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Review

# Functional mitral regurgitation
# From normal to pathological anatomy of mitral valve

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ABSTRACT

Mitral valve (MV) is composed of several structures working in synchrony to open during diastole and close in systole within the high-pressure systemic environment. Its morphological features ensure a normal leaflet closure that prevents regurgitation of blood back into the left atrium causing loss of ventricular pressure and forward flow. The complex interactions of the normal MV are reliant on each component playing a complete role for the efficient working of the valve.

In this review we firstly discuss the overall MV structure in terms of a complex make up of the annulus, the leaflets, their tendinous cords, and the supporting papillary muscles, and then the anatomical changes of each MV components due to left ventricular geometry and function alterations, underlying functional mitral regurgitation.



## 1. Normal anatomy

The mitral valve (MV) had its name by Andreas Vesalius (De Humani Corporis Fabrica. 1543), due to its shape similar to the bishop's hat (Mitre). The MV lies in the floor of the left atrium, separating the inflow from the outflow tract of the left ventricle, by shifting its position. The complex architecture of MV is at the basis of its different roles: the diastolic passage of blood from the left atrium into the left ventricle and systolic hindrance of blood backflow from the left ventricle into the left atrium. Furthermore, the mitral valve, differently from the tricuspid one is part of left ventricular outflow tract and of the aortic root, thus, it facilitates the accommodation of blood, eventually followed by its rapid, efficient and forceful ejection through the left ventricular outflow tract into the aortic root [1].

The mitral valvular complex is made up of several individual parts, which need to function in harmony in order to perform the above-mentioned roles. These parts are the annulus and the leaflets (the valve), the papillary muscles and the tendinous cords (the subvalvular apparatus).

### *1.1. The annulus*

The mitral annulus (MA) is a concept rather than an anatomical well defined structure [1] and can be described as the junctional zone which separates the left atrium and left ventricle, at the hinge point of the leaflets. In a bidimensional (2D) view, MV appears to be more kidney- or D-shaped than circular [2] with intercommissural diameter longer than the septo-lateral one. While the mural component coincides with the atrioventricular junction, the flattened portion of the D extends away from the junction, incorporating the mitro-aortic continuity (Fig. 1). In 2D, two measurements are important to be evaluated: the septolateral and the intercommissural distances.[3] Actually the so-called septolateral diameter is considered the aorto-mural diameter, [4] even if, from an anatomical point of view, the septo-lateral diameter skirts closer to the intercommissural one (Fig. 2) [1].

MV annulus is also far from being a planar structure, possessing in three-dimensional (3D) view a distinct saddle-shaped configuration (Fig. 3), with the highest point along the anterior annulus towards the left atrium and the lowest point at the level of the commissures, having the shape of a hyperbolic paraboloid [5].

From a histological point of view, the mitral annulus is made of a fibrous support and a muscular portion. The fibrous support can appear as cord-like or curtain-like according to its sectional structure. Except for the mitro-aortic continuity that is defined as a fibrous

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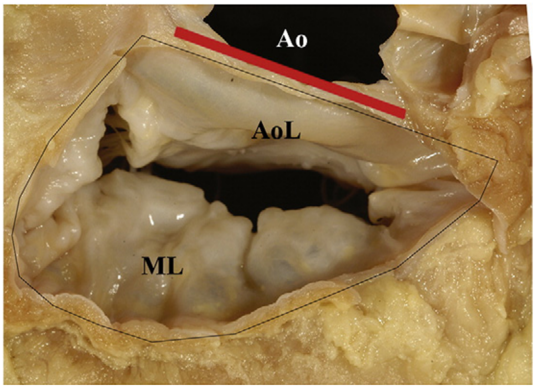


**Fig. 1.** Anatomical view: the D-shape of mitral annulus; the flattened portion of the D incorporate the mitro-aortic continuity (red line). Ao = aortic valve, AoL = aortic leaflet, ML = mural leaflet.

sheet between the aortic valve and the portion of MV anterior leaflet insertion (between the two trigones), the fibrous support can be differently present along the ring in the normal population. A cord-like fibrous support encircling the entire annulus is very rare. More commonly, dense fibrous aggregations resembling a cord-like ring are detectable just at the site of the two trigones (left and right) which represent the anchorage of the overall valvular complex to the walls of the left ventricle. The region of mural (posterior) leaflet insertion is defined as the hinge and is dynamic, being mainly formed by muscular components (Fig. 4)[6].

The normal mitral annulus is a dynamic structure that undergoes area changes throughout the cardiac cycle of roughly 23–40%, [7] reaching a maximum in late diastole ($7.1 \pm 1.8\ cm^2$) and a minimum in late systole ($5.2 \pm 1.6\ cm^2$), thus facilitating both left ventricular (LV) filling and competent valve closure. The narrowing of MV annulus is due to the left atrial contraction in pre-systole and might reach even more than 90%, whereas the systolic ventricular contraction is responsible for the remaining 10% of annulus narrowing. The role of the atrial contraction for a correct closure of the mitral valve is essential. In an experimental setting, ventricular pacing increased the septo-lateral distance by only 8%, but cause delayed leaflet coaptation and a 16% regurgitant fraction [8]. The diastolic relaxation determines the increase in the dimensions of the mitral annulus [9]. Moreover, the mitro-aortic continuity plays an important role, forcing both valves to work in synchrony. In systole, the posterior annulus

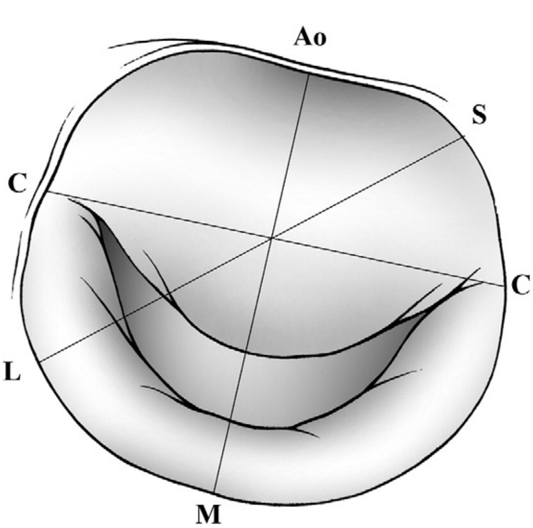


**Fig. 2.** Septolateral diameter (SL) is usually considered the aorto-mural (AoM) diameter, even if, from an anatomical point of view, the septo-lateral diameter skirts closer to the intercommissural one (CC).

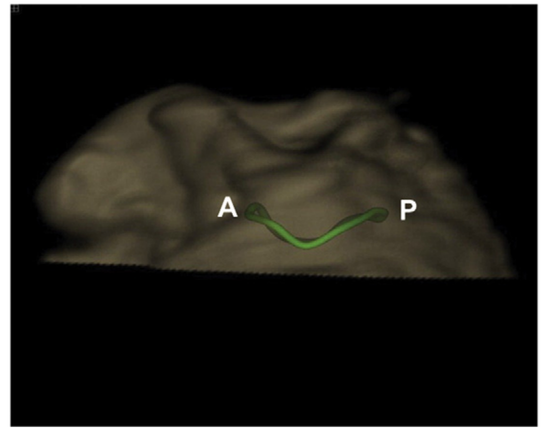


**Fig. 3.** Echocardiographic view: the 3D silhouette of mitral valve is saddle-shape with the highest point indicated as A, along the anterior annulus towards the left atrium and the lowest point indicated as P at the mid of posterior annulus, deep into the left ventricle.

moves toward the apex, while the anterior horn of the saddle moves toward the left atrium, contributing to the late systolic increase of the aortic orifice, and accompanies the aorta in its movement. All these changes cause an increase of the mitroaortic angle, thus preparing the following opening of the anterior leaflet. In diastole, the anterior horn of the saddle moves toward the aortic annulus, contributing to the diastolic increase of the mitral area, and upwards, accompanying the aorta in its movement. All these changes cause a decrease of the aortomitral angle, and prepare the MV for the next closure of the anterior leaflet. The synchronized movements of the mitral and aortic annuli are a complex mechanism designed to facilitate the filling and emptying of the left ventricle. The 3D mitral hinge motion contributes to changes in mitral septo-lateral dimension [10].

### *1.2. The leaflets and commissures*

The leaflets represent the parts of the valve that attract the greatest divergence in description, particularly their number [11]. Traditionally, the mitral valve has been presumed to have two leaflets (hence its alternative title of the bicuspid valve) usually identified as *anterior* and *posterior*, even if it would be more correct to define them antero-superior and infero-posterior, according to a more appropriate description of their real orientation (Fig. 1) [12]. They were firstly described by Vesalius who called them aortic (anterior) and mural (posterior). The thickness of normal leaflets is about 1–2 mm, without any change age-related, and anyway it has to be considered normal up to 4–5 mm.

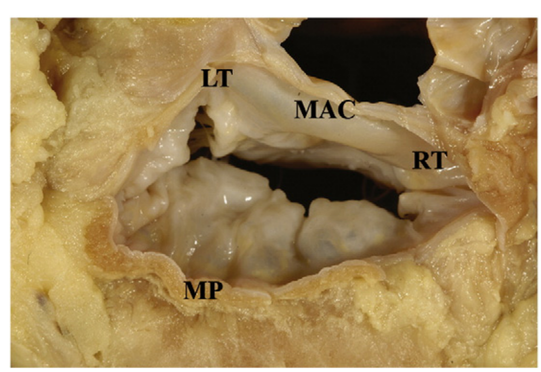


**Fig. 4.** The fibrous portion of the anterior leaflet is most commonly represented by mitroaortic continuity (MAC) up to the trigones, left (LT) and right (RT), even if the fibrous portion can occasionally extend laterally from each trigones. The remaining portion is usually muscular (MP).