INTRODUCTION

Two-thirds of the world's populations live in developing countries where a high prevalence rheumatic heart disease exists. Up to 30 million school children and young adults have chronic rheumatic heart disease worldwide, and nearly a third or more of these have mitral stenosis which has been regarded almost synonymous to rheumatic heart disease, as rheumatic heart disease is the etiology of mitral stenosis in most of the patients[1-5].

Systolic dysfunction of the RV (RV) is well documented in patients with rheumatic mitral stenosis[6]. Right ventricular failure plays an important role in the development of clinical symptoms, and significantly affects exercise capacity, prognosis, and survival of patients with pure mitral stenosis[7,8]. Right ventricular dysfunction is usually overlooked before the emergence of clinical signs of systemic venous congestion because of difficulties in the quantitative assessment of right ventricular function.

Balloon Mitral valvuloplasty is considered the treatment of choice for patients with Mitral stenosis, yet the immediate results on right ventricular pressure overload relieve is not detected by conventional 2D & Doppler studies.

The evaluation of global and regional right ventricular function is difficult because of its asymmetric and complex anatomy. Various imaging techniques have been used to assess right ventricular function including contrast right ventriculography, radionuclide angiography, and newer methods such as magnetic resonance imaging, but all have significant limitations[(9,10)].

On the other hand, transthoracic echocardiography is a noninvasive and widely used technique that has reproducible and concordant results with other imaging methods[(11)]. Until now, Tissue Doppler Imaging and Doppler derived strain and strain rate analysis are the most widely used techniques for the evaluation of right ventricular myocardial function (12-15). However; those measurements have major disadvantages such as angle dependence, limited spatial resolution, and deformation analysis in one dimension (16).

Nowadays, a novel method, two dimensional strain and strain rate imaging, has been developed for the quantitative assessment of global and regional myocardial function. This technique is based on gray-scale images that are analyzed by the dedicated software system. Although two dimensional strain imaging has been frequently used to investigate left ventricular function, little is known about global and segmental right ventricular function (17, 18).

AIM OF THE WORK

The aim of the present study was to assess global and regional left and right ventricular functions using two dimensional strain and strain rate in patients with moderate and severe mitral stenosis before and after balloon mitral valvuloplasty.

Chapter One

ANATOMY OF THE MITRAL VALVE

According to Walmsley (19), it was Andreas Vesalius who suggested the picturesque term "mitral" to describe the left atrioventricular valve owing to its resemblance to a plan view of the bishop's mitre (figure 1). Guarding the inlet to the left ventricle, the mitral valve (MV) prevents backflow to the left atrium (LA) during ventricular systole. In its open state, the valvar leaflets are like a funnel extending from the hinge line at the atrioventricular junction to the free margins. Tendinous cords attach the leaflets to two closely arranged groups of papillary muscles. The interchordal spaces serve as important pathways for blood flow. As emphasized by Perloff and Roberts (20), the MV requires all its components, together with the adjacent atrial and ventricular musculature, in order to work properly.

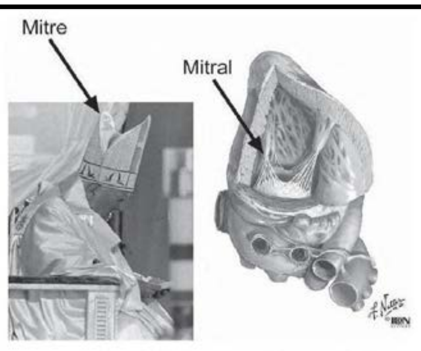

Figure (1): The mitral valve, which is so named because of its resemblance to a cardinal's hat, known as a mitre. ***(From: Weinhaus AJ, Roberts KP. Anatomy of the human heart. In: Laizzo PA, ed. Handbook of cardiac anatomy, physiology, and devices. Totowa, NJ: Humana Press Inc.: 2005:67).***

The valvar complex comprises the annulus, the leaflets, the tendinous cords, and the papillary muscles. Also important for its functioning is the LA musculature inserting to the leaflets and the myocardium to which the papillary muscles are inserted. The valve is obliquely located in the heart and has a close relation to the aortic valve (figure 2A). Unlike the tricuspid valve which is separated by muscles from its counterpart, the pulmonary valve, the MV is immediately adjacent to the aortic valve (21) (figure 2B).

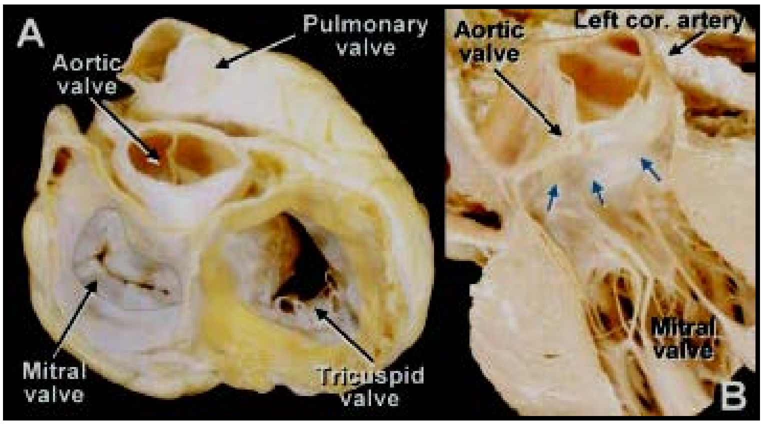

Figure (2): (a) View of the base of the heart in anatomical orientation **(b)** Dissection of the heart viewed from the anterior aspect ***(Heart 2002; 88(Suppl IV):iv5–iv10)*.**

Normally, extensions of atrial muscle mark the so-called ring when the valve is viewed from the atrium. The degree of muscular extension varies from heart to heart and from area to area within the same heart. When the parietal atrioventricular junction is cut in profile, the variability of insertion of the hinge, or fulcrum, of the mural leaflet relative to atrial myocardium can be seen. At the aortic ("anterior") leaflet of the valve, the distal edge of atrial myocardium marks the hinge (21) (figure 3).

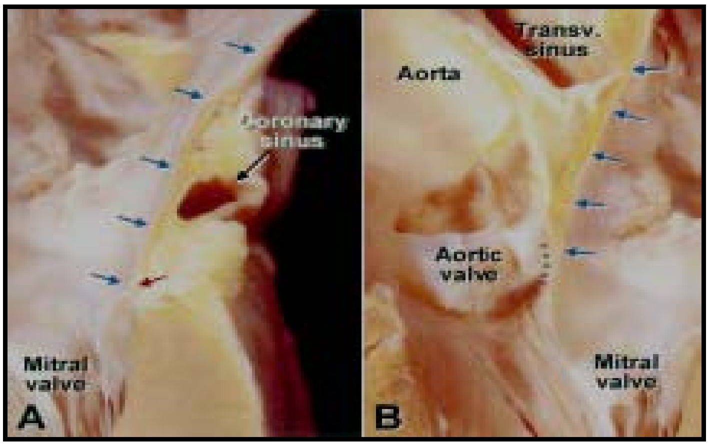

Figure (3): (A) The left parietal atrioventricular junction **(B)** The aortic leaflet of the MVcut in profile ***(Heart 2002; 88(Suppl IV):iv5–iv10).***

The annulus marking the hinge line of the valvar leaflets is more D shaped than the circular shape portrayed by prosthetic valves. The straight border accommodates the aortic valve allowing the latter to be wedged between the ventricular septum and the mitral valve. In this region, the aortic valve is in fibrous continuity with one of the two leaflets of the mitral valve. Expansions of fibrous tissues at either extreme of the area of continuity form the right and left fibrous trigones. The atrioventricular conduction bundle passes through the right fibrous trigone (21) (figure 4).

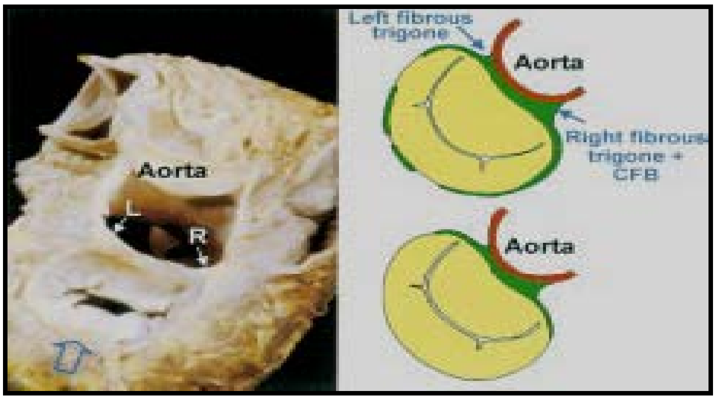

Figure (4): A dissection showing the left (L) and right (R) fibrous trigones ***(Br Heart J 1988; 59:712–6).***

Although the term annulus implies a solid ring-like fibrous cord to which the leaflets are attached, this is far from the case. In the area of aortic-mitral fibrous continuity, the distal margin of atrial myocardium over the leaflet defines the hinge line. When viewed from the ventricular aspect, however the hinge line is indistinct since the fibrous continuity is an extensive sheet. McAlpine (22) disfavored the term annulus, preferring to describe the sheet like fibrous area as the aortoventricular membrane that extended around the subvalvar region, along the remainder of the annular circumference, the detailed studies of Angelini and colleagues (23) demonstrated pronounced variations not only from heart to heart but within the same heart. The same range of variations was found in hearts with floppy valves. Contrary to the report by Hutchins and colleagues (24), the so-called disjunction at the annulus was found as frequently in normal as in prolapsed valves. In agreement with previous studies, Angelini and colleagues (23) traced prongs of fibrous tissues form each of the fibrous trigones but these were not continuous around the orifice. The annulus opposite the area of valvar fibrous continuity tends to be weaker in terms of lacking a well formed fibrous cord.

Distinctly different from the tricuspid valve, the MV has two leaflets although some may argue that it has four leaflets. These are notably different in shape and circumferential length. Owing to the oblique location of the valve, strictly speaking, its two leaflets do not occupy anterior/posterior positions nor is one of the leaflets “septal”. The septal leaflet is characteristic of the tricuspid valve whereas neither of the mitral leaflets is attached to the septum. The corresponding terms for anterior and posterior are “aortic” and “mural”. It is the aortic leaflet that is in fibrous continuity with the aortic valve. The aortic leaflet has a rounded free edge and occupies a third of the annular circumference, whereas the other leaflet is long and narrow, lining the remainder of the circumference (21).

The aortic leaflet hangs like a curtain between the left ventricular inflow and outflow tracts. When the valve is closed, this leaflet appears to form the greater part of the atrial floor but is approximately equal in area to the mural leaflet. It meets the mural leaflet to form an arc shaped closure line, or zone of apposition, that is obliquely situated relative to the orthogonal planes of the body. With the leaflets meeting, the view of the valve from the atrium resembles a smile (25).

From the attachment point of each leaflet at the annulus to the free edge, the leaflet is described as having basal, clear and rough zones (figure 5); the basal zone is described as the area where the leaflet connects to the atrioventricular junction. The thin central portion of the leaflet is the clear zone. The thick rough zone at the free edge of the leaflet is the main area of chordal attachment and the region of coaptation (i.e. where the leaflets meet) and apposition (overlap of the leaflet free edge) (26).

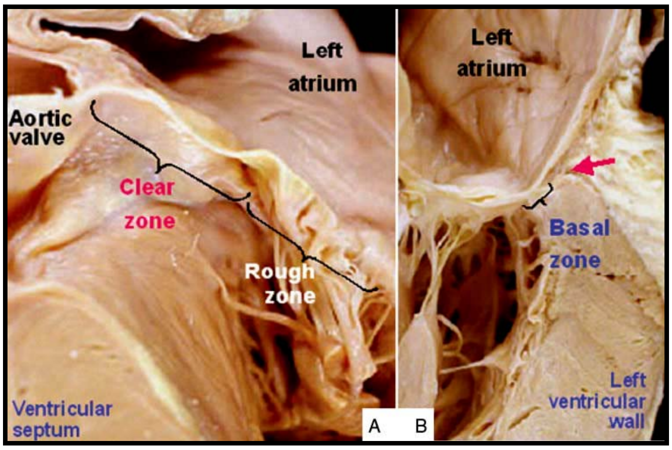

Figure (5): The aortic leaflet of the MV is in fibrous continuity with the leaflets of the aortic valve, this comprises the clear zone of the leaflet. The undersurface of the rough zone in this mitral leaflet has many cordal attachments. The mural leaflet of the MV has a basal zone (bracket) which inserts into the annulus at the left atrioventricular junction (arrow).

Each end of the closure line is referred to as a commissure (figure 6A). These are designated the anterolateral and posteromedial commissures. It is worth noting, however, that the indentations between leaflets do not reach the annulus but end about 5 mm short in the adult heart. Therefore, there are no clear cut divisions between the two leaflets. Furthermore, the free edge of the mural leaflet is often divided into three or more scallops or segments described as lateral, middle, and medial or assigned terms like P1, P2, and P3 (27).

Although three scallops are most common, the scallops are not equal in size. Rangnathan and colleagues found the middle scallops to be larger in the majority of hearts (figure 6). Victor and Nayak likened the slits between scallops to the pleats of a skirt (28, 29).

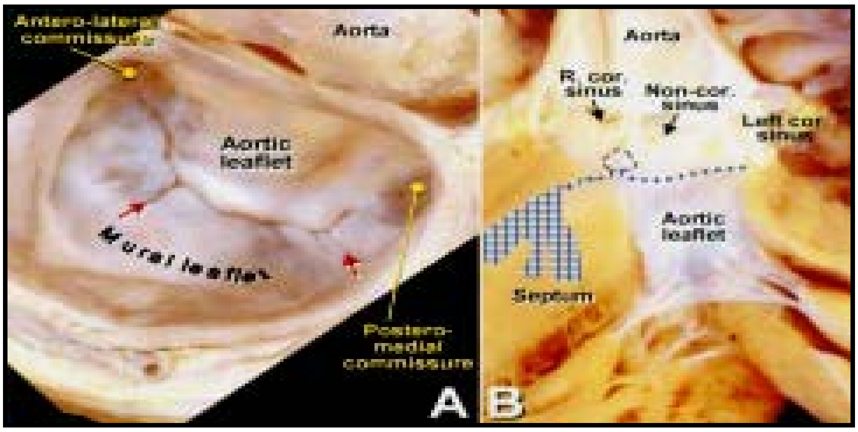

Figure (6): (A) the atrial aspect of the mitral valve. (B) The aortic leaflet of the MV hangs between inflow and outflow tracts of the left ventricle ***(Heart 2002; 88 (Suppl IV):iv5–iv10).***

Normally, the valvar leaflets are thin, pliable, translucent, and soft. Each leaflet has an atrial and a ventricular surface. When viewed in profile, two zones can be distinguished in the aortic leaflets and three zones in the mural leaflet according to the insertions of the tendinous cords (21).

In both leaflets, there is a clear zone that is devoid of cordal attachments. Nearer the free edge, the atrial surface is irregular with nodular thickenings. This is also the thickest part, corresponding with the line of closure and the free margin. Tendinous cords attach to the underside of this area described as the leaflet's rough zone. The rough zone is broadest at the lowest portions of each leaflet but tapers toward the periphery, or commissure, of the closure line (21).

The basal zone that is found only in the mural leaflet is the proximal area that has insertions of basal cords to its ventricular surface. Being distant from the ventricular wall, the aortic leaflet does not have attachments to basal cords. In normal valve closure, the two leaflets meet each other snugly with the rough zone and free edge in apposition but at an angle to the smooth zone (21) (figure 7).

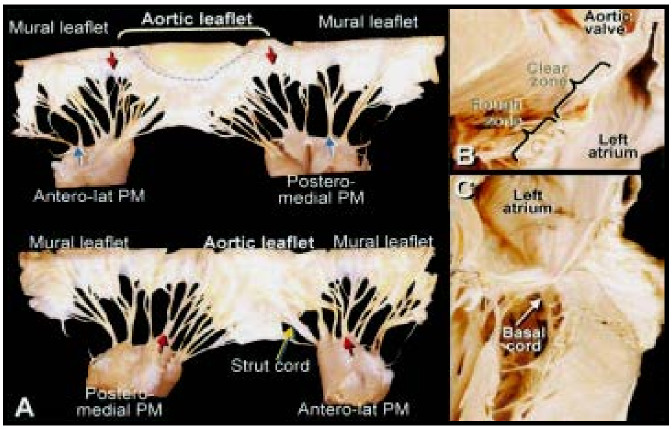

Figure (7): A) Atrial surface (upper panel) and ventricular surface (lower panel) of a mitral valve. B). cordal attachments to the rough zone. C) A basal cord inserts to the basal zone on the ventricular surface of the mural leaflet ***(Heart 2002; 88(Suppl IV):iv5–iv10).***

When the closed valve is seen in profile, the major part of the closure line lies below the plane of the atrioventricular junction rising toward the commissures at the peripheral ends so that the atrial surface of the leaflets has a saddle-like configuration. Being tethered by the tensor apparatus, the line of coaptation in a normal valve does not extend above the level of the junction during ventricular systole (30).

The tendinous cords are string-like structures that attach the ventricular surface or the free edge of the leaflets to the papillary muscles. Characteristically, the tricuspid valve has cordal attachments to the ventricular septum allowing it to be distinguished from the MV on cross sectional echocardiography. The tendinous cords of the MV are attached to two groups of papillary muscles or directly to the postero-inferior ventricular wall to form the tensor apparatus of the valve. Cords that arise from the apices of the papillary muscles attach to both aortic and mural leaflets of the valve. Since cords usually branch distal to their muscular origins, there are five times as many cords attached to the leaflets as to the papillary muscles (25).

There are numerous classifications of tendinous cords. One of the earlier classifications of cords is that cited in Quain's elements of anatomy (19), following the precedence of Tandler (31). This classification distinguishes three orders of tendinous cord according to the site of attachment to the leaflets. The first order cords are those inserted on the free edge. They are numerous, delicate, and often form networks near the edge.

Second order cords insert on the ventricular surface of the leaflets beyond the free edge, forming the rough zone. These are thicker than first order cords. Third order cords attach only to the mural leaflet since they arise directly from the ventricular wall or from small trabeculations. They insert to the basal portion of the leaflet and run only a short distance toward the free margin. In this area, webs may be seen in place of cords. Subsequent workers emphasized individual cords such as the commissural cords (32) strut cords (33), and cleft cords (34) in relation to function (figure 8).

The Toronto group distinguished between leaflet and interleaflet or commissural cords. Normally there are only two commissural cords, one supporting each free margin of the commissural region (figure 9). These cords arise as a single stem but branch like the struts of a fan that, on closing and opening, allow the adjacent leaflets to coapt and to move apart.

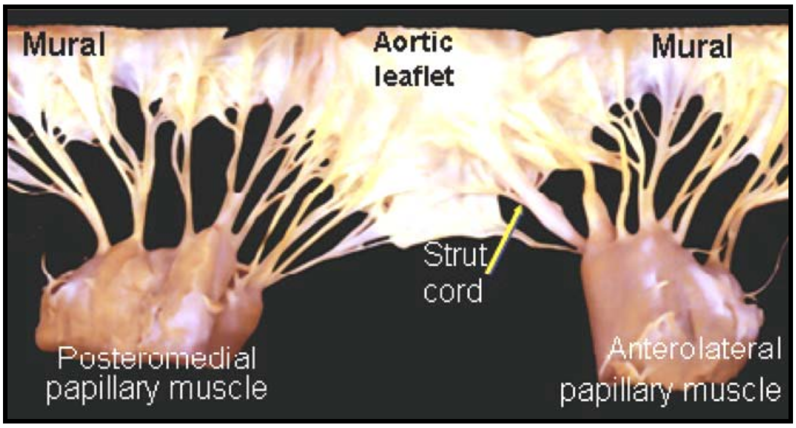

Figure (8): View of the ventricular surface of an adult mitral valve ***(Heart 2002; 88(Suppl IV):iv5–iv10).***

Leaflet cords are of several forms. The most numerous are rough zone cords. Lam and colleagues describe these as single cords that typically split into three cords soon after their origin from the papillary muscle. One cord inserts to the free margin of the leaflet, and the other two to the rough zone, reinforcing the zone of apposition (34).

Rough zone cords in the mural leaflet are generally shorter and thinner than those found in the aortic leaflet. Among the rough zone cords of the aortic leaflet are two that are the largest and thickest. Termed strut cords, these arise from the tip of each papillary muscle and are thought to be the strongest (34).

Another type of cord, the cleft cord, is found only in the mural leaflet. Each is a miniature version of a commissural cord whose branches insert into the free margin between adjacent segments while the main stem runs into the rough zone. In the Toronto classification, self evidently, the basal cords correspond to third order cords (28, 35). The strut cords and parts of the rough zone and cleft cords correspond to second order cords. Parts of the rough zone cords, cleft cords, and the commissural cords that insert to the free edge of the leaflets correspond to first order cords (34).

The papillary muscle bundles are generally described in anterolateral and posteromedial positions and are positioned along the mid to apical segments of the left ventricle. The former is usually seen to attach at the border of the anterolateral (lateral) and inferolateral (posterior) walls, and the latter over the inferior wall of the left ventricle and in the majority of adults the papillary muscle can have up to three heads (26).

As a functional unit, the papillary muscle includes a portion of the adjacent left ventricular wall. Tendinous cords arise from the tips of the papillary muscle. Alterations in the size and shape of the left ventricle can distort the locations of the PM, resulting in disturbed valvar function (37).

Described in most textbooks as two in number, however, there are usually groups of papillary muscle arranged fairly close together. At their bases, the muscles sometimes fuse or have bridges of muscular or fibrous continuity before attaching to the ventricular wall. Extreme fusion results in parachute malformation with potential for valvar stenosis (33).

Viewed from the atrial aspect, the two groups are located beneath the commissures, occupying anterolateral and posteromedial positions. Rusted and colleagues' study of 200 normal hearts revealed a single anterolateral papillary muscle in 70% of cases. This contained a groove that pointed toward the commissure. The same study showed in 60% of cases that there are two or three papillary muscle, or one muscle with two or three heads (32), in the posteromedial location.