A Revised Terminology for Recording Surgical Findings of the Mitral Valve

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The existing terminology for the various structures of the mitral valve are diverse and numerous. With the resurgence of interest in reparative procedures for mitral valve disease, it becomes imperative to have a unified terminology which would convey precise connotations in recording the pathology as well as the corrective procedures applied. In an effort to suggest a commonly acceptable nomenclature, we reviewed the available terminology and propose a simple system which will fulfill the needs of recording the intraoperative observations of the pathology of each valve and the manoeuvres carried out to correct them by the surgeon. This involves designating all structures anterior to the intercommissural line as “anterior” or “A” and those posterior as “posterior” or “P”. The structures, as observed by the surgeon through a standard left atriotomy, to the left of the line dropped perpendicular to the middle of the aortic curtain will be designated by the numeral “1” and those to the right “2”. The chords will be termed in groups based on their point of insertion, irrespective of whether they are inserted to the free edge or the ventricular surface of the leaflet. The anterior leaflet chords will further be subdivided based on their relation to the stay chords. We hope that this system of naming the structures would provide a unified method of reporting intraoperative findings of mitral valve disease.

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Review of the literature

We recognize that functionally the mitral valve apparatus includes the atrial and ventricular myocardium (9). Nonetheless, as the objective of our work was directed towards developing a simple and hopefully a generally acceptable surgical terminology, we concentrated on the definitions of the structures amenable to surgical intervention. We therefore analyzed the structures and terminology employed to describe the mitral annulus, the leaflets, the chordae tendineae and the papillary muscles.

The mitral annulus

The reality of the mitral annulus in terms of the presence of a continuous anatomically identifiable fibrous structure has often been discussed (10,11). All authors, however, agree at least in its functional definition as the part of the circular area that surrounds the base of the left ventricle and encompasses the inlet, inflow or mitral orifice separated from the outflow (aortic) orifice by the aortic curtain which stretches between the two fibrous trigones of the heart (8,12). The actual shape and size of the mitral annulus is now universally accepted to change continuously during the cardiac cycle (13,14) having a sphincterial function due to the
Figure 1. The fibrous skeleton of the heart. Note the large right trigone or "central body of the heart" (With permission from Zimmerman and Bailey, J Thorac Cardiovasc Surg, 1962:44:701-12)

systolic contraction of the deep bulbospiral muscle (9,15). Although some authors (9) used indiscriminately the terms mitral annulus and mitral ring, nowadays most refer to it as mitral annulus.

Essential constituents of the mitral annulus are the right and left trigones or collagenous thickenings of the fibrous skeleton of the heart. This structure, although known by the old anatomists for a long time, was beautifully described by Zimmerman and Bailey in 1962 (16) (Fig. 1). The right or "central body of the heart" (16) is the larger, teats cartilaginous and bony in the bovines. The smaller left trigone is situated on the opposite extremity of the aortic curtain. The two trigones provide anchorage for the anterior or aortic leaflet and are easily identified at surgery by a downward pull of the free edge of this leaflet which reveals two creases directed towards them (8). The realization that because of their fibrous nature the distance between them, or "the intertrigonal distance", is not affected by pathologic dilation of the mitral annulus, determined the use by some authors (8) of this distance as the basis for selecting the appropriate annuloplasty ring size.

Leaflets

Since the description and christening of the mitral valve by Andrea Vesalius (17) as a bicuspid valve, all anatomists and surgeons have acknowledged the presence of a "large" anterior and "smaller" posterior mitral leaflet. The mitral valve was described as "a continuous veil around the entire mitral orifice" (18) with the free edge of the veil showing several indentations. Two of them are regularly placed and "permut division of the veil into anterior and posterior leaflets" (19). Although specific terms have widely varied, most surgeons call the larger leaflet "anterior", "aortic" or "septal" and the smaller leaflet "posterior" or "mural" (9). The actual size, shape and structure of the leaflets have been widely studied (2,9,10,19,20). More discussion still exists on the flexion areas between these two leaflets. While some authors describe a "cleft" (21) or "indentation" (19,22) at this level, others characterize a specific commissural leaflet (9,18,23). Functional studies showing that full mitral opening requires their existence (9), together with the direct intraoperative observation of the non-rheumatic mitral valve, confirm without any doubt their presence. These "commissural leaflets", or less controversial "areas", although easy to identify as such, their exact limits are difficult to determine because of their variability in size and continuity with the anterior and posterior leaflets. It is easier to define them as the leaflet space between both mitral leaflets delineated by the attachment of the commissural "fan" chordae (vide infra).
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Figure 3: Diagram of the left atrial aspect of the mitral valve. The different names applied to each structure are followed by the references to the corresponding author.

The posterior leaflet has two indentations or clits that divide it into three sections or scallops. These scallops or different size have been termed lateral and central (8), anterolateral, middle and posteromedial (7,19) and scallops two, three and four (22). The middle one is the most frequently affected in degenerative disease of the mitral valve, with prolapse secondary to chordal elongation or rupture.

All leaflets present a “superior”, “atrial” or “inflow” smooth surface and an “inferior”, “ventricular” or “outflow” rough surface crisscrossed by the insertions of the chordae tendineae. The smooth atrial surface becomes rough in its distal portion all along the area of contact with the opposite cusp. This area, which is variable in width according to the leaflet, has been termed “rough zone” (10,18,19), “margin of closure” (9), “contact area” (7), “line of apposition” (22), “zone of apposition” (11) and less precisely “free edge” (2,4). Whatever its name, this part of the leaflet is very important since it determines the amount of apposition between opposing leaflets, essential in reducing stress on the chordae tendineae described as acting as the keystone in an arch (24,25).

Chordae tendineae

This is without any doubt the area where the confusion is greatest. Their complicated anatomy fascinated the enquiring mind of Leonardo da Vinci, who drew them repeatedly (Fig. 2). Their variability in origin from the papillary muscles, number and type of insertion into the leaflets has stimulated detailed studies, usually complex and often not useful to the practising surgeon. According to their site of origin and insertion, Tandler (1) is credited with their classification into three types or chords of 1st, 2nd and 3rd order. First-order chords would be those originating from a papillary muscle and inserted into the free edge of the leaflet. These chords have been also called “free edge” (6,7), “marginal” (9,10) “rough zone” (6,26) and “strut” (25) chords. Second-order chords are defined as those that, although also arising from the papillary muscle, are inserted into the ventricular or undersurface of the leaflets. Among these, two particularly strong and thick chords stretching from each papillary muscle to the undersurface of the anterior leaflet have been identified and termed “intermediate” (10), “strut” (26) and “principal” (6) chords. Their function has been assumed to be support for the belly of the anterior leaflet (25) and their importance considered “critical” by Lord Brock (27). In our opinion, probably due to a nautical bias, these chords should be called more appropriately “stay chords” as ropes supporting both the mast and the sail. The presence of posterior “principal” chords or “strut chords” has only been mentioned by Van Rijk (10) in her videoscopic study of the isolated beating porcine heart. Third-order chords, only present in the posterior leaflet, are those that arise from the ventricular wall and end on the ventricular aspect of the posterior leaflet. They have also been named “mural” (7) and “basal” (6,10,26). It has been suggested that their division would increase leaflet mobility in valves affected by rheumatic pathology. A different and easier classification follows the leaflet or the area to which the chord is attached to, so that “anterior”, “posterior”, “commissural” and “left” chords result. Their numbers and lengths have been the subject of detailed studies (6,22,26).

Papillary muscles

The papillary muscles are trabeculae carneae arising from the junction of the middle and apical third of the left ventricular wall on a plane slightly posterior to the intercommissural plane in diastole (10). The classical description of two papillary muscles, one superior and one inferior, was revised by Rusten et al. (28) as one anterior (anterolateral) and one posterior (posterome-
dial). They observed the consistent relationship that each papillary muscle bears with its respective commissure, although occasionally these commissural areas have their chordal attachments arising from an independent muscle head. In about 70% of the hearts studied the anterior muscle consisted of a single head, while the posterior had multiple heads in 60% of the cases (2,9). The chordal origins from the papillary muscle are roughly semicircular, with the commissural chordae arising from its tip (5). The "stay" chordae are described as originating from the apex by some authors (9,26), while others describe them as taking origin from the lowest part of the corona (10), or variable (7). The function of the papillary muscles in the normal and diseased heart has been extensively studied but is outside the scope of the present revision (8,23,29-32).

**Proposed terminology and classification**

Careful analysis of this previous published work reveals that although all authors have described the same structures, their perspective was different (anatomic, surgical or functional) (Fig. 3), and the more precise the terminology, the more confusing, sometimes impossible to apply in the daily work of the surgeon.

We therefore studied the possibility of finding a simple classification accessible to the surgeon based on

- dividing all structures into what is perceived by the surgeon who observes the valve through a left atriotomy, as anterior, posterior and left/right;
- naming the chords by the area of the leaflet they are inserted, independently of whether inserted into the free edge or the ventricular surface;
- because of the variability in their number, avoid naming all possible chords but rather group them according to their area of insertion into the leaflet;
- utilizing the easily identifiable and important "stay" chords as markers to divide all anterior leaflet chords as being to the "right" or "left" of them.

The resulting classification is shown in Figure 4. The main leaflet is called the "anterior", the mural "posterior" and the commissural areas "commissures". If abbreviations are considered useful, the anterior structures are labelled "A" and the posterior "P". Those parts of any leaflet situated to the left of the surgeon carry a figure 1 and those to the right of the surgeon a figure 2. Therefore the anterior leaflet is divided into two halves, A1 and A2, and the commissural areas are identified as C1 and C2. Given the surgical importance of the middle scallop of the posterior leaflet (P) and its central situation, its name is retained as "middle" (PM). The two lateral scallops would be P1 and P2 according to their location to the left or to the right of the middle scallop. The anterolateral papillary muscle would be termed M1 and the posteromedial muscle M2. The chords follow the same nomenclature as the part of the leaflet they are attached to (Figs. 5 & 6), i.e. the commissural would be C1 and C2 chords and the posterior leaflet chords would be named P1, PM and P2. The two stay chords (S), attached to the anterior leaflet (A) would be S1 and S2. The remaining chords inserted into the anterior leaflet would be divided by each "stay" chord (S1 and S2) into those to their left and those to their right. For example, those chords attached to the left half of the anterior leaflet (A1) would be termed S1.1 if situated to the left of that stay chord and S1.2 if to the right of the stay chord.
In the clinical situation, although initially more demanding than the usual report, the uniformity and the precision of data obtained was far superior than the standard surgical operative descriptions, which varied not only among different surgeons but even among different reports of the same surgeon. Without expecting a rapid and universal acceptance of this nomenclature, it is hoped that this attempt will constitute a step towards the goal of a more precise data collection that will improve the analysis of the results of specific procedures and pathology, not only for a particular group but between different centers.

References:
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