle is to restore the function of mitral valve using one or several combined techniques following the "resect with respect" concept. That is to resect redundant or diseased tissues while keeping healthy tissue as so as possible.

Fourteen surgical techniques were used to repair mitral valve. Among them, the most frequently used first three techniques were triangular resection, chordal transferring, and post-PPM repositioning. Other techniques include quadrangular resection, PPM repositioning, PPM shortening, artificial chord, patching, annular sliding, chordal transferring, decalcification, height reduction, commissurotomy, and indentation closure. In general, one or two techniques were applied to deal with one lesion. Sometimes, several techniques were often related to a certain lesion. Inversely, several lesions were often related to a certain techniques [Supplementary Figure 2]. To restore normal valvular anatomy with several combined techniques, it is so-called "French repair." On the contrary, another way to repair mitral valve with the intent of restoring normal valve function is called "American correction." Its principle is "respect, not resect," as repair involves placement of artificial chordae, minimal to no leaflet resection, and flexible annuloplasty. These differing methods of mitral valve repair reflect an evolution in principles, but both approaches require complete understanding of the valve anatomic pathology and correction of leaflet prolapse and annular dilatation. Even now, the controversy on "respect" and "resect" the leaflet is going on, making sure no patient leaves the operating room with significant persistent MR which will produce durable results and satisfactory long-term outcomes.[5]

In the confounding factors of various etiology, pathology, functional change, and surgical technique, no predictor of the midterm mitral dysfunction was found; maybe the sample capacity failed to meet the requirement of multifactor analysis.

In conclusion, in the patients with regressive mitral lesions, different etiologies showed different pathologic lesions, which resulted in different mitral functional changes. We need to select one or more different techniques based on different lesions of the mitral valve. No matter what the etiology, mitral repair could achieve good early and midterm results.

Supplementary information is linked to the online version of the paper on the Chinese Medical Journal website.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

References

1. Delling FN, Rong J, Larson MG, Lehman B, Fuller D, Osypiuk E, *et al.* Evolution of mitral valve prolapse: Insights from the framingham heart study. Circulation 2016;133:1688-95. doi: 10.1161/CIRCULATIONAHA.115.020621.
2. Silaschi M, Chaubey S, Aldalati O, Khan H, Uzzaman MM, Singh M, *et al.* Is mitral valve repair superior to mitral valve replacement in elderly patients? Comparison of short – And long-term outcomes in a propensity-matched cohort. J Am Heart Assoc 2016;5:e003605.doi: 10.1161/JAHA.116.003605.
3. Dreyfus GD, Souza Neto O, Aubert S. Papillary muscle repositioning for repair of anterior leaflet prolapse caused by chordal elongation. J Thorac Cardiovasc Surg 2006;132:578-84. doi: 10.1016/j.jtcvs.2006.06.003.
4. Suri RM, Burkhart HM, Schaff HV. A novel method of leaflet reconstruction after triangular resection for posterior mitral valve prolapse. Ann Thorac Surg 2010;89:e53-6. doi: 10.1016/j.athoracsur.2010.03.071.
5. Schubert SA, Mehaffey JH, Charles EJ, Kron IL. Mitral valve repair: The french correction versus the american correction. Surg Clin North Am 2017;97:867-88. doi: 10.1016/j.suc.2017.03.009.

Supplementary Table 1: Preoperative data of 252 consecutive patients with degenerative mitral valve disease

Variable	Values
Clinical characteristics	
Age (years)	66.3 ± 13.4
Female, *n* (%)	77 (30.6)
BMI (kg/cm^2)	24.6 ± 3.9
NYHA, III–IV, *n* (%)	96 (38.1)
Atrial fibrillation, *n* (%)	80 (31.7)
Pacemaker, *n* (%)	15 (6.0)
Inotropes, *n* (%)	13 (5.2)
Chronic pulmonary disease, *n* (%)	15 (6.0)
Extracardiac arteriopathy, *n* (%)	6 (2.4)
Creatinine clearance (Cockcroft-Gault) <50 ml/min, *n* (%)	19 (7.5)
Neurological dysfunction, *n* (%)	8 (3.2)
Previous cardiac surgery, *n* (%)	12 (4.8)
Emergency operation, *n* (%)	12 (4.8)
Echocardiography characteristics	
MR (Grade 1/4–4/4)	4.0 ± 0.2
LVED volume (ml/m^2)	88.0 ± 24.7
LA volume (ml/m^2)	83.5 ± 38.2
Systolic PAP (mmHg)	38.7 ± 12.6
LVEF (%)	65.3 ± 9.4

1 mmHg = 0.133 kPa. BMI: Body mass index; NYHA: New York Heart Association; MR: Mitral regurgitation; LVED: Left ventricular end-diastolic; LA: Left atrium; PAP: Pulmonary artery pressure; LVEF: Left ventricular ejection fraction.

Supplementary Table 2: Comparison of the frequency of mitral valve lesions caused by different etiologies

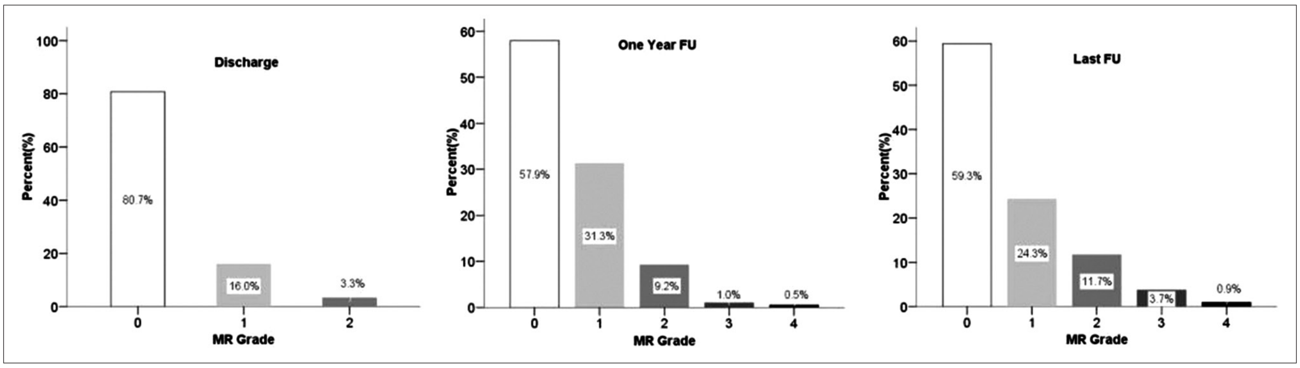
Items	Etiologies, *n* (%)		*P*
	FED (*n* = 62)	BD (*n* = 190)	
Excess PL height	32 (51.6)	132 (69.5)	0.010
Excess PL width	16 (25.8)	67 (35.3)	0.169
Excess AL tissue	3 (4.8)	24 (12.6)	0.085
Ruptured chord	42 (67.7)	87 (45.8)	0.002
Elongated chord	11 (18.0)	70 (37.0)	0.004
Calcificated annulus	10 (16.1)	32 (16.9)	0.528
Calcificated subvalvular apparatus	1 (1.6)	4 (2.1)	0.641
Pathologic indentation	3 (4.8)	25 (13.2)	0.073
Commissural fusion	0	5 (2.6)	0.240

FED: Fibroelastic Deficiency; BD: Barlow's disease; PL: Posterior leaflet; AL: Anterior leaflet.

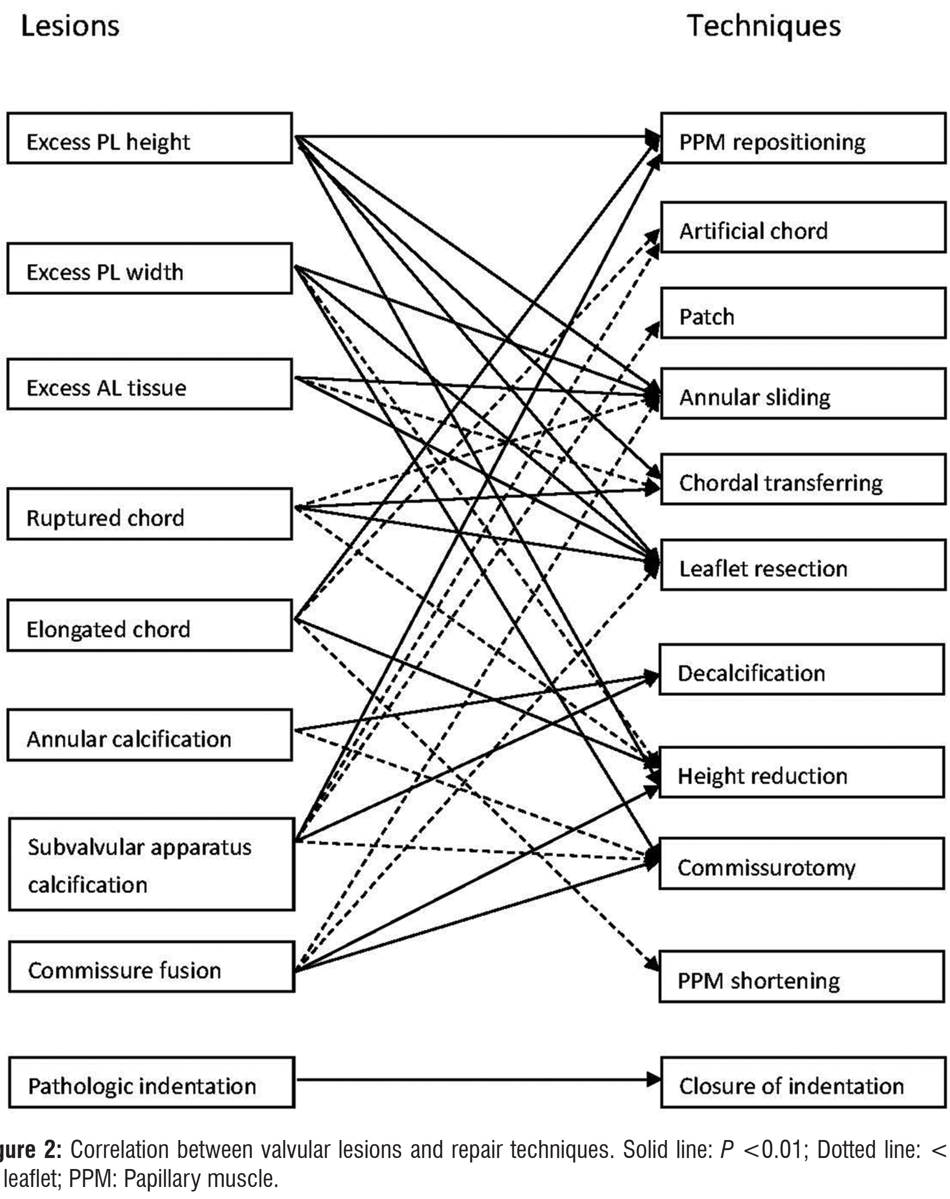
Supplementary Table 3: Frequency distribution of prolapse in different segments of mitral valve with different etiologies

FED	AC	A1	A2	A3	PC
(*n* = 62)	1 (1.6%)	5 (8.1%)	11 (17.7%)	8 (12.9%)	13 (21.0%)
		P1	P2	P3	
		6 (9.7%)	48 (77.4%)	15 (25.0%)	
BD	AC*	A1	A2†	A3†	PC†
(*n* = 190)	15 (7.9%)	26 (13.8%)	83 (43.7%)	71 (37.6%)	88 (46.3%)
		P1*	P2	P3*	
		41 (21.7%)	159 (83.7%)	73 (38.6%)	

Compared with FED, **P*<0.05; †*P*<0.01. A1–A3, P1–P3: Segments of mitral valve. FED: Fibroelastic deficiency; BD: Barlow's disease; AC: Anterior commissure; PC: Posterior commissure.



Supplementary Figure 1: Postoperative change of MR during midterm FU. MR: Mitral regurgitation; FU: Follow-up.



Supplementary Figure 2: Correlation between valvular lesions and repair techniques. Solid line: $P < 0.01$; Dotted line: < 0.05. PL: Posterior leaflet; AL: Anterior leaflet; PPM: Papillary muscle.