Mitral commissural prolapse

Review Article

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Disclosures:

Dr A. Pitsis serves as a Consultant (for teaching and training) for Abbott and Medtronic. The rest of the authors have nothing to disclose

ABSTRACT

Mitral commissural prolapse or flail, either isolated or combined with more extensive degenerative valve disease imposes several challenges both on its diagnosis and management whilst being a risk factor for valve reoperation after mitral valve repair. Accurate identification of the prolapsing segment is often not feasible with transthoracic 2D echocardiography, with transesophageal 3D imaging then required for correct diagnosis and surgical planning. Various surgical techniques employed alone or in combination, have yielded good results in the repair of commissural prolapse. Herein, we analyze the specific characteristics of commissural disease focusing our attention on 2D and 3D echocardiographic findings and we briefly comment on techniques employed for surgical correction of the disease.

KEY WORDS

Commissural prolapse, mitral regurgitation, bicommissural view, mitral valve repair, neochords, 3D transesophageal echocardiography

ABBREVIATIONS

ALC: anterolateral commissure

BD: Barlow's disease

CMR: cardiac magnetic resonance

CT: computed tomography

EROA: effective regurgitant orifice area

FED: fibroelastic deficiency

IE: infective endocarditis

LAA: left atrial apendage

LV: left ventricle

LVOT: left ventricular outflow tract

MAD: mitral annular dysjunction

MF: myocardial fibrosis

MR: mitral rerurgitation

MV: mitral valve

MVP: mitral valve prolapse

MVRepair: mitral valve repair

PISA: proximal isovelocity surface area

PMC: posteromedial commissure

PTFE: polytetrafluoroethylene

PVC: premature ventricular contraction

RV: regurgitant volume

SAM: systolic anterior motion

VC: vena contracta

Introduction

Degenerative mitral valve disease is the major cause of mitral regurgitation (MR). Mitral valve repair (MVRepair) is the gold standard for the treatment of significant MR and is more favoured than replacement, since retaining the native valve is beneficial in terms of perioperative morbidity, preservation of left ventricular function and long-term survival (1). Although less prevalent than segmental prolapse, commissural prolapse is an important cause of MR and represents a risk factor for residual disease and reoperation following MVRepair. Its pre-operative recognition using echocardiography poses several challenges, since eccentric jets and apparent absence of diseased segments in standard 2D echocardiographic views may obscure the diagnosis.

Mitral valve anatomy-The commissures

The anterior and posterior mitral leaflet are separated by two commissures, the anterolateral and the posteromedial commissure. The anterolateral commissure (ALC) lies adjacently to the left fibrous trigone and the left atrial appendage (LAA), whereas the posteromedial commissure (PMC) is alongside the right fibrous trigone and the interatrial septum. The commissures define distinct areas, where anterior and posterior leaflets approach and merge prior to their insertion into the annulus. Although they may exist as well defined leaflet segments, they are usually identified as rudimentary structures, each one assembling with its corresponding papillary muscle through committed commissural chords. These chords have a characteristic fan-like configuration and are regularly inserted at the apex of the papillary muscles (Figure 1). Freestanding commissural leaflet segments may also be encountered, however their exact prevalence is difficult to estimate since the ones recognized are the diseased, causing mitral regurgitation. The free edge of the commissures is separated from the annulus by 3-5 millimeters of valvular tissue which must be respected during mitral valve surgery, otherwise, residual regurgitation may ensue (2) (Figure 2).

Commissural prolapse

Commissural prolapse is present in aproximately 20% of patients operated for mitral leaflet prolapse or flail (3). The lesion responsible for commissural prolapse is variable and may involve the leaflet tissue, chords or papillary muscle. The most common injury is elongation of the commissural chord in the context of Barlow's disease and in this case, the severity of the prolapse depends on the extent of the area supported by the chord. A separate commissural head of a subdivided papillary muscle is usually short and supports a confined part of the valve producing less severe regurgitation, whereas a commissural chord emerging from a single papillary muscle located deep into the ventricle, produces more severe hemodynamic sequelae when it is elongated or ruptured (4). Occasionally, commissural prolapse is the result of chordal rupture. Infective endocarditis (IE) represents an important cause of commissural chord rupture (Figure 3). Ischemic commissural prolapse -usually affecting the PMC and the A2 and A3 scallops- can also be encountered. Commissural prolapse (Figure 4) and flail may occur alone (Figure 5) or in association with another leaflet disease (Figure 6). The prolapse is termed limited when it involves the commissural scallop only, measuring ≤5 mm of the leaflet margin and extensive when it involves the commissural leaflet with either one or both paracommissural areas. It may be unilateral or bilateral. Posteromedial is twice as common as anterolateral commissural prolapse (5, 6).Commissural prolapse/flail poses several diagnostic and management challenges related to its unique characteristics. Apparent absence of diseased segments on standard 2D echocardiographic views, along with the eccentricity of jets produced by commissural prolapse/flail may interfere with both the diagnosis and the regurgitation quantification; valve repairability is often not easy to comment on. Frailty of the commissural tissue and its supporting subvalvular apparatus may increase the difficultyof repair whilst absence of a standardized surgical approach to correct commissural prolapse may jeopardize the surgical result.

In a series of 50 consecutive patients in our department, operated by a mitral repair surgeon in a one-year period (2019) for mitral valve prolapse (MVP) with a totally endoscopic mitral repair, commissural prolapse was found in

10 patients (20%). PMC flail/prolapse was seen in 9/10 patients (90%), whereas none of the patients had bilateral commissural prolapse. In the majority of cases patients commissural prolapse was associated with another leaflet disease (3). In a Korrean study by Kim and colleagues, isolated commissural prolapse was more frequent (25% of cases) and posteromedial was approximately twice as common as anterolateral prolapse (5, 6). Posteromedial was three times more common than anterolateral prolapse in a large japanese study and similar results were obtained in a German study (7).

Echocardiography is the principal tool for preoperative diagnosis, surgical planning and intraoperarive/postoperative review of the surgical result of MVRepair.

Preoperative diagnosis

Correct identification of commissural, leaflet, chordal or papillary muscle involvement enables proper surgical staging and planning and should be pursued preoperatively. However, in commissural disease, correct diagnosis is achieved in only 30-40% of cases using standard transthoracic 2D echocardiographic views, whereas accurate scallop prolapse identification is feasible in nearly 90% of cases when the commissures are not involved (4).

Commissural prolapse is overlooked in one third of cases since the appearance of the valve may seem completely normal in standard transthoracic views. Bicommissural two chamber, either transthoracic or transesophageal, is usually the most informative view to the presence of commissural prolapse since not uncommonly a prolapsing commissure can be depicted solely in this view (Figure 7A, 7C). Occasionally, commissural prolapse mimics the appearance of leaflet perforation The mechanism of prolapse is frequently difficult to determine; ; as already mentioned, it is usually caused by commissural chord elongation -in the context of Barlow's disease- or rupture. In the case of IE, meticulous inspection for extravalvular extension of the infection should be pursued, ruling out abcesses, aortomitral continuity lesions and vegetations of the non-coronary aortic cusp -if the posteromedial- or the left coronary aortic cusp –if the anterolateral- commissure is affected.

Extremely “oblique” orientation of the regurgitant jets of commissural prolapse introduces an additional confounder in the assessment of commissural MR. Occasionally in the parasternal short axis view a proximal flow convergence zone at the lateral side of the valve implies the presence of commissural disease. Several other clues derived from the color Doppler interrogation denote the presence of commissural disease such as the presence of a V-shaped double jet flow, an oblique regurgitant flow from the origin of the prolapse toward the anterolateral or posteromedial direction without adhering to the left atrial wall and a horizontal regurgitant flow (8) (Figure 7B, D, Videos 1-3). At times, transesophageal deep transgastric views at 90 degrees can help unravel posterior commissural prolapse. In this case, the regurgitant jet can be seen completely parallel to the ultrasound beam and Doppler can be aligned so that Vena contracta (VC) and proximal isovelocity area (PISA) are correctly measured - which may be not feasible in other views due to the eccentricity of the jet leading to underestimation of the degree of rerurgitation-. Transesophageal 3D echocardiography offers a comprehensive illustration of mitral valve anatomy and is an excellent tool for preoperative evaluation of the extent of mitral valve disease. After sizing the zoom sector at the region of interest in 2D preferably in 60°, live 3D zoom modality is enabled with adequate decrease of the sector width to improve temporal resolution and image quality. Subsequently, live 3D full volume acquisition is constructed using narrow volume data from 2 to 7 cycles stiched together to form a pyramidal set. Although multibeat acquisition may not always be feasible due to arrhythmia or breathing difficulties that cause stiching artifacts, when properly obtained, offers the higest temporal resolution. Detailed multibeat live 3D full volume color acquisition is useful to determine the regurgitant flow origin. Once volumetric data are obtained, images can be rotated, angulated and cropped to obtain adequately illustrative MV views. To avoid drop-out, due to low gain settings or loss of 3D perspective usually with excess gain, both gain and compression settings should be set around the midrange (50 units) and optimized with slightly higher time gain compensation (Figures 2-6, Videos 4-7) (8).

A comprehensive pre-opearative echocardiography report should comment on specific qualitative parameters concerning the valve. Reported parameters should include leaflet morphology (structurally normal, nonspecific

thickening, extent and degree of calcification, myxomatous degeneration), chordal characteristics (ruptured or reduntant chords), annular size and morphology (normal/dilated/calcified) leaflet mobility (prolapsed or flail segments/commissures), submitral morphology (thickening, calcification) and mitral jet characteristics (duration and direction, single or multiple jets). These parameters will determine the likelihood of repair (repair likely, possible or challenging) and the surgeon should be informed preoperatively. The report should also comment on the hemodynamic consequences of MR, as determined by left ventricular (LV) size and function, left atrial size, pulmonary artery pressure and right ventricular size and function (9). The diameter of the tricuspid annulus -traditionally from the apical 4 chamber view in diastole or with 3D echocardiography when available- must also be reported. This will affect the surgeon's decision to proceed with concomitant tricuspid annular valvuloplasty with a threshold value of 40 mm (or 21 mm/m^2) (10). The presence of a high velocity systolic spike configuration in the pulsed wave Doppler signal of the mitral annulus, particularly the posterolateral, the so-called Pickelhaube sign, may help predict the risk of malignant arrhythmias in patients with MVP and when present, should be discussed since it may have an impact on further clinical decisions (11). Specific clinical questions may be addressed with advanced cardiac imaging; myocardial fibrosis -with or without mitral annular dysjunction (MAD)- is assessed with cardiac magnetic resonance (CMR). Accurate sizing of the mitral annulus and measurement of the aorto-mitral angle as well as septal bulge identification -parameters which help predict post-operative LVOT obstruction- may be accomplished with computed tomography (CT). These techniqes may be used in selected cases (12-15).

Surgical techniques-Intraoperative echocardiography

Almost all (>99%) degenerative mitral valves are suitable for repair. Various surgical techniques and their combinations are proposed for anatomical restoration of the valve. These include resection or plication of prolapsing or reduntant leaflet tissue, papillary muscle repositioning and chordal transposition, chordal replacement with expanded polytetrafluoroethylene (PTFE) neochords and annuloplasty with implantation of a prosthetic ring (semi-rigid) or band (flexible) to support the repair and prevent further annular dilatation (3-7, 16-19).

Limited commissural prolapse can be effectively treated with simple prolapse segment resection (trigonal or quadrangular). If the prolapse is more extensive, prolapsed segment resection is followed by sliding plasty with the use of either annular plication or a compressive suture. Leaflet coaptation is then restored using Carpentier's magic stitch, an infolding stitch used to increase the coaptation between the leaflets. A functional, rather than anatomical repair of the commissural prolapse, involves "edge to edge" approximation of the anterior to the posterior leaflet at the commissural level. The technique is called "commissural closure". Papillary muscle repositioning is a demanding surgical technique that may be used in commissural prolapse, provided that the subvalvular apparatus is intact, since it requires manipulation of the subvalvular structures. Remodelling of the mitral annulus by means of annuloplasty is of utmost importance in mitral valve repair surgery. Mitral annuloplasty restores normal annulus dimensions and shape, prevents further annular dilatation and increases the coaptation surface of the leaflets. All surgical techniques should be followed by a ring annuloplasty.

Implantation of artificial chords tendineae -neochords- is another technique to treat commissural prolapse with or without leaflet flail. Artificial chords made of 3/0, 4/0 or 5/0 PTFE sutures, are fastened to the fibrous portion of the papillary muscle on one end and to the free margin of the prolapsing portion on the other. Determination of the optimal length of the artificial chords is the principal difficulty of this technique (3). Prefabricated artificial chords with a premeasured loop have recently been introduced to facilitate the choice of the appropriate length. We use the preoperative TOE, 4 chamber view, systolic frame to find the correct neochord lenghth by calculating the distance between the tip of the papillay muscle and the coaptation point of the two leaflets (3,20). All the chords of a human mitral valve have equal lengths. Therefore, if we calculate the length of the chords of a non prolapsing segment of the valve, then we know the optimal length of the prolapsed/flail commissure. In our experience, the average length of chords that we have used to treat commisural prolapse is 20 mm (median = 20 mm, min = 18, max = 22) (Figure 8). The implantation of neochords is a technique which is well suited to minimally invasive (robotic or endoscopic) approaches.

Post-procedural echocardiography

Successful reconstructive mitral valve surgery is based on three basic principles as described by Alan Carpentier and colleages. These include preservation of leaflet mobility, creation of a large surface of leaflet coaptation and restoration of annular remodeling to provide an optimal and stable orifice without restriction (21). Residual MR should be no more than mild and there should be no systolic anterior motion (SAM) of the mitral valve. If flow acceleration is seen by color flow Doppler on the atrial side of the heart, iatrogenic mitral stenosis must be suspected. It is confirmed in the presence of a mean transmitral pressure gradient of more than 6 mmHg and a MV area less than 1.8 cm^2 and it warrants re-repair or replacement. A comprehensive examination of LV function and screening for wall motion abnormalities should be part of the post-operative examination as the left circumflex coronary artery may be compromised during mitral valve surgery particularly if the commissures are involved. All these parameters must be evaluated intraoperatively as soon as the aortic cross clump is released, while the heart is contracting and the LV is at least partially volume loaded and then after the patient is weaned from cardiopulmonary bypass with visual inspection, water test and by transesophageal echocardiography (22).

Conclusions

Commissural prolapse usually accompanies leaflet prolapse or flail and is difficult to diagnose preoperatively using 2D transthoracic echocardiography. Accurate localization of the prolapsing segment(s), determination of the mechanism of the prolapse and identification of the valvular/subvalvular structures that are affected are of paramount importance and can be accomplished to a certain level preoperatively, using transesophageal 3D echocardiography. Intraoperative systematic surgical valve analysis is guided by- and is complementary to-preoperative imaging. MVRepair has become the standard of care for mitral valve regurgitation involving the

commissures and various surgical techniques can be used alone or in combination, to treat this lesion successfully in more than 99% of cases in the hands of experienced surgeons.

E.P and A.P. have participated in the conception of the analysis, data acquisition and drafting the manuscript. A.P. participated in data acquisition and drafting the manuscript. A.Z. and M.M. participated in data acquisition. F.P. crtically revised the manuscript and had the final approval of the MS to be submitted. All author have seen and approved the finalversion of the manuscript.

Dr Dr A. Pitsis serves as a Consultant (for teaching and training) for Abbott and Medtronic. The rest of the authors have nothing to disclose.

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Figure legends

Figure 1. Schematic diagram of commissures

The commissures are the areas where the anterior and posterior leaflet of the mitral valve approach prior to their insertion into the annulus. Although they may exist as distinct segments, they are usually identified as rudimentary structures using two landmarks, namely the commissural chords -which as shown here have a specific fan-like configuration- and the axis of their corresponding papillary muscle.

ALC: anterolateral commissure, PMC: posteromedial commissure

Figure 2. The relationship of the commissures with the annulus

A. A 3D-transesophageal echo-based reconstructed model of the mitral valve with its scallops and commissures. The commissures represent the segments between the insertion point of the leaflets and the annulus

B. 3D image showing the anterolateral and the posteromedial commissure. Prolapse of the P2 scallop is illustrated

ALC: anterolateral commissure, AO: aorta, MV: mitral valve, LAA: left atrial appendage, LA: left atrium, LV: left ventricle, PMC: posteromedial commissure

Figure 3. Infective endocarditis affecting the commissure

A. 3D image in 3 saggital planes (Flexi-slice mode, GE) from a 72 year old patient with infective endocarditis. Posteromedial commissure prolapse (yellow arrow), a vegetation and ruptured tendinous chords (red arrows) are simultaneously shown.

B. Again from the same patient, 3D image showing the posteromedial commissural prolapse (yellow arrow), the vegetation and ruptured tendinous chords (red arrow)

C. Transesophageal 3D echocardiogram of a 16 year-old female with previous history of surgically corrected secundum atrial septal defect and subvalvular aortic stenosis presenting with prolonged fever and blood cultures positive for Streptococcus viridans. This is the 3D mitral valve perspective from the left atrium (surgeon's view) depicting vegetations on the P1 scallop and the posteromedial commissure

Com: commissure, LA: left atrium, LV: left ventricle, P1: p1 scallop, PSM: posteromedial, TC: tendinous chords Veg: vegetations

Figure 4. Isolated propapse of the posteromedal commissure

Transesophageal 3D echocardiogram of a 58 year-old man presenting with exertional dyspnea. His left ventricle was dilated but initial standard transthoracic 2D images showed no major mitral valve pathology. However, a horizontal holosystolic jet of mitral valve regurgitation implied underlying commissural prolapse. This is the left atrial view of the mitral valve clearly depicting isolated posteromedial mitral commissural prolapse (white arrow)

ALC: anterolateral commissure, LAA: :left atrial appendage, LA: left atrium, LV: left ventricle, PMC: posteromedial commissure

Figure 5. Flail posteromedial commissure

A. 3D mitral valve perspective from the left atrium (surgeon's view) , showing prolapse of the posteromedial commissure due to rupture of commissral tendinous chords (white arrow). Placing the aorta at the top of the

image (12 o'clock) , the left atrial appendage is to the left (9 o'clock) and the posteromedial commissure at 3 o'clock

B. 3D dataset illustrating the 3D appearance of the mitral valve and the three 2D-axis planes. Arrows show the ruptured tendinous chords. It is not feasible to distinguish whether ruptured tendinous chords emerge from the commissure based solely on 2D images

ALC: anterolateral commissure, LAA: Left atrial appendage, LA: Left atrium, LV= Left Ventricle, PMC= Posteromedial commissure, P1,P2,P3 are the scallops of the posterior mitral leaflet

Figure 6. Combined prolapse of the anterolateral commissure and of the P2 scallop

A. 3D perspective of the mitral valve from the left atrium (surgeon's view) , with the aorta at the top (12 o'clock) demonstrating prolapse of the anterolateral commissure (white arrow) and the P2 scallop of the posterior mitral leaflet

B. 3Ddataset illustrating the 3D appearance of the mitral valve and the 2D axis planes. In 2D images it seems that the P1&2 scallops are prolapsing but 3D images clearly demonstrate that actually it is the anterolateral commissure that prolapses

ALC: anterolateral commissure, LAA: Left atrial appendage, LA: Left atrium, LV: Left Ventricle, PMC: Posteromedial commissure, P1,P2,P3 are the scallops of the posterior mitral leaflet

Figure 7. 2D echocardiographic "hints" of commissural prolapse

A. Transthoracic 2D echocardiogram of a 63 year-old patient with isolated posteromedial commissural prolapse. This is a modified commissural view, the only one suggesting the presence of primary mitral valve disease (arrow)

B. Transthoracic 2D ehchocardiogram, color Doppler interrogation from the same patient, revealing the presence of a horizontal regurgitant jet

C. Transesophageal 2D echocardiogram, midesophageal position modified bi-commissural view from the same patient confirming posteromedial commissural prolapse (arrow)

D. Transesophageal 2D echocardiogram, midesophageal position modified bi-commissural view. An eccentric almost horizontal jet from the posteromedial to the anterolateral commissure is depicted

Com: commissure, LAA: left atrial appendage, LA: left atrium, LV: left ventricle, MV: mitral valve

Figure 8. Endoscopic view of a PMC prolapse during totally endoscopic mitral valve repair

a) and b): PMC prolapse c) repair with 4 prefabricated neochords of 22 mm in length, d) posterior annuloplasty with a band

PMC: posteromedial commissure

Video legends

Video 1 Transthoracic 2D echocardiogram, commissural view of a 63 year old patient with isolated posteromedial commissural prolapse

LA: left atrium, LV: left ventricule

Video 2 Transesophageal 2D echocardiogram, modified bicommissural view of the same patient depicting posteromedial commissural prolapse

LA: left atrium, LV: left ventricle, MV: mitral valve

Video 3 Transesophageal 2D echocardiogram, color Doppler interrogation with a horizontal eccentric jet

Video 4 Transesophageal 3D echocardiogram, showing isolated prolapse of the posteromedial commissure (same patient as in video 1)

AO: aorta, LA: left atrium, LV: left ventricle, PMC: posteromedial commissure

Video 5 Transesophageal 3D echocardiogram depicting prolapse of the anterolateral commissure

AO: aorta, ALC: anterolateral commissure, LAA: left atrial appendage, LA: left atrium, LV: left ventricle

Video 6 Trasnesophageal 3D echocardiogram with A2 and posteromedial commissural prolapse

AO: aorta, LA: left atrium, LV: left ventricle, LAA: left atrial appendage, P2: p2 scallop, PMC: posteromedial commissure

Video 7 Transesophageal 3D echocardiogram showing P2 and bi-commissural prolapse

ALC: anterolateral commissure AO: aorta, LAA: left atrial appendage, LA: left atrium, LV: left ventricle, P2: p2 scallop