SURGICAL ANATOMY OF THE MITRAL VALVE LEAFLETS

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SURGICAL ANATOMY OF THE MITRAL VALVE LEAFLETS (Abstract): The mitral valve is a complex three-dimensional structure and mitral valve repair is the therapeutic intervention of choice in patients with significant mitral regurgitation due to lower rates of mortality and reoperation, lower incidence of heart failure, infective endocarditis and atrial fibrillation compared to valve replacement. The aim of the present study is to review the classical concepts regarding the anatomy of mitral valve leaflets and to analyze their morphology related to current clinical and surgical practices. The authors analyzed intraoperatively the mitral valves of 45 patients that benefited from mitral valve repair between 2002-2014 at the Cardiovascular Diseases Institute from Iasi, Romania. The mean age was 60.09±13.68 years and the indication for surgery was established for mitral regurgitation in all cases. From a morphological point of view, two commissures separating anterior and posterior leaflets were observed in all cases. Standard clefts described by Carpentier as separating P1 from P2 scallops and P2 from P3 scallops were inconstant and noted in 30 cases (P1-P2 cleft) and 34 cases respectively (P2-P3 cleft). In 40 cases, additional clefts were noted inside conventional Carpentier scallops. Morphometrically, the A2 scallop measured 25.31±2.54 mm, the anterior leaflet height was of 36.12±4.73 mm and the intercommissural length 35.63 ± 5.18 mm. An accurate in vivo evaluation of the mitral valve and a common nomenclature are mandatory to mitral valve surgery as confusions, anatomical variants and incomplete knowledge of the morphology and structure of mitral apparatus could interfere the result of surgical intervention. Key words: MITRAL VALVE LEAFLETS, MITRAL VALVE REPAIR, ANATOMICAL VARIANTS, NOMENCLATURE

INTRODUCTION

The mitral valve is a complex three-dimensional structure, better known as a mitral valve apparatus, comprising 5 distinct components. These components are highly integrated, and consist of leaflets, commissures, fibrous ring, tendinous chords (chordae tendinae) (1) and papillary muscles related to the corresponding walls of the left ventricle. The mitral valve presents anterior and posterior leaflets, each consisting of 3 distinct segments or scallops, designated from the lateral to the medial portion as A1, A2 and A3 for the anterior leaflet, and P1, P2 and P3 for the posterior leaflet (2). Each leaflet receives chords from both the anterolateral and posteromedial papillary muscles, which present a central role in this complex valve apparatus, determining the suspension and tension of the leaflet at the end of systole. The tendinous chords are called primary or marginal when inserted at the free edge of the leaflet, secondary or intermediate when attached to the ventricular surface of the leaflet and tertiary or basal, or even commissural when inserted at the base of the leaflet, close to the ring and commissures (2-4). The mitral competence depends on the integrated action of the valve and its subvalvular apparatus. During systole, the papillary muscles contract, increasing the tension of the cords, which prevents the
eversion of the leaflet towards the left atrium.

Carpentier proposed an anatomical and pathological classification of the mitral valve, considering the mobility of the leaflets and dividing the mitral valve dysfunction into three types: (1) type I with normal leaflet mobility, such as in the presence of ring dilatation, leaflet perforation or congenital cleft; (2) type II with excessive leaflet movement, as in prolapse; (3) type IIIa with diastolic restriction of leaflet movement, as occurs in rheumatic mitral stenosis; type IIIb with systolic restriction, as observed in rheumatic insufficiency and in ischemic or dilated cardiomyopathy (3).

Mitral valve repair is the therapeutic intervention of choice in patients with significant mitral regurgitation due to lower rates of mortality and reoperation, lower incidence of heart failure, infective endocarditis and atrial fibrillation compared to valve replacement.

The aim of the present study is to review the classical concepts regarding the anatomy of the left atrioventricular valve leaflets and to analyze their morphology related to current clinical and surgical practices.

MATERIAL AND METHODS

The authors analyzed intraoperatively the mitral valves of 45 patients that benefited from mitral valve repair between 2002-2014 at the Cardiovascular Diseases Institute from Iasi, Romania. All mitral valves were approached through the left atrium after median sternotomy performed by the same surgical team. A photograph of the mitral valve was taken immediately after exposing it, the morphology was noted and the anterior leaflet were measured before decalcification using a silk non-absorbable suture. Mitral annulus was measured with a surgical sizer inserted into the annular space (intercommissural length and the height of the anterior mitral leaflet).

RESULTS

The mean age in the moment of surgery was 60.09±13.68 years and most patients were males (32 cases – 71.11%).

The indication for mitral valve repair was established for mitral regurgitation in all cases due to degeneration (18 cases), rheumatic disease (13 cases), Barlow disease (6 cases), endocarditis (5 cases), dilative cardiomyopathy (ischemic or non-ischemic) (2 cases), post-ischemic papillary muscle rupture (1 case).

Surgical intervention consisted in annuloplasty (32 cases), quadrangular or triangular resection (resection of marginal tendinous chords together with the leaflet segment where they are inserted) (15 cases), chordal replacement (8 cases), commissuroplasty (7 cases), leaflet repair (5 cases), chordal transposition, reinsertion or splitting (3 cases).

Mitral valve leaflets’ morphometrically parameters are described in table I.

From a morphological point of view, two commissures separating anterior and posterior leaflets were observed in all cases. Standard clefs described by Carpentier as separating P1 from P2 scallops and P2 from P3 scallops were inconstant and noted in 30 cases (P1-P2 cleft) and 34 cases respectively (P2-P3 cleft). 15 pa-
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Fig. 2. Mitral valve surgical nomenclature according to Carpentier (2)

Fig. 3. Mitral valve surgical nomenclature according to Kumar and Duran (12)

Patients presented no P1-P2 cleft and 11 patients no P2-P3 cleft.

In 40 cases, additional clefts were noted inside conventional Carpentier scallops (fig. 1):
• 3 – A1 scallop;
• 3 – A2 scallop;
• 6 – A3 scallop;
• 6 – P1 scallop;
• 14 – P2 scallop;
• 10 – P3 scallop.

Two patients present 2 rare clefts: A3 and P2 and A2 and P2. Subsequently, these cases can be described as having more than 3 scallops for a leaflet.

From the 15 patients with no P1-P2 cleft, 13 presented additional clefts compared to 10 of the 11 patients with no P2-P3 cleft.

Scallop and cleft variability may interfere with valve repair procedures especially in case of valve prolapse due to chordal rupture or elongation or when resection and leaflet repair with pericardial path are needed.

DISCUSSIONS

The leaflets are the dominant elements of the left atrioventricular valve and there are important conceptual divergences among authors, from classical to contemporary, such as, for example, the number of leaflets, the existence or not of additional scallops, and even the nomenclature of each one of them.

Classically, the left atrioventricular valve has been described as being formed by 2 leaflets, anterior and posterior. Recalling the shape and arrangement of a miter, Andries van Wesel (1514-1564) (latinised Andrea Vesalius) named it “mitral valve” in the 16th century. Gray on the other hand, preferred the term “bicuspid valve” even if he described accessory leaflets (5).

Other authors like Bourgery (6), Cruveilhier (7), Testut (8), Cunningham (9), Poirier (10) and Tandler (11) consider the left atrioventricular valve as being formed by 4 leaflets.

The most recent and worldwide accepted description of the mitral valve nowadays is the one attributed to the French surgeon, Alain Carpentier (2,3), who considers the mitral valve as being formed by two leaflets separated by commissures, each leaflet with 3 scallops (A1-3 for the anterior and P1-3 for the posterior), the posterior leaflet scallops being separated by clefts (fig. 2).

Different from Carpentier, Kumar and Duran (12), considered in 1995 the anterior leaflet as being formed only by 2 scallops (A1 and A2) and defined the two commissural areas as C1 and C2. For the posterior valve, they named the 3 scallops P1, PM and P2 corresponding to Carpentier’s P1, P2 and P3 (fig. 3).

Anatomical nomenclature refers to the 3 scallops of the posterior leaflet as anterolateral, middle and posteromedial.

Our findings correspond more to the initial description of Henle (13), which considers the left atrioventricular valve to be constituted by a continuous strip of valve tissue, presenting a fixed border to the atrioventricular ostium, in continuity with the aortic ring, and a free border in the ventricular cavity presenting a variable number of clefts and chordal insertions. The number and depth of these clefts determine leaflets’ morphology. These clefts do not reach the fixed edge of the valve cuff at any point. Thus, the leaflets are in direct continuity.

Generally, the mitral valve presents a dominant anterior leaflet usually without clefts and
a non-dominant posterior leaflet crossed by several clefts ranging from 1 (2 cases) to 4 (1 case) in our study.

The anterior leaflet is trapezoidal and fixed to the aortic root from which it detaches like a curtain in the left ventricular cavity, separating the inflow from the outflow regions. It presents 2 faces: atrial and the ventricular, 1 base, 2 side edges and 1 apex.

The atrial face of the anterior leaflet is smooth and its base is represented by a well-defined semicircular groove, with an inward-facing concavity, resulting from the reflection of the atrial endocardium. Zimmerman (14) first described two small depressions corresponding to leaflet’s insertion on the fibrous skeleton of the heart (commissures) on the inner wall of the left atrium just above the valve plane. These depressions are related to the origin of the circumflex branch from the left coronary artery and to the region where the bundle of His pierces the right fibrous trigone.

Viewed from the left ventricle, the base of the anterior leaflet continues and merges with the mitro-aortic intervalvular fibroses (MAIVF), a surgically important structure related to the functional integrity of both mitral and aortic valve (15). The MAIVF is located above the plane corresponding to the implantation of the base of the anterior leaflet and can be damaged during surgery by calcifications or endocarditis. Except this continuity, the anterior leaflet is suspended between the right and left fibrous trigones.

Because of the continuity between the mitral and aortic valve through the fibrous triangles and the membranous portion of the interven-tricular septum, Wallace McAlpine introduced the term “Aorto-Ventricular Unit” in his book “Heart and Coronary Arteries” (16). For the ventricular face of the leaflet, Ranganathan et al. described an irregular surface corresponding to chordal insertions and name it “rough zone”, opaque to transillumination, and a smooth “clear zone” corresponding to the rest of the leaflet, translucent to transillumination (17).

The “rough zone” is crescent shaped, higher in the apical portion of the leaflet, decreasing gradually towards the commissures where it terminates. In this area, on the atrial aspect, Cruveilhier (7) first described the presence of nodular prominences later called “Albini nodules”, small, whitish spots, arranged in rows and corresponding to remnants of embryonic or terminal insertion of tendinous chords on the ventricular face of the leaflet. These nodules are not to be confused with degenerative lesions (fibrous deposits).

The borders and the apex of the anterior leaflet float freely in the left ventricular cavity and give insertion to marginal tendinous chords.

The posterior leaflet is composed from a variable number of effective scallops (ranging from 2 to 5 in the current study) separated by clefts. As a whole, the posterior leaflet has a rectangular shape and presents a fixed border or base, a free border, an atrial face and a ventricular face. Along its free border, there are incomplete clefts separating several scallops. Ranganathan et al. proposed that all scallops located between commissural areas to be considered as belonging to the posterior leaflet. Individualization of each scallop facilitates surgical or echocardiographic references (17).

Additional clefts occurred more frequently in our study similar to the results obtained by Quill et al. (15) Also, standard clefts described by Carpentier (2) and Kumar (12) were not found in all patients.

The atrial face was almost entirely smooth. Similar to the anterior leaflet, the ventricular face of the posterior leaflet presents a “rough zone” where intermediate cords are inserted, and a smooth “clear zone” that may receive, in its most basal portion, the insertion of a variable number of small and short tendinous chords originating directly from the ventricular wall (basal chords). The free border of the posterior leaflet gives insertion to marginal tendinous chords (18, 19).

From the atrial aspect, the base is represented by a bended reflection of the atrial endocardium.

In the sub endocardial plane lays the “fibrous ring” of the mitral valve. According to Zimmerman, the “fibrous ring” is in fact an incomplete circular structure in its anterior and posterior parts. The anterior portion part is represented by the intertrigonal space, while the posterior part is absent. Due to lack of fibrous support in this region, the posterior leaflet would take insertion directly to the atrioventricular junction. This portion could be considered as a “weak point” of the left atiroventricular junction as the posterior leaflet is in close relation with the circumflex branch of the left coronary artery. An extensive manipulation or traction could lead to ventricular wall rupture and coronary lesions. Given the weakness of the car-
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diac wall in this region, in our clinic, the posterior leaflet is preserved in case of mitral valve replacement as it is beneficial for postoperative left ventricular performance (20,21).

During ventricular systole, the atrioventricular orifice is closed by the apposition of “rough zones” of both anterior and posterior leaflets. The angle formed between the clear and rough zone during systole has been extensively studied by Carpentier as the displacement of this angle characterizes “valve prolapse”.

The motion of each leaflet can be defined according to coaptation and classified into 3 groups according to Carpentier (fig. 3): type I – normal leaflet motion; type II – leaflet prolapse; type III – restricted leaflet motion during diastole (IIIa) or systole (IIIb) (3).

As long as leaflet dimensions are concerned, there are important differences between the living human, fresh and formalinized cadavers, as formalin leads to leaflet shortening. Also, differences can be explained by racial factors and methodology used. Carpentier stated that sex is not a relevant factor for morphological studies, since the difference found is a factor related to body surface area rather than to individual’s sex (2).

An accurate in vivo evaluation of the mitral valve is mandatory to mitral valve surgery as the presence or absence of clefts could change surgeon’s decision concerning the procedure of choice for valve repair. For example, the presence of additional clefts in the A2 or P2 scallops could interfere with the edge-to-edge technique which involves joining the anterior and posterior leaflets by stitches in the area of maximal regurgitation.

CONCLUSIONS

The mitral apparatus is a complex structure and there are important conceptual divergences among authors, from classical to contemporary. An accurate in vivo evaluation of the mitral valve and a common nomenclature are mandatory to mitral valve surgery as confusion and incomplete knowledge of the morphology and structure of mitral apparatus could interfere the result of surgical intervention.

REFERENCES