INTRODUCTION

Valve disease is an important public health problem, as it carries a poor prognosis and its prevalence is strongly linked to the phenomenon of population ageing ***(Nkomo et al., 2006)***.

Significant aortic stenosis affects nearly 5% of individuals over 75 years of age ***(Nkomo et al., 2006)***.

Aortic stenosis may be caused by degenerative calcification, congenital malformations, or rheumatic fever. It may also be found in association with systemic diseases such as Paget’s disease of bone and end-stage renal disease. Congenital malformations include unicommisural and, more commonly, bicuspid valves ***(Selzer and Lombard, 1988)***.

Aortic stenosis has rapid clinical progression after a long asymptomatic period ***(Stöhr et al., 2011)***. Hemodynamically significant aortic stenosis is initially counteracted by left ventricular hypertrophy. Progression of outflow obstruction and ventricular hypertrophy lead to cardinal symptoms of aortic stenosis: angina, syncope, and congestive heart failure ***(Braunwald, 2001)***.

Valve replacement is the definitive therapy for patients with severe AS who have symptoms or objective consequences such as left ventricular (LV) dysfunction ***(Bonow et al., 2006)***.

Operative mortality is quite low, even in elderly patients when properly selected, and long-term results have been shown to be satisfactory ***(Kolh et al., 2007; Melby et al., 2007)***. However, the risk of surgery may be higher in elderly patients with significant comorbidities ***(Iung et al., 2005)***. In the EURO HEART Survey, 31.8% of all patients indicated for surgical valve replacement were accordingly rejected ***(Iung et al., 2003)***.

Balloon aortic valvuloplasty (BAV) is now rarely used, mainly due to its limited long-term efficacy ***(Iung et al., 2003)***.

In the year 2002 a novel alternative approach to surgical aortic valve replacement among critically ill patients with severe aortic valve stenosis has been first introduced by Cribier – the percutaneous aortic valve replacement ***(Cribier et al., 2002)***.

Transcatheter aortic valve implantation (TAVI) has emerged as an alternative treatment for patients with severe AS considered at high surgical risk with promising early and mid-term results ***(Patel et al., 2009)***.

Since the first-in-man TAVI by Alain Cribier in 2002, TAVI became a dynamic field of research and development. Two devices are under clinical investigation for TAVI. One device is the Edwards-Sapien valve (Edwards Lifesciences Inc., CA, USA), The other device is the CoreValve Revalving System (CRS TM, CoreValveInc, Irvine, CA, USA) ***(Vahanian et al., 2008)***.

TAVI is currently carried out using two different approaches (retrograde transfemoral and anterograde transapical), which share the same main principles ***(Vahanian et al., 2008)***.

Patient selection plays a crucial role in the success of transcatheter aortic valve implantation (TAVI). The patient must be assessed from access to implantation site. In addition to patient risk evaluation, anatomical selection criteria need to be considered. Multimodality imaging, using a combination of angiography, echocardiography and multislice computed tomography (MSCT), is necessary to determine the anatomical suitability for the procedure. In particular, assessment of the peripheral vasculature and aortic valvar complex will allow selection of the access route and prosthesis type and size, respectively ***(Piazza et al., 2012)***.

Despite the lesser degree of invasiveness of TAVI compared to open aortic valve replacement (AVR), TAVI is associated with a significant potential for serious life-threatening complications, both intraoperatively and postoperatively. These include vascular injuries, stroke, structural injury to the aorta and the heart and its valves, aortic root or annulus injury, conduction tissue injury, paravalvular leak, valve malposition, coronary complications such as obstruction or ischemia, pericardial effusion and tamponade, and procedural cardiac depression requiring immediate cardiopulmonary bypass for resuscitation ***(Vallabhajosyula and Bavaria, 2011).***

AIM OF THE WORK

The aim of this work is to provide information about the transcatheter aortic valve implantation with special reference to:

1- Preoperative selection of the patients.

2- Preoperative preparations.

3- Operative instruments.

4- Operative technique & Routes of access.

5- Complications of TAVI.

6- Comparison between:

- Transapical access of TAVI

&

- Transfemoral access of TAVI.

DEVELOPMENTAL ANATOMY OF THE AORTIC VALVE

The primitive heart tube consists of 5 segments which are: the venous sinus, the atrial segment, the inlet component of ventricular segment, the outlet component of the ventricular segment and the arterial segment. The outlet component of the ventricular segment is the conus which becomes continuous with the major artery “the truncus arteriosus”. At an early stage, together they may be called the trunco-conal channel. The aortic root and the pulmonary trunk are derived from partitioning of the trunco-conal channel by fusion of the lining of the trunco-conal ridges “trunco-conal septum”. Theses ridges follow a spiral course; therefore the septum that results from fusion of the two ridges has a spiral shape ***(Edwards, 1961)***.

The lower most part of the trunco-conal septum fuses with the developing ventricular septum to share in dividing the ventricular outflow into right and left ventricular components. At the junction of the cardiac and arterial ends of the trunco-conal canal channel, the aortic and the pulmonary semilunar valves are formed. The right and left cusps of the aortic valve are derived from the trunco-conal septum. The non septal cusp is derived from non specialized tissue in the lining of the trunco-canal channel ***(Zimmerman et al., 1969; Robicsek, 1991)*** (Fig. 1).

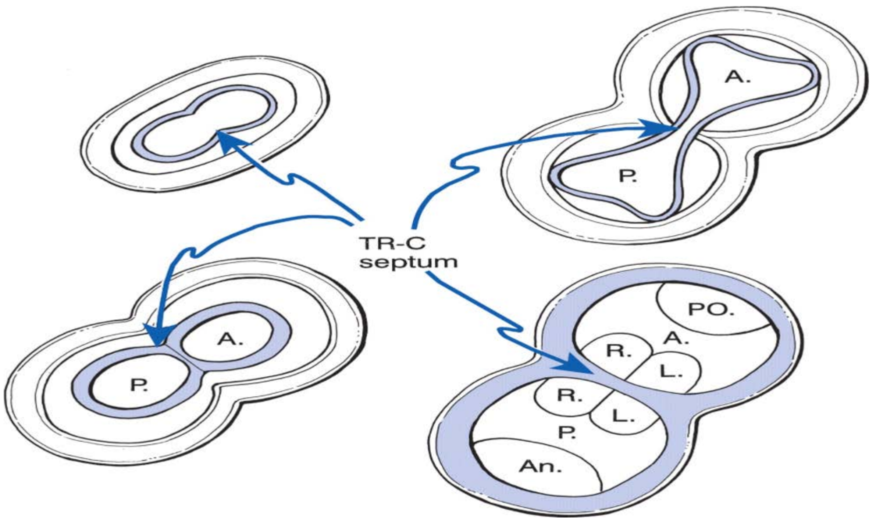

Figure (1): Development of the aorta and pulmonary artery, with subsequent development of the aortic valve leaflets. TR-C= Trunco-conal, A= Aorta, P= Pulmonary artery, An.= Anterior, PO.= Posterior, R.= Right, L.= Left ***(Alan et al., 2005).***

STRUCTURAL ANATOMY OF THE AORTIC VALVE

The aortic valve is a structure composed of leaflets supported in a connective tissue tube. It has been defined as a thin mobile layer of tissue located in a canal allowing free flow through the passage way and preventing reflux. Studies on the dimensional changes of the aortic root during each cardiac cycle reveal that; the sinuses of Valsalva account for significant variations during opening and closing of the valve. Accordingly, the sinuses have been suggested to play a more active part in the function of the valve than has been previously thought. The aortic valve sinuses along with the triangles of fibrous tissue interposed between the sinuses in the subvalvular ventricular outflow tract must be considered as constituent parts of the aortic valve ***(Sliver and Roberts, 1985)*** (Fig. 2).

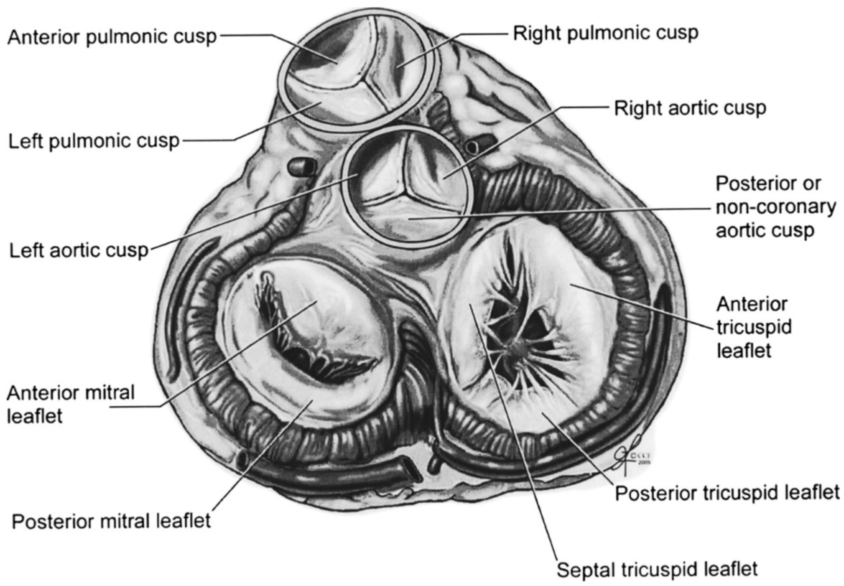

Figure (2): Anatomic relationship between the aortic valve and surrounding structures ***(Anderson et al., 2005)***.

The normal aortic valve can be considered as a complex structure made up of several components:

1- The aortic leaflets (the aortic semilunar cusps or valvules).

2- The aortic sinuses.

3- The fibrous interleaflet triangles of the subaortic outflow tract "fibrous skeleton" (Fig. 3)

(Sliver and Roberts, 1985)

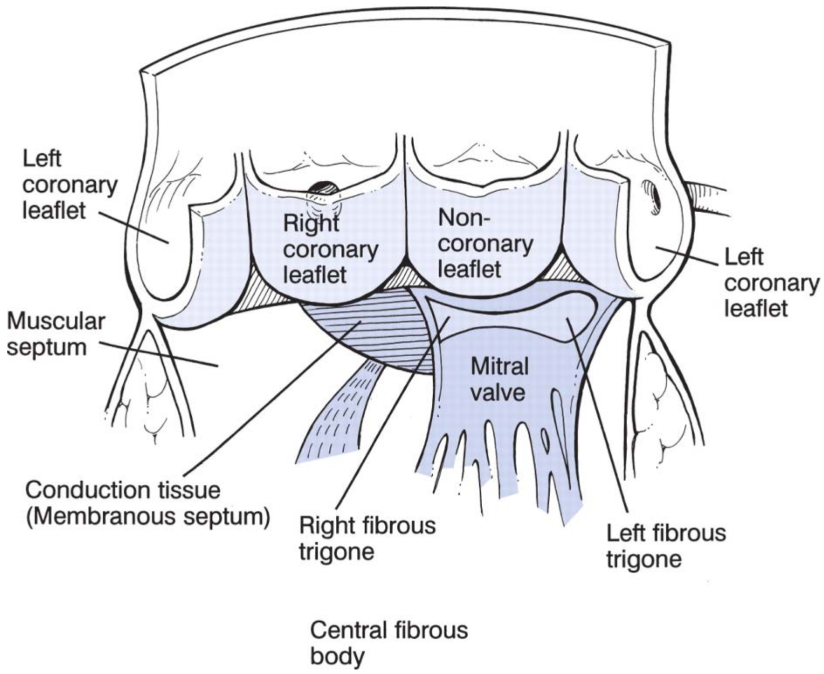

Figure (3): A schematic diagram of the relationship of the aortic valve leaflets to the structures underlying the commissures ***(Michaljevic et al., 2003)***.

The Aortic leaflets (the aortic semilunar cusps or valvules)

The normal aortic valve is reduplication of the endocardiurn enclosing a central lamina fibrosa ***(Sliver and Roberts, 1985)***.

They are three in number, the superior edge of each cusp is unattached and the remaining edges of the cusps attached to the aortic wall, the space between the aortic wall and the related cusps is called an aortic sinus or sinus of Valsalva. The three cusps are oriented in right anterior, left anterior and posterior cusps and are usually named as the right, left and posterior leaflet. The junctional zone between the two adjacent cusps is own as commissure. At the commissure there is thickening of the aorta called commissural mount into which each cusp inserts ***(Waller et al., 1973)***.

Because the cusps are semilunar in shape, there is no continuity across the commisure of tissue from one cusp to the other ***(Titus et al., 1991)***.

The commissures are three in number each named for two cusps which form it, the commissures of the aortic valve are right posterior, left posterior and anterior ***(Carpentier et al., 1969)***. (Fig. 4).

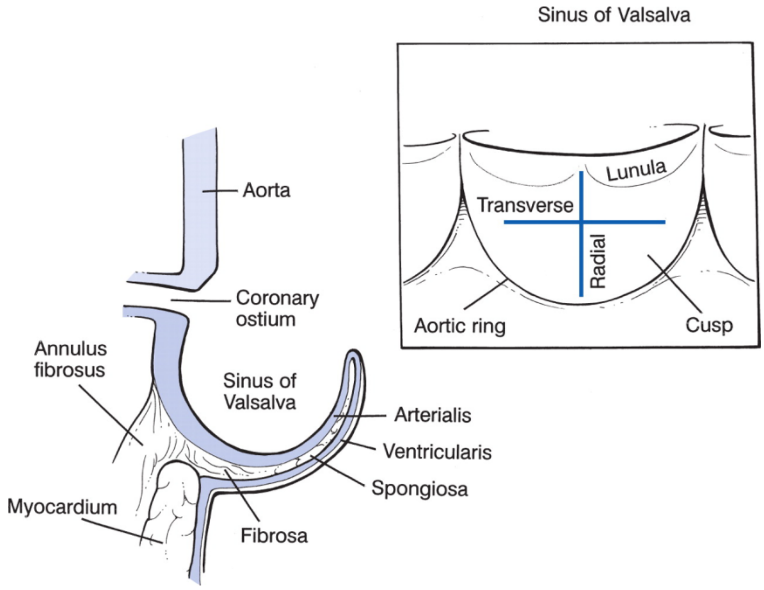

Figure (4): Schematic representation of a cross section through the aortic valve leaflet ***(Michaljevic et al., 2003)***.

The free edge of each cusp is tougher than the remainder of the cusp, at the mid point of the free edge there is a fibrous nodule of Arantus from which the two edges extended downward, these ridges mark the closure line on each cusp. The part of the valve below this line separates the aortic cavity from the left ventricular cavity, while on closure, the part of the valve above this line is called lunula and overlies the neighbouring cusp and serves as supporting strut. The lunula is sometimes fenestrated near the commissure ***(Carpentier et al., 1991)***.

The leaflets overlap in their closed position, as the cross sectional area of the aortic root is less than the sum of areas of the leaflets. The closure line produced by the opposition of the adjacent leaflets is visible on their ventricular surface 2 to 3 mm from the free edge ***(Angelini et al., 1989)***.

The fibrous interleaflets triangles (annulus)

There is no discrete circular structure within the aortic root which can be taken to represent the ring or annulus; however, there is series of three fibrous triangles separating the sinuses on their ventricular aspect. These areas of fibrous tissue have their apices at the attachment of the commissures to the aortic wall and their bases towards the proximal border of the leaflets. The interleaflets triangles complement the semilunar shape of the sinuses; these together with leaflets were considered to compose the aortic root. From the surgical view the apices of the triangles separate the ventricular outflow tract from outside of the heart, since tips of the commissures are attached to the aortic wall. The triangle between right and left coronary sinus faces pulmonary valve and has its base on the septal component of the right ventricular outflow tract, its apex points to the tissue space between the arterial trunks. The triangle between the right and non-coronary sinuses faces the right atrium and being in direct continuity with the membranous septum, and is closely related to the septal leaflets of the tricuspid valve ***(Sliver and Roberts, 1985)***.

Also the apex communicates with the transverse sinus above the supraventricular crest of the right ventricle. The triangle between the left and non coronary sinus is in direct continuity inferiorly with the aortic leaflets of mitral valve, its apex points directly into the transverse sinus in front of the left atrium ***(Sliver and Roberts, 1985)***.

The sinuses of Valsalva

The sinus of Valsalva is the space which exists between aortic surface of an aortic cusp and the wall of aorta behind that cusp. It is bounded caudally by basal attachment of the aortic cusp and above by the sino-tubular junction, this space serves as a reservoir of the blood during ventricular diastole ***(Sliver and Roberts, 1985; Angelini et al., 1989)***.

The origin of the coronary arteries is the base of the nomenclature for the sinus and cusps. The ostia of the right and left coronary arteries identify the right and left sinuses and cusps, the third sinus and cusp without an associated coronary artery named non coronary ***(McBride et al., 1996)***.

Some investigators used the term right, left and posterior (non coronary) for the cusps and the sinuses correspondingly. The term of coronary cusp or sinus is best avoided as a coronary artery may originate from the wall of the aorta behind the posterior cusp or a coronary ostium may be absent from one or both anteriorly located cusps ***(Sliver and Roberts, 1985)***.

- ***The right aortic sinus (the right coronary sinus):***

It is related to the right ventricular infundibulum and its lowermost attachment is to the muscular part of the ventricular septum at the junction of its infundibular and muscular parts. Above this level, the infundibular septum, with the parietal limb of the crista supraventricularis, lies against the outer wall of the right aortic sinus with a wedge of epicardium separating them. The right coronary artery arises from this sinus at a point level with the free edge of the leaflet. At times, the orifice is close to one of the commissures which constitute a point of surgical interest. Also of interest is the fact that the ostium of the right coronary artery maybe located above the sinus in the tubular portion of aorta in some cases. Another important point is that the circumflex, conus, or left coronary artery may originate from right coronary sinus ***(McBride and Carpentier, 1996)***.

- ***<u>The left aortic sinus (the left coronary sinus):</u>***

The most posterior one third of the left aortic sinus has the same relationship as does the adjacent part of the posterior sinus. The central part of the left aortic sinus lies against the epicardium and below the origin of the left coronary artery. The right most third of the left sinus is related to left pulmonary sinus. The left coronary artery arises from the center of the aortic sinus and in 30% of cases may arise above the level of the sinus in the tubular portion of the aorta ***(Grondin, 1996)***.

- ***<u>The posterior aortic sinus (the posterior coronary sinus):</u>***

The aortic origin at the posterior aortic sinus has two main attachments, the right one third and the left two thirds. The right one third of the aortic origin at the posterior sinus is attached to the membranous portion of the ventricular septum. In this way, the sinus lies above the septal leaflet of the tricuspid valve and against the arterial septum. The left two thirds of the posterior aortic sinus in common, with the posterior one third of the left sinus, exhibit attachments which vary greatly from the remainder of the aortic root, it is related and connected to the ventricle indirectly via the anterior mitral leaflet. This part of the aorta is connected with the anterior mitral leaflet via an intervening thin layer of connective tissue called “the mitral-aortic intervalvular fibrosa” ***(Harken, 1989)***.

APPLIED ANATOMY OF THE AORTIC VALVE

An important anatomic consideration for surgeons performing aortic valve replacement is the position of the atrioventricular conduction system (Fig. 5), the bundle of His passes through the interventricular septum beneath the non-coronary cusp of the aortic valve near its junction with the right coronary cups. The surgeon must be aware of these anatomic relationships to safely perform an aortic valve replacement and avoid technical mishaps. A thorough understanding of the anatomy is particularly important during aortic annular enlargement procedures and root reconstruction for endocarditis or other causes ***(Antunes, 2005)***.

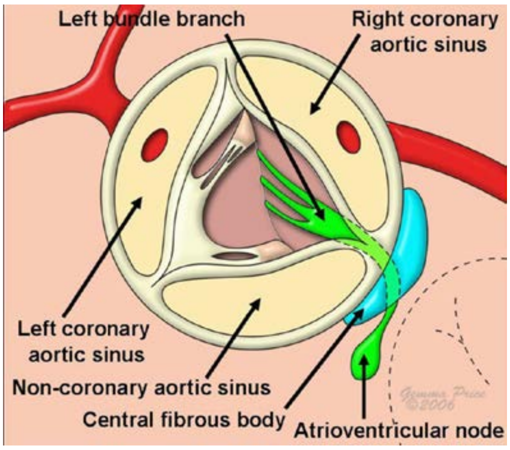

Figure (5): The cartoon shows the location of the atrioventricular conduction axis as it would be seen by the surgeon looking down through the aortic root ***(Anderson, 2000)***.