THE STUDY OF CARDIAC VALVE ANNULAR DIMENSIONS AND THEIR CLINICAL SIGNIFICANCE

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BRANCH - V DEGREE EXAMINATION

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CERTIFICATE

This to certify that **R. Hannah Sugirthabai Rajila** is a bonafide student of **Stanley Medical College** , Chennai-600001 and her study on **the cardiac valve annular dimensions and their clinical significance** is a bonafide original work done by her for this dissertation towards partial fulfillment of the M.S. Degree examination . She has done this study under guided supervision and no part of this study has been submitted for the award of any degree or diploma.

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AIM OF STUDY

"Knowledge of detailed cardiac anatomy is

a pre-requisite for successful surgery"

- R.H.Anderson, B.R. Wilcox.

Hippocrates (460-377 BC) described the valves and chambers of heart. Since then, the cardiac valves have undergone a vast research and their study is of great importance to cardiothoracic surgeons. The diagnosis of their pathology, the severity of disease and the course of their treatment, all depend on the accurate knowledge of the anatomy. The inter-relationships among the heart valves in normally formed hearts are remarkably uniform. The aortic valve occupies a central position wedged between the mitral and tricuspid valves, whereas the pulmonary valve is situated anterior , superior and slightly to the left of the aortic valve. The annuli of mitral and tricuspid valves merge with each other and with the membranous septum to form the fibrous skeleton of the heart. The core of the skeleton is the central fibrous body with two extensions, the right and left fibrous trigones.

Cardiac valves are affected both by congenital malformations and by acquired valvular diseases. Disease can cause either a stenotic or a regurgitant lesion. In the former condition there is a narrowing of the orifice but the annulus remains normal , whereas in the later the vale annulus is widened. So to replace the valve and to know the severity of the regurgitant lesion the normal valve size should be known. When a valve is being replaced, it can result in a condition called patient –prosthesis mismatch. This can result in restrictive changes of the heart due to the prosthetic valve being smaller than the annular size of the valve. Similarly in mitral valve lesion, left ventricular size changes. To know the impact of valvular lesion to left ventricular size and function, the normal correlation between the two should be known.

Hence, the annuli of cardiac values are used as the size index for prosthetic valves, to diagnose and categorize the severity of regurgitant lesions and to know impact of the left ventricular size variations on the mitral valve diameter.

The annular dimensions depends on age, sex and individual's body surface area. These dimensions are of utmost significance for repair and replacement of cardiac valves. These parameters were studied in western population and the standard measurements are derived from them. Hence a study of Indian population was undertaken to compare with the available data.

The study was done under the following parameters:

- Dimensions of mitral valve, tricuspid valve, pulmonary valve and aortic valve were correlated with body surface area and compared with the standard values.
- Their correlation with body mass index was assessed.
- Their correlation with age was assessed.
- Their correlation with sex was assessed
- Mitral valve dimensions were studied against left ventricular size.

REVIEW OF LITERATURE

The Anatomical and surgical history of heart:

Hippocrates (460-379C) described the valves and chambers of the heart. He described the pericardium as a smooth tunic which envelops the heart and contains a small amount of fluid resembling urine. He also demonstrated that fluid could flow in only one direction through the aortic valve.

Herophilus (385-280BC) described the pulmonary artery .

Galen (130 BC- 200 AD) observed that the heart can beat independently of central nervous system control.

Mondiro de Luzzi (1270-1326) accurately described the anatomy of heart

Leonardo da vinci (1452-1519) illlustrated heart anatomy and observed that air does not pass through the heart.

Columbus (1511) gave correct account of the shape and cavities of the heart.

Berenger (1614) demonstrated the existence and operation of tricuspid valve in right ventricle.

Scarpa (1974 - 1832) illustrated the nerves of the heart.

Einthoven (1903) performed first electrocardiogrphy.

Korotkoff (1905) described the method of blood pressure measurements.

Cutler, Levine and Beck in 1924 operated on stenosed mitral valves.

Frossman in 1929 performed a rightsided heart catheterization on himself.

Sellors in 1948 reported of mitual valvuloplasty for mitral stenosis

Bailey in 1948 performed a successful mitral valvulotomy.

Gibbon in 1953 successfully closed an atrial septal defect using cardio pulmonary bypass.

Kolesov in 1964 performed first coronary artery bypass graft with internal mammary artery.

Barnard in 1967 performed first heart transplant in humans.

Edwards stated that the adult human heart averages 325 ± 75g in men and 275 ± 75 g in women.

Literature regarding patient prosthesis mismatch:

The commonest acquired valvular disease is the rheumatic heart disease. If atrio-ventricular valves are affected, commissural fusion and leaflet thickening can result in stenotic lesion. Associated chordal thickening , fusion and shortening can occur resulting in narrowing of valvular orifice, but the annular dimension remains normal.

Cardiac valve replacement can be done in severe cares of stenotic lesions. For example, if the mitral valve replacement is done, the mitral leaflets are excised 2mm away from the annulus. The prosthetic valve is sutured on to the mitral annulus, which remains unchanged, using it as a mattress to hold the valve in position.

The term patient prosthesis mismatch was introduced by Rahimtoola in 1978 to describe a condition in which the invivo prosthetic valve effective orifice area is smaller than that of the native value. Obstructive aortic prosthetic valve with effective orifice area less than $0.8 cm^2/m^2$ may increase the operative mortality and impair functional recovery after aortic valve replacement. Previous studies have shown that the effective orifice area of an aortic prosthetic valve may be too small in relation to the patients body surface area resulting in abnormally high pressure gradients causing left ventricular dysfuncion.

Hence, careful selection of stented bioprosthetic valves with an adequate ratio of effective orifice area to body surface area should be ensured. The prosthetic valves available in the market take the standard values for this manufacture. These can vary in Indian population. Moreover, the effective orifice area is indexed to the patient's body surface area, which shows that there are individual or racial variations in the annular dimensions.

Westaby S et al., in 1984 has given the mean circularized orifice area in cm^2 as follows:

Valve	**Male**	**Female**
Aortic	4.81 ± 1.3	3.73 ± 0.98
Pulmonary	4.88 ± 1.25	4.32 ±1.03
Mitral	8.7 ± 2.08	6.94 ± 1.41
Tricuspid	11.9 ±2.12	9.33 ± 2.02

Comparison of these sizes with the manufacturer's calculated area for current prosthesis show that most mechanical valves and bioprosthesis are potentially restrictive at rest. He has quoted that improved prosthetic design, valve repair whenever possible and annular enlargement procedure would be required to eliminate this size disparity.

Pibarot P, Lemieux M, Cartier P et al.,in 1998 have stated that patients with mismatch have less symptomatic improvement and worse hemodynamics that continue to deteriorate with time.

.**Pibarot P and Dimensil JH** in 1998, described that patient prosthetic mismatch is present when the effective orifice area of the inserted prosthetic valve is too small in relation to body size and also that mismatch is common, about 20-70%, in aortic valve replacements.

Tirone E. David, MD pointed that small prosthetic aortic valve should be avoided in larger and physically active patient to reduce the operative risk and optimize functional recovery and therefore to prevent patient prosthesis mismatch.

Claudia Blais, Jean G. Dumensil, Richard Baillot in 2003 stressed that patient prosthesis mismatch is a strong and independent predictor of short term mortality among patients undergoing aortic valve replacement and its impact is related both to its degree of severity and the status of left ventricular function.

Rao V, Jamieson WR, Ivanov J, Armstrong S, David TE showed that patient prosthetic mismatch results in significantly higher early and late mortality after bioprosthetic aortic valve replacement. An effective orifice area to body surface area ratio of greater than 0.75 cm^2/m^2 may avoid residual left ventricular outflow tract obstruction and persistent transvalvular gradients.

Marc R. Moon et al., (2006) demonstrated that patient prosthetic mismatch is a size and age dependent phenomenon. Patients with body surface area greater than 2.1 m^2 had a dramatic fall in survival from 78% to 25% with patient prosthetic mismatch, whereas patients with body surface area less than 1.7m^2 did not experience the same response with patient prosthetic mismatch.

Tasca et al., in 2006 has showed that patient prosthesis mismatch is an independent predictor of cardiac events and midterm mortality in patients with pure aortic stenosis can be avoided with the use of a prevention strategy at the time of operation.

Literature regarding cardiac valves and body surface area:

Body surface area , which is a measure of the individual's height and weight is used as a index for annular dimensions of cardiac valves. There are studies to show the definite correlation between annular size and body surface area.

Tei C , pilgrim JP, Shah PM, in 1982 have stated that the mean maximum annular circumference and annular area of the tricuspid valve were 11.9+/- 0.9 cm and 11.3 +/- 1.8 cm^2 . Fixed hearts were similar to measurements by echo in normal subjects.

Riggs et al.,in 1983 stated that in normal subjects, mitral valve area had excellent correlation with body surface area as described by the formula mitral valve area = 4.83x body surface area –0.07.

King DH et al., in 1985 stated that the best predictor for valve annular diameter was a logarithmic function of body surface area with a calculated correlation coefficient ranging from 0.9 - 0.93 for 3 annular dimensions.

Berishvili II and Mchedlishvili KA (1989) showed that echo allowed a fairly accurate estimation of dimension of atrioventricular valves. Quantitative mitral and tricuspid valve characteristics were dependent on body surface area, but the dependence being non-linear, the variation followed a strict pattern.

Habbal ME, Somerville J in 1989 showed that if the dimensions of cardiac valves were corrected with body surface area , the two dimensional echo and surgical measurements were identical.

Gutgesell HP and French M in 1991 showed that the valve areas were linearly related to body surface area. Their data validate the practice of indexing valve area for body surface area. For body surface area ranging from 0.08 - 2.1m^2 aortic valve diameter was 0.3-2.2cm and pulmonary valve diameter was 0.4 - 2.8cm. Indexed mean aortic valve area was 1.33 cm^2/m^2 and pulmonary valve are was 1.7 cm^2/m^2.

Singh B and Mohan JC in 1994 have recorded for a body surface area of 0.25 - 1.9m^2, the mitral valve area is 3.37 ± 1.13cm^2 and tricuspid valve area is 4.07 ± 1.5cm^2. These values significantly correlated to body surface area. But, they found that aortic valve area of 2.63 ± 0.31 cm^2 poorly correlated with body surface area and also the pulmonary valve area of 3.01 ± 0.36 cm^2 moderately correlated with body surface area. They found no difference between the values of males and females.

Capps SB, Elkins RC, Frank DM (2000) showed that in males the aortic valve dimater is 23.1 ± 2mm and in females it is 21.0 ± 1.8mm pulmonary valve diameter is 26.2 ±2.3mm in males and 33.9 ± 2.2mm in females. The indexed aortic valve area in 2.02 ±0.52cm^2/m^2 and pulmonary valve area is 2.65 ± 0.52cm^2/m^2. They showed that aortic valve and pulmonary valve diameter are closely related to body size. Thus, body surface area is a useful tool for estimating normal aortic valve and pulmonary valve size.

Literature regarding cardiac valves and age:

Cardiac valves went through a lot of changes with age, one of them being an increase in diameter with age. These changes start from birth and continue on for life. The changes in early life till adolescence and early adulthood have a great impact on the surgeries performed in this age group.

Krovetz LJ in 1975 proved that aortic valve size increased linearly with age.

Schenk KE , Heinze G, in 1975 have shown that the diameter of atria, mitral, tricuspid, pulmonary and aortic ranges increased continuously upto ninth decade of life.

Krovetz LJ in 1975 proved that aortic valve size increased linearly with age.

Gardin JM et al in 1979 compared the oldest (7 0 years) with the youngest (21 - 30 year) and found significant ($p < 0.001$) increase in aortic root by 22%

Scholz DG , Kitzman DW, in1988 , have stated that mean valve circumference increased throughout adult life . This increase was greater for semilunar valves than the atrio ventricular valves. Aortic valves surpassed pulmonary valves in the fourth decade and approached that of mitral by tenth decade of life.

Kitzman DW and Edwards WD in 1990 described that with advancing age, there is a significant increase in valve circumference. The aortic and mitral valves thicken and become fibrotic along their appositional surfaces and their annuli are sites of collagen degeneration, lipid accumulation and calcification. Hence, there is a decreased ability of aged heart to adapt to stress imposed by a number of cardiovascular diseases.

Huwez et al., in 1994 showed that age and body surface area highly correlated with the cardiac valve dimensions but a separate equation should be available for both.

Literature regarding cardiac valves and variation in different sexes:

When the diameters of cardiac valve annuli were independently recorded, various researchers have given different opinions regarding their values in males and females.

Kitzman DW, Scholz DH, Ilstrup DM (1988) showed that mean valve circumference is usually greater in males than in females and in both sexes, mean valve circumference increases throughout adult life; this trend was greater for semilunar than atroventricular valves.

Zilherman MV, Khoury PR, Kimball RT (2005) pointed that males had larger valve dimension at all ages even after adjustment for the differences in body sizes.

Literature regarding cardiac valves and height and weight :

Direct correlation with height and weight of the individual were documented earlier. The correlation between the diameters of all cardiac valves and body surface area itself proves it as the former is calculated using the two parameters only. Along with this, body mass index which is another index calculated from height and weight of the individual was used as a factor against which the dimensions of cardiac valves were plotted in this study.

Roman MJ, Devereux RB, Kramer-Fox R, Loughlin J in 1989 stated that aoretic root dimension s are influenced by age and body size.

Vasan RS, Larson MG, Levy D (1995) stated that age, height, weight and sex emerged as the principal determinants of aortic root dimensions.

Evangelista A et al., (1996) gave the area index in cm^2 / m^2 for aortic valve as 2.2 ± 0.4, pulmonary valve as 2.5 ± 0.5, mitral valve as 4.4 ± 0.8 and tricuspid valve as 6.7 ± 1.0 They stated that valvular annular area in influenced mainly by height and weight and that aortic valve area is similar to pulmonary valve area and half of mitral valve area.

Haimerl J et al., (2005) pointed out the strongest correlation of aortic valve area to height in normal subjects.

ANATOMY OF CARDIAC VALVES

A knowledge of the normal anatomy of cardiac valves and of the anatomic abnormalities caused by specific disease is important in clinical detection of abnormalities of cardiac valves and in the development of specific therapeutic intervention that prove to be helpful in patient care.

The cardiac valves are collagenous structures covered by the continuous layers of endothelium that lines the cardiovascular system. The valves that guard the exit from the ventricle are the pulmonary and aortic valves (semilunar valves) and those at the atrio ventricular junction are tricuspid and mitral valves.

Fibrous skeleton of heart:

All the intercellular spaces in the heart are permeated by connective tissue. Fibrocellular components of subepicardial and subendocardial layer blend on their mural aspects with the endomysial and perimysial connective tissue on the myocardium. Each cardiac myocyte is invested by a delicate endomysium composed of fine reticular fibres, collagen and elastin fibres embedded in ground substance. The matrix is lacking only at desmosomal and gap junctional contacts with the working myocardium.

The connective tissue matrix itself is interconnected laterally to form bundles, strands or struts of macroscopic proportions showing a complex geometric pattern. The larger myocardial bundles are surrounded by and attached to stronger perimysial condensations.

The myocardial matrix, running at the ventricular base is intimately related to atrio- ventricular valves and the aortic orifice. It is a complex framework of dense collagen with membranous, tendinous and fibroareolar extensions. This whole, distinct matrix is termed as the fibrous skeleton of the heart. The cusps of the pulmonary valve are supported on a free standing sleeve of right ventricular infundibulum which can easily be removed from the heart without disturbing either the fibrous skeleton or the left venticle.

The fibrous skeleton is strongest at the junction of the aortic, mitral and tricuspid valves, the so called central fibrous body. The pairs of curved, tapering collagenous prongs, named fila coronaria extend from the central fibrous body. They are stronger on the left, passing partially around the mitral and tricuspid orifices, which incline to face the cardiac apex. The aortic valve is anterosuperior and to the right of mitral valve and faces up, right and slightly forwards. Two of the cups of the aortic valve are in fibrous continuity with the aortic cusp of the mitral valve. This aortic - mitral or subaortic curtain is also an integral part of the fibrous skeleton. The two ends of the curtain are strengthened as the right and left fibrous trigones, which are the strongest part of the skeleton. The right trigone, together with the membranous septum, constitutes the central fibrous body. This is penetrated by atrio ventricular conduction bundle. Hence, the fibrous skeleton functions as a stable but deformable base for the attachments of the fibrous cores of the atrio ventricular valves and also as a electrophysiological barrier between atria and ventricles.

The aortic root is central within the fibrous skeleton and is the annulus integrated within the fibrous skeleton. The mitral and tricuspid annuli are not simple but are rigid collagenous structures. They are dynamic, deformable lines of valvular attachment that change considerably with each phase of cardiac cycle and with increasing age.

The tricuspid valvular complex:

The tricuspid valvular complex comprises the tricuspid atrio-ventricular orifice and its associated annulus. Valvular leaflets, chordae tendinae and papillary muscles. Interplay of all these depends on and mechanical cohesion provided by the cardiac fibro elastic skeleton. The annulus of each atrio ventricular valve is somewhat saddle shaped and represents an ill defined fibrous tissue from which the leaflets arise. The line of free leaflet attachment is termed annulus. In the tricuspid valve, the annulus includes a) an angled line across the membranous septum, b) the tricuspid aspect of the right fibrous trigone, c) the tapering, dense, fibro elastic anterior and posterior fila coronaria from the trigone and d) the tenuous sulcal connective tissue completing the annular circumference between the tips of the fila.

The annular circumference in fixed postmortem specimens averages 11.0 ± 1.5 cm, it is approximately 1cm greater in fresh than in fixed specimens. Annular area is about 11.3 ± 1.8cm^2. Tricuspid valve leaflets, usually three, are septal, anterior and posterior, corresponding to the marginal sector of the atrio ventricular orifice. They are marginally continuous with chordae tendinae and basally with the annular connective tissue. Commissures represent cleft like slits in the leaflet tissue, which represent the sites of separation of one leaflet from its neighbouring leaflet.

All tricuspid leaflets possess, passing from the free margin, rough, clear and basal zones. The rough zone is relatively thick, opaque and uneven on both aspects, particularly ventricular, where most chordae tendinae are attached, its atrial inflowing aspect making contact with another leaflet during full valve closure. The clear zone is smooth and translucent. The basal zone, extending about 2.3mm from its peripheral arrangement is thick, is vascularized and frequently contains actual myocardium.

The anterior leaflet is the largest and is attached chiefly to the atrio ventricular junction on the posterolateral aspect of the supra ventricular crest but extends along its septal limb to the membranous septum ending at the anteroseptal commissure. The septal leaflet is the smallest, its attachment passes from the posterior ventricular wall across the muscular septum and then angles across the membranous septum to the anteroseptal commissure. The posterior leaflet is wholly mural in attachment. The posterior leaflet and posteroseptal half of the septal leaflet are horizontal, where the latter's anteroseptal half and anterior leaflet slop up to meet on the membranous septum at the anteroseptal commissures.

Chordae tendinae are true when they link papillary muscles to the leaflets, their clefts, commissures or bases and are false when they interconnect papillary muscles. Five classes of chordae tendinae are described a) Fan - shaped, b) Rough zone, c) Free edge, d) Deep, e) Basal.

Papillary muscles in right ventricle comprise of two principal muscles- anterior and posterior and smaller septal muscle. The anterior is the largest and is attached to anterior and posterior tricuspid leaflets from the right anterolateral ventricular wall. The posterior arises from ventriculospetal myocardium and is attached to septal and posterior leaflets.

The Mitral Valvular complex:

The mitral vavlular complex comprises a) The mitral atrio-ventricular orifice and its valvular annulus b) leaflets, c) chordae tendinae and d) papillary muscles. The mitral annulus, in contrast to tricuspid, constitutes a relatively continuous ring of fibrous tissue. Although the entire annuluar circumference contacts the underlying left ventricular wall, the remaining 20% to 30% of the annulus is intracavitary and continuous with the aortic valve and the right and left fibrous trigones. Between the membranous septum and the cardiac crux, the mitral annulus becomes increasingly more posterior than the tricuspid annulus as the coronary sinus ostium and atrio ventricular septum intervene between the two valves.

In the living subject, the annular area is about 7.1 ± 1.8 cm^2. In fixed postmortem specimens, the normal mitral annular circumference averages 9.5 ± 2 cm and is about 1 - 1.5 cm greater in fresh than in fixed specimen.

The mitral leaflets form a continuous funnel - shaped veil with two prominent indentations, the anterolateral and the posteromedial commissures. There are only two mitral leaflets, the anterior and posterior. The anterior leaflet is semicircular and by virtue of its intracavitory position, subdivides the left ventricle into inflow and outflow tracts. The posterior leaflet is rectangular and can be subdivided by minor commissures into three semicircular scallops. The basal portion of anterior leaflet contains actual myocardial cells. The mitral leaflets normally have no septal insertions.

The chordae tendinae are fan shaped and emanate from each of the two papillary muscles. The mitral papillary muscles occupy the middle third of the left ventricular base-apex length. The two originate from trabeculae carnea of anterolateral and posteromedial free wall, the former being larger.

The Pulmonary valve:

The outflow valve of right ventricle faces superiorly to the left and slightly posteriorly. It has three semilunar cusps attached by convex bases to a trilunate fibrous thickening in the wall of the pulmonary trunk at its junction with the ventricle forming a valvular annulus.

In fixed postmortem specimens, the pulmonary annular circumference measures 7.0 ± 1 cm and is approximately 0.5 cm greater in fresh than in fixed specimens. The annuli of the semilunar valves (both pulmonary and aortic) contribute to the fibrous cardiac skeleton and are intact non planar rings of dense collagen. Each annulus assumes the shape of a triradiate crown, the three points of which attain the level of the sino tubular junction and demarcate the commissures; the commissures represent the sites of lateral separation of one cusp from its adjacent cusp.

The cusps are half moon shaped pocket like flaps and are three in number. Two cusps are anterior named as right and left and the third one is posterior. Each cusp is a fold of endocardium with an intervening lamina fibrosa. Central in each cuspal free margin is a localised thickening of collagen, the nodules of Arantii, from which fibres radiate through the lamina to reach the annulus. On each side of a nodule, the collagen is much reduced in the narrow lunule. Opposite the semilunar cusps, the arterial wall presents three sinuses of Valsalva.

The infundibular spetum lies subjacent to the right - left pulmonary commissure, whereas infundibular free wall subtends the remainder of the valve. A lip of right ventricular myocardium extends onto the pulmonary sinuses, such that the pulmonary valve appears in part buried within the crater of the right ventricular infundibulum. The anterosuperior limb of the septal band extends onto the left pulmonary sinus and prominent trabeculae parallel to the parietal band insert onto the right palmonary sinus; trabecular extensions onto the anterior sinus are less prominent.

The Aortic valve:

The aortic valve resembles the pulmonary in possessing three semilunar cusps, supported with the three aortic sinuses of valsalva. It is stronger than the pulmonary valve. Although the aortic valve, like the pulmonary valve, is often described as possessing an annulus in continuity with the fibrous skeleton, there is no complete collagenous ring supporting the attachments of the cusps. The plane of the artic valve faces posteriorly, rightward and superiorily, the normal aortic annular area averages 3.1 ± 0.6 cm^2. In fixed postmortem specimens, the normal aortic annular cicumference measures 6.5 ± 10 cm and is approximately 0.5 cm greater in fresh than in fixed specimen.

The cusps are attached in part to the aortic wall, to the subaortic curtain and are continuous with the aortic cusp of mitral valve. This area of continuity is thickened at its two ends to form the right and left fibrous trigones. The sinuses and cusps are named as right, left and non-coronary, according to the origins of the coronary arteries.

The semilunar attachments incorporate three trigones of aortic wall within the apex of the left ventricular outflow tract. The base of the triangle between the non-coronary and the left cusps is continuous inferiorly with the fibrous aortic - mirtal cushion. The apex points into transverse pericardial space. The triangle between right and noncoronay cusps has the membranous septum for the base and the apex points to the transverse pericardial space behind the origin of the right coronary artery. The third triangle between the two coronacy cusps has its base on muscular septum and apex points to the plane of space found between the aortic wall and the free-standing sleeve of right ventricular infundibular musculature that supports the cusps of pulmonary valve.

Each cusp has a thick basal border, deeply concave on its aortic aspect and a horizontal free margin. The latter is only slightly thickened, except at its midpoint, where there is an aggregation of fibrous tissue, the valular nodule of the semilunar cusp. Flanking each nodule, the fibrous core in tenuous and forms the lunules of translucent and occasionally fenestrated valvular tissue.

Aortic sinuses are more prominent than those in pulmonary valve. The upper limit of each sinus reaches beyond the level of the free border of the cusp and forms a well defined complete circumferential sinotubular ridge when viewed from the aortic aspect. Coronary artery usually open near this ridge. The walls of the sinus are largely collagenous near the attachment of the cusps, but the amount of lamellated elastic tissue increases with distance from the zone of attachment. At the mid level of each sinus, its wall is about half the thickness of the supravalular aortic wall and less than one quarter of the thickness of the sinutubular ridge. At this level, the mean luminal diameter of the beginning of the aortic root is almost double that of the ascending aorta.

MATERIALS AND METHODS

Study population:

The study was conducted on live patients who visited the cardiology out patient department at Stanley Medical College, Chennai - 600001. All the subjects were healthy and were at cardiology out patient department for regular check up.

The total number of subjects were four hundred and six, out of which two hundred and fifty two were males and one hundred and fifty four were females.

The male female ratio in this study is given here as it is not an observation but a prelude and an essential part of this study. The differences found in the dimensions of cardiac valves with respect to the age and sex factors are tabulated and assessed in the observations chapter.

They were still further classified according to their ages. Twenty two were less than five years range (out of which 13 were males and 40 were females) and forty were in the range of six to ten years (20 each in male and female category).

In the eleven to fifteen age group, 44 were studied , out of which 28 were males and 16 were females. In the sixteen to twenty years forty three were studied out of which 33 were males and 10 were females.

In those aged between twenty one and twenty five, forty two (22 males and 20 females) were studied and in between twenty six and thirty, thirty six (22 males and 14 females) were studied. Similarly thirty two subjects (18 males and 14 females) in thirty one to thirty five year category and thirty two subjects (21 males and 11 females) in the thirty six to forty years category were studied.

In the forty one to forty five age group, twenty four (10 males and 14 females) and in forty six to fifty years category thirty three (25 males and 8 females) were subjects of this study. In the fifty to fifty five age group twenty six (20 males and 6 females) subjects and in the fifty six to sixty age group thirty two (20 males and 12 females) subjects were studied.

Method of Study:

The study was conducted on all 406 subjects by means of echocardiogram. The dimensions of annuli of mitral, tricuspid, pulmonary and aortic valves were measured by two dimensional echocardiogram, which is an instrument used to create an image using a transducer which sends ultrasound waves. The transducer converts the returning echoes to electrical impulses, which then go to the receiver and the signal amplifier and are displayed on the cathode ray tube.

Echocardiogram used in this study is a spatially oriented B mode scan which provides a cross-sectional or two dimensional image of an object. This 2D echo has three basic orthogonal views –

(i) The long axis plane runs parallel to the heart or the left ventricle.

(ii) The short axis plane is perpendicular to the long axis.

(iii) The four chamber plane is orthogonal to the other two and somewhat represents a frontal plane.

Mitral and tricuspid valvular dimensions were recorded in early diastole, whereas aortic and pulmonary valves in early systole.

1. Tricuspid valve in echo

The tricuspid valve was examined using the apical four chamber view. This view passes through the tricuspid orifice along a line extending from roughly the 10’0 clock to the 4’0 clock positions relative to the corresponding short axis plane transecting the anterior and septal tricuspid leaflets. The anterior leaflet is displayed medially. This plane is ideal for determining the position of the right - sided atrio-ventricular ring and for defining the plane of leaflet closure relative to this anatomic landmark.

It is also useful for defining the level at which the septal tricuspid leaflet inserts into the interventricular septum and for comparing this insertion point to that of the corresponding anterior mitral leaflet. The apical four chamber view is also the primary view for Doppler recording of tricuspid inflow and for assessing the size and distribution of regurgitant jets.

2. Mitral valve in echo

The mitral leaflets represent a continuous veil of fibrous tissue whose base is attached around the entire circumference of the mitral orifice to the fibromuscular ring, the mitral annuals. The valve was examined using:

a) The parasternal long axis view of the left ventricle:

This imaging plane transects the mid point of the holder of both the anterior and posterior mitral leaflets from their points of insertion with the mitral annulus to their free edge. It also includes the anterior and posterior extremes of the mitral annulus. This plane if angled either in a medial or a lateral direction will record the papillary muscles. This plane records the motion of both mitral leaflets in an anteroposterior direction with their systolic and diastolic positions and spatial configurations, the anteroposterior mitral annular diameter, the motion pattern of the mitral annulus in both superoinferior and anteroposterior direction and the temporal and spatial positions of the mitral leaflets in relation to the left ventricular cavity, annulus and atrium.

b) The apical four chamber view :

This plane passes through the mitral leaflet at approximately a 30° angle to the line of leaflet coaptation. The coaptation line of the leaflets is ordinarily displaced toward the posterior position of the ventricle, this oblique orientation causes the plane to transect more of the anterior mitral leaflet than the posterior. This plane is ideal for determining the position of the atrioventricular ring, for defining the point of leaflet closure relative to this anatomic landmark, the point of mitral leaflet insertion with the interventricular septum and for retaining it to the level of insertion of tricuspid leaflet.

3. Pulmonary valve in echo

The pulmonary valve was examined in the short axis view from the parasternal transducer location. In this view the pulmonary annulus in its normal orientation lies at an approximately 60°C angle to the path of the imaging plane. The valve orifice is oriented as if viewed from the left shoulder with the ascending aorta recorded beneath the pulmonary artery coursing to the viewer's right.

4. Aortic valve in echo:

The aortic valve was examined using the parasternal long axis view. In this view the imaging plane transect s the aortic valve in an anteroposterior direction and its x axis is aligned parallel to the long axis of aorta. Because the aorta is normally to the right of the transducer when it is in the parasternal location, the long axis plane is usually oriented such that it passes through the right and noncoronary aortic leaflets.

During diastole, a thin linear echo is produced by the coapted free edges of the aortic cusps which are oriented perpendicular to the path of the imaging plane. The bodies of the their smooth leaflets, in contrast, are oriented parallel to the imaging plane. During systole, the leaflet echoes are separated and lie in close apposition to the walls of the aorta. The right coronary leaflet is interior and the non coronary leaflet is posterior. At peak systolic opening, the aortic cusps are normally parallel to the inner margins of aortic annulus.

5.Left ventricle in echo:

Left ventricle is viewed in the parasternal long axis view in the echocardiogram . Left ventricular dimensin was measuired at the level of chordae tendinae.

The obtained dimensions were correlated with the body surface area and body mass index.

The body surface area was calculated using

Mosteller's formula:

$$\text{Body surface area } (m^2) = \sqrt{\frac{\text{Height(cm)xwt(kg)}}{3600}}$$

And the body mass index was calculated as follows:

$$\text{Body mass index} = \frac{\text{Weight in kg}}{\text{height in } m^2}$$

OBSERVATIONS

The dimensions of mitral, tricuspid, pulmonary and aortic valves were recorded using two dimensional echocardiogram. Total number of subjects was four hundred and six. The distribution of males ands females are given in the materials and methods chapter. Each valve was studied according to the views specified in materials and methods. The diameters was recorded for all four valves in millimeters. From this data, the circumference and area was deduced. The diameters of mitral, tricuspid, aortic and pulmonary valves were tabulated against body surface area .

Age, sex, height and weight of the subjects were recorded simultaneously. The diameters were again plotted against the age of the subjects dividing them into five year categories. The area was calculated and was tabulated against males and females. The recorded and weight data helped in the calculation of body surface area and body mass index of the subjects.

THE CARDIAC VALVES AND BODY SURFACE AREA:

Table.1 DIAMETERS OF MITRAL, TRICUSPID, PULMONARY AND AORTIC ANNULUS [mm]

BSA	MV	TV	PV	AV
0.61 - 0.7	15.5 ± 0.5	18.0 ± 1.0	12.5 ± 0.7	12.2 ± 0.5
0.71 - 0.8	18.0 ± 1.0	22.0± 1.5	14.0 ± 1.0	14.0 ± 1.0
0.81 - 0.9	18.2 ± 1.6	23.1 ± 0.9	16.2 ± 1.8	15 ± 2.2
1.01 - 1.1	18.6 ± 1.4	24.1 ± 1.6	16.3 ± 1.0	15.9 ± 1.1
1.11 - 1.2	22.6 ± 0.6	25.3 ± 1.7	18.0 ± 1.0	16.6 ± 0.4
1.21 - 1.3	22.8 ± 1.2	25.1 ± 2.1	18.1 ± 1.8	18.0 ± 2.0
1.31 - 14	23.2 ± 2.0	25.7 ± 2.8	19.5 ± 2.5	18.4 ± 1.6
1.41 - 1.5	23.8 ± 2.8	25.6 ± 2.6	20.1 ± 2.5	18.8 ± 1.8
1.51 - 1.6	24.0 ± 2.2	26.5 ± 2.5	21.1 ± 1.8	19.6 ± 2.6
1.61 - 1.7	24.5 ± 2.0	27.3 ± 2.0	21.7 ± 2.7	21.3 ± 2.3
1.71 - 1.8	25.3 ± 1.0	29 ± 1.0	21.6 ± 0.4	21.6 ± 1.6
1.81 - 1.9	25.5 ± 1.0	29.5 ± 2.2	21.7 ± 1.4	21.6 ± 1.0

BSA -Body surface area in m^2 MV -Mitral valve .

TV- Tricuspid valve PV-Pulmonary valve AV-Aortic valve

Table 2. STANDARD VALUES [mm]

BSA	MV	TV	PV	AV
0.61 - 0.7	19.5 ± 2.2	26.1 ± 3.4	16.0 ±1.8	13.5 ± 1.3
0.71 - 0.8	20.8 ± 1.8	28.0 ± 3.4	16.6 ± 1.5	14.1 ± 1.1
0.81 - 0.9	22.0 ± 1.8	29. 7 ± 3.5	17.6 ± 2.0	14.6 ± 1.5
0.91 - 1.0	23 ± 1.8	31.1 ± 3.4	18.7 ± 1.9	15.6 ± 1.3
1.01 - 1.1	23.9 ± 1.8	32.4 ±3.3	19.5 ± 1.8	16.3 ± 1.5
1.11 - 1.2	24.4 ± 1.6	33.5 ± 3.4	20.4 ± 1.9	17.2 ± 1.9
1.21 - 1.3	25.5 ± 1.7	34.6 ±3.3	20.6 ± 1.8	17.1 ± 1.6
1.31 - 1.4	25.8±1.8	35.4 ±3.5	20.6 ± 2.1	18.7 ± 1.7
1.41 - 1.5	26.8 ± 1.8	36.5 ±3.4	22.3 ± 2.5	19.1 ± 2.3
1.51 - 1.6	27.0 ±1.6	37.4 ±3.4	23.5 ± 2.3	20.7 ± 2.7
1.61 - 1.7	27.9 ± 1.8	38.2 ±3.4	23.7 ± 2.4	20.8 ± 2.1
1.71. - 1.8	28.2 ±1.7	39.2±3.3	24.5 ± 2.4	21.5 ± 2.0
1.81. 1.9	28.9 ± 1.8	39.6 ±3.4	25.2 ± 2.2	22.3 ± 2.1

BSA- Body surface area in mm^2 MV-Mitral valve

TV-T ricuspid valve PV-Pulmonary valve AV- Aortic valve

Diameters of cardiac valves were recorded using echocardiogram. As observed in table.1, Mitral valve diameter ranged from 15.5 to 25.5 mm averagely in subjects with body surface area varying from 0.6 to 1.9 m^2 . Mitral valve was viewed by parasternal long axis view, which is commonly the anteroposterior iew. Tricuspid valve ranged from 18 mm to 29.5 mm in the body surface area range of 0.6 to 1.9 m^2 when examined in the apical four chamber view .The pulmonary valve ranged from 12.5 mm to 21.7mm in the body surface area ranging from 0.6 to 1.9 m^2. This was viewed by the parasternal short axis view. The aortic valve ranged from 12.2 mm to 21.6 mm in the body surface area range of 0.6 to 1.9 m^2. The aortic valve was examined using the parasternal long axis view.The mitral and tricuspid valvular dimensions were recorded in early diastole and the aortic and pulmonary valvular dimensions in early systole.

The following observations regarding the four valves of the heart are made from the table.1

Mitral valve showed a study rise in its diameter with rise in body surface area. For body surface area 0.61 - 0.7 m^2 mitral valve was 15.5 mm. There is a sudden increase of 15.5 mm for body surface area 0.71 - 0.8 to 18 mm. After this sudden increase, mitral valve diameter increases steadily by 0.2 to 0.6 mm for every 0.1 m^2 increase in body surface area.

Tricuspid valve diameter increased by 4 mm from 18 mm to 22 mm in body surface area range of 0.61 - 0.7 m^2 to 0.71 - 0.8 m^2. There is an increase of 1 mm till the body surface area of 1.21 - 1.3m^2, 0.6 mm increase for body surface area 1.31 - 1.4m^2, and a decrease of 0.1 mm for body surface area range of 1.41 - 1.5m^2. Then, there is an increase of 0.5 to 0.8 mm till the body surface area range of 1.81 - 1.9m^2.

Pulmonary valve increased by 1.5 mm for 0.61 - 0.7m^2 to 0.71 - 0.8 m^2 body surface area. There is an increase by 2.2 mm for the next range of body surface area. Afterwards, there is a steady increase by 0.1 - 1.4 mm at different range of body surface area.

Aortic valve also increases by 1.8 mm from 0.61 - 0.7 m^2 body surface area to 0.7 - 0.8 m^2 body surface area. Afterwards a linear increase in diameter ranging from 0.4 to 1 mm is seen for body surface ranging from 0.9 m^2 to 1.8 m^2. There is no change between the diameter for the former and the next range of body surface area from 1.81 - 1.9m^2.

THE CARDIAC VALVES AND THEIR RELATION TO AGE

Table. 3 DIAMETERS [mm] AND AGE [years]

AGE	MV	TV	PV	AV
0 - 5	15.5	18.5	12.0	12.0
6 - 10	18.2	21.1	15.4	14.6
11 - 15	20.7	23.4	17.4	16.5
16 - 20	24.8	27.2	18.3	18.7
21 - 25	24.9	27.9	20.4	19.7
26 - 30	24.7	27.4	20.6	19.4
31 - 35	24.7	27.5	20.5	19.5
36 - 40	24.3	27.6	19.6	19.4
41 - 45	24.6	27.8	20.0	20.5
46 - 50	25.0	27.3	20.6	20.0
51 - 55	25.2	27.3	20.6	20.0
56 - 60	25.6	27.8	20.3	20.6

MV- Mitral valve TV-Tricuspid valve

PV-Pulmonary valve AV-Aortic valve

The following observations are made from table.3.The age range is from birth to sixty years. The number of subjects assessed in each age group is discussed in detail in materials and methods chapter.

Diameter of mitral valve increases with age. The diameter is 15.5mm in the less than five year olds. In the next five year group 2.7 mm has increased and the mitral valve measures 18.2 mm. There is another 2.5 mm increase in the next five years and 4.1 mm increase in the next five years. After twenty years, the diameter of mitral valve remains more or less the same, showing an fluctuation of 0.2 mm - 0.4 mm till the sixty years.

Tricuspid valve measures 18.5 mm in diameter till five years, increases approximately 2 mm for every five years, till the fifteenth year. There is a sudden 4 mm increase in the next five years. After twenty years , the diameter of the tricuspid valve remains steady till sixty years.

Pulmonary valve, is about 12 mm in diameter averagely at birth to five years. 3 mm increase in seen in the next five years, 2 mm in the next five years, 1mm in the next five years and 2 mm in the next five years. After twenty years, it remains more or less constant till sixty years.

Aortic valve is 12 mm in diameter till five years, 14.6 mm, 16.5 m 18.7 mm and 19.7 for the next consecutive five year range. From trwenty-one years onwards, the aortic valve diameter was around 19.4 mm to 20.6

mm in diameter till sixty years, flutuating by 0.5 mm during the ages of twenty and sixty.

THE CARDIAC VALVES AND THEIR RELATION TO SEX

The following observations were made regarding the relation between the dimensions of all cardiac valves as the area in cm^2 for ages from birth to sixty for males and females separately.

The observation made for mitral valve area for all age groups is tabulated in table .4. For each ten year range , the diameter of mitral valve measured 2.1, 4.0 , 4.5, 4.9, 4.8 and 4.6 m^2 in males and 2.3, 3.8, 4.3, 4.4, 4.8 and 4.9 m^2 in females. For the early age range there is a marked difference between males and females and also an increase of area with age can be noted

Table.4 AREA IN CM^2 - MITRAL VALVE

Age in years	Male	Female
0 - 10	2.1	2.3
11 - 20	4.0	3.8
21 - 30	4.5	4.3
31 - 40	4.9	4.4
41 - 50	4.8	4.8
51 - 60	4.6	4.4

Similarly for tricuspid valve, the observations are made from the table.5. The tricuspid valve area showed 2.1 cm^2 and 2.3 cm^2 in the less than ten year group in males and females respectively. Dividing the whole study population into five groups of ten years each, the tricuspid valve area measured 5.1, 5.8, 5.9 and 5.9 cm^2 for males and 4.9, 5.0, 5.6, 5.8 and 5.7 cm^2 for females. Here again, for the earlier years and in late years there is a definite difference observed between the two sexes. Apart from sex difference, the increase in area with age can also be observed.

Table.5. AREA IN CM^2 - TRICUSPID VALVE

Age in years	Male	Female
0 - 10	2.7	3.5
11 - 20	5.1	4.9
21 - 30	5.8	5.0
31 - 40	5.9	5.6
41 - 50	5.9	5.8
51 - 60	5.9	5.7

Table.6. AREA IN CM^2 - PULMONARY VALVE

Age in years	Male	Female
0 - 10	1.5	1.4
11 - 20	2.6	2.3
21 - 30	3.6	2.6
31 - 40	3.4	2.6
41 - 50	3.4	3.2
51 - 60	3.5	3.4

The pulmonary valve area in males and females was tabulated as in table.6.For the ages less than ten years the area was 1.5cm^2 in males and 1.4cm^2 in females. For the ages between eleven and twenty, the same was 2.6cm^2 and 2.3 cm^2 in males and females respectively. For those between twenty-one and thirty the area measured 3.6cm^2 in males and 2.6 cm^2 in females. In the ages ranging from thirty-one to forty, forty-one to fifty and fifty-one to sixty the areas were 3.4$cm^{2,}$ 3.4 cm^2 and 3.5 cm^2 in males and 2.6 cm^2, 3.2 cm^2 and 3.4 cm^2 in females.

Table.7. AREA IN CM^2 – AORTIC VALVE

Age in years	Male	Female
0 - 10	1.5	1.4
11 - 20	2.5	2.0
21 - 30	2.8	2.7
31 - 40	3.1	2.8
41 - 50	3.2	2.9
51 - 60	3.5	2.9

Observations found when aortic valve area was calculated for both sexes from table.7 are as follows . In the less than ten years group , the aortic valve area measures 1.5 and 1.4cm^2 in males and females respectively. The aortic valve area has 2.5 cm^2, 2.8 cm^2 and 3.1 cm^2 in eleven to twenty, twenty-one to thirty and thirty-one to forty years group in males and 2cm^2, 2.7cm^2 and 2.8 cm^2 in the females in the same categories respectively. In the forty- one to fifty years and fifty-one to sixty years group, mitral valve measured 3.2 and 3.5 cm^2 in males and 2.9 cm^2 for females.

THE CARDIAC VALVES AND BODY MASS INDEX

The Correlation between the body mass index and the area in cm^2 for all four valves are given in the table 8. The range of body index mass measured for this study is from fourteen to thirty. Body index mass utilizes the individual's height and weight and can be related to the patient whose annular size needs to be assessed individually. Body index mass is measured in kilgram per square metre.

Table 8. BODY MASS INDEX AND AREA OF CARDIAC VALVES in CM^2

BMI (kg/m^2)	MV	TV	PV	AV
14 - 16	3.1	3.4	1.9	1.9
16.1 - 18	3.9	5.2	2.5	2.4
18.1 - 20	4.5	5.4	2.7	2.8
20.1 - 22	4.4	5.5	2.8	2.9
22.1 - 24	4.4	5.5	2.9	2.9
24.1 - 26	4.6	5.6	3.5	3.2
26.1 - 28	4.7	5.7	3.5	3.5
28.1 - 30	4.9	5.8	3.5	3.6

BMI – Body mass index

MV- Mitral valve TV-Tricuspid valve

PV- Pulmonary valve AV –Aortic valve

For mitral valve when correlated with the body mass index there is an increase of 0.8 cm^2 from body mass index range of 14.1-16 to 16.1 to 18 kg/m^2 and then an increase of 0.6 cm^2 for 18.1 to 20 kg/m^2. There is a increase of 0.2 cm^2 and 0.1 cm^2 for the body mass index ranging from 24.1 to 26 kg/m^2 and 26.1 to 28 kg/m^2. Then there is an increase of 0.2 cm^2 for the body mass index ranging from 28.1 to 30 kg/m^2.

For tricuspid valve, there is an increase of area for 3.4 cm2 to 5.8 cm^2 for body mass index ranging for 14 kg/m2 to 30 kg/m^2. For the body mass index ranging from 14 to 18 kg/m^2 there is sharp increase in the area of tricuspid valve by nearly two cm^2 .There is a increase of 0.2 cm^2 for 18.1 to 20 kg/m^2 and then an increase of 0.1cm^2 in area for the rest of the whole range of body mass index till 30 kg/m^2.

Similarly, for pulmonary valve, there is increase from 1.9 cm^2 to 2.7 cm^2 till 20 kg/m^2 body mass index . Then a small increase of 0.1 cm^2 for 22kg/m^2 which continues till 24 kg/m^2 and then an increase of 0.6 cm^2 till 30 kg/m^2.

For aortic v alve, there is an increase in the area from 1.9 cm^2 to 3.5 cm^2 till body mass indexd of 14 kg/m^2 to 30 kg/m^2 A small in crease in area of 0.5c m^2 and 0.4cm^2 for body mass index range till 18 kg/m^2 and 20 kg/m 2 respectively which is significant is noted. After this, only 0.1cm ^{2} increase in area is noted till body mass index o0f 24 kg/m^2 and a sharp increase of 0.6 cm^2 is seen in the next range which remains the same till body mass indesx of 30 kg/m^2.

MITRAL VALVE DIAMETER AND LEFT VENTICULAR SIZE

Table. 9. MITRAL VALVE DIAMETER AN LEFT VENTRICULAR SIZE

Left ventricular size in cm	Average Mitral valve diameter in mm
3.1 - 4	18.7
4.1 - 5	23.8
5.1 - 6	24.8

The mitral valve diameter for the left ventricular sizes ranging from 3.1 to 7cm were recorded. Directing the left ventricular size into 3 categories with a range of 1cm each, the mitral valve diameter in mm was 18.7, 23.8, and 24.8 mmin the increasing order of left ventricular size.

DISCUSSION

The data recorded in the observation, was studied in detail and were correlated with the available data.

The diameter of all four valves with regard to body surface area:

Mitral Valve

There was a steady increase in the diameter of mitral valve with increasing body surface area, as noted from table.1. Hence, body surface area as a predictor of normal diameter of the mitral valve is confirmed in this study. The obtained values of mitral valve diameter, when compared with standard valves, given in table.2, were significantly lower in our study population. The values obtained from Indian population was definitely lower than the lower end of standard deviation of the standard values.This shows that the mitral valve diameter in our Indian population is significantly lower.

As already elucidated in the review of literature chapter this difference can lead to a number difficulties encountered during surgical replacement of cardiac valves. One of the most important post operative effect is the patient prosthesis mismatch. This condition is solely caused by the discrepancies between the prosthetic valve size and the patient's annular size. The prosthetic valves available in the market are manufactured to fit in the standard annular sizes. Moreover when a patient is taken for surgery the annular dimensions are checked against the patient's body surface area. Simultaneously, the left ventricular size was also measured and the subjects with no obvious pathology of the heart, as studied in the echocardiogram were only taken fit for this study. This still makes this study a valuable one. So the mitral valve can be concluded to be smaller in this normal study population as when compared to the standard values. Hence, this study has shed some light as to the normal diameter of mitral valve in Indian population and the discrepancy between these and the standard values.

***Tricuspid valve*:**

The diameter of tricuspid valve showed a linear increase with the body surface area for the whole range, ranging from 0.61 to 1.9 m^2 , as deduced from table .1.. Tricuspid valve diameter in mm, was very lower than the standard valves. The size of tricuspid valve in Indian population were about 6 m to 10mm lower than the Western population for differing body surface area. This is a very significant observation. However , concluding on such a vast range of difference in the diameter of the tricuspid valve, without taking into account the other factors influencing this parameter is difficult and beyond the scope of this study. The diameter increases with increase in the body surface area, which proves that body surface area is a dependable predictor of the normal diameter of the tricuspid valves.

Pulmonary Valve:

The pulmonary valve also showed a steady increase in diameter with increasing body surface area, as noted from table.1.Here again the body surface area has a direct correlation with the pulmonary valve diameter. On comparison with the standard values(table .2.), the diameter of the pulmonary valve was slightly smaller than the standard value but it was within the lower extreme of the standard deviation or showed a difference of 0.5mm from the lower end of the standard deviation. Hence, no major deviations from the normal values in Western population when compared with the Indian study population was observed. Therefore, the diameter of the pulmonary valve coincides with the standard values.

Aortic valve:

Singh B and Mohan JC have stated that aortic valve dimension does not correlate directly with the body surface area. But in this study aortic valve showed a steady increase with increasing body surface area (as in table.1.), proving again that body surface area is a strong predictor of the aortic valves, as for all other valves. Aortic valve diameter on comparison with standard valves (from table.2.), correlated with it and was well within the standard deviation of the standard values.

Gutgesell HP and French M showed that the valve dimensions were linearly related to body surface area. Similarly Capps S.B. et al., Singh B and Mohan J.C (for mitral, tricuspid and pulmonary valves) also showed that the valve diameter directly and significantly correlated with the body surface area.. King DH showed that best predictor of annular diameter was a logartihmic function of body surface area.

In this study, all the four valves show linear increase in diameter with body surface area and hence approves with the above literature. A significant decrease in mitral valve diameter in the Indian population was also observed.

Diameter of cardiac valves and their relation to increasing age

There is a steady increase in the diameter of all four cardiac valves with increasing age, as found table.3.. The maximum range of increase in diameter by 4mm for mitral and tricuspid valve was observed in the sixteen to twenty years category and 3mm in six to ten years category. Similarly pulmonary valve showed an increase of 3mm for each 5 years when observed in the six to fifteen years age group. Maximum increase of aortic valve by 2mm was observed for each 5 years from birth to twenty years.

Hence, mitral valve and tricuspid valve increased in diameter till ten years and again a spurt was seen in the sixteen to twenty years. Pulmonary and aortic valve increased in diameter steadily by 3cm and 2cm respectively for each five year interval. After twenty years till sixty years the valves were more or less the same size or increased by about one to one and a half mm.

Kitzman DW and Edwards WD had described that valve dimensions increase with the advancing age.This study has supported their view.

The cardiac valve dimensions and their relation to males and females

The observations are tabulated in tables 4, 5, 6, 7. All the four cardiac valves were smaller in females than in males till 40 years of age. After 40 years till 60 years, the valves were either equal in size or were smaller in females. In these tables, the relation between the linear increase in valve size with increasing age can again be noted.

Kitzman DW, Scholz DG, Ilstrup DM showed that the size of valves were greater in males than in females. The study correlated with their study and proved the general tendency of smaller valves in females as compared to males.

The cardiac valve dimensions and body mass index:

All four cardiac valves show an increase in the area of the valve with regard to increase in body mass index, as observed from table.8. Body mass index is a index of a person's height and weight. Vasan RS, Larson MG, Levy D have showed that height and weight are principal determinants of cardiac valve dimensions.

This study proves that as shows in the above literature study, that height and weight which can be studied by both body surface area and body mass index, are indeed the principal determinants of valve dimensions.

Size of left venticle and its effect on mitral valve diameter

The normal range of left ventricular chamber size is 3 -5.5 cm. When mitral valve annular diameter in mm was recorded with regard to left ventricular size as in table .9. For each cm increase of the left ventricular size , the mitral valve diameter increased linearly. Hence, we can conclude, that with the increase in left ventricular size, the mitral annulus also proportionately increases.

SUMMARY

This study on the cardiac valve annular dimensions and their clinical significance has shown that:

- All the four cardiac valve dimensions increased as the body surface area increased.

- The diameter of the mitral valve is significantly smaller in the study population.

- The diameter of the tricuspid valve is also smaller, but requires to be studied further.

- The diameters of the aortic and pulmonary valves are within normal values.

- With increasing age the cardiac valves also increased in size upto the age of twenty.

- The cardiac valve areas were definitely more in males when compared to females.

- All the four cardiac valve dimensions showed a linear increase with body mass index , proving height and weight to be the principal determinants of their dimensions.

- Mitral valve diameter increased with increase in the left ventricular size.

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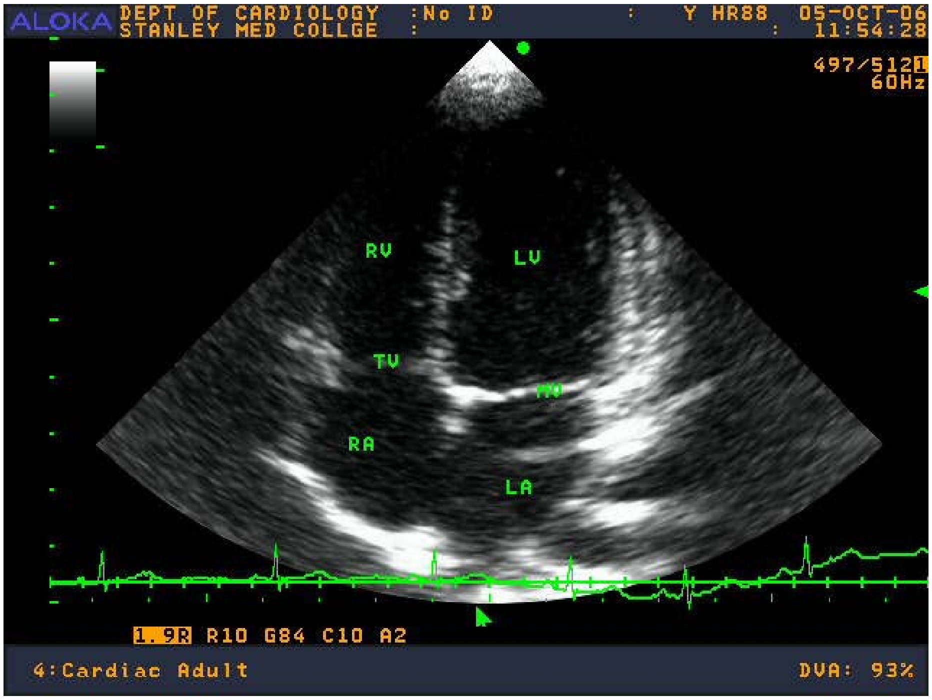
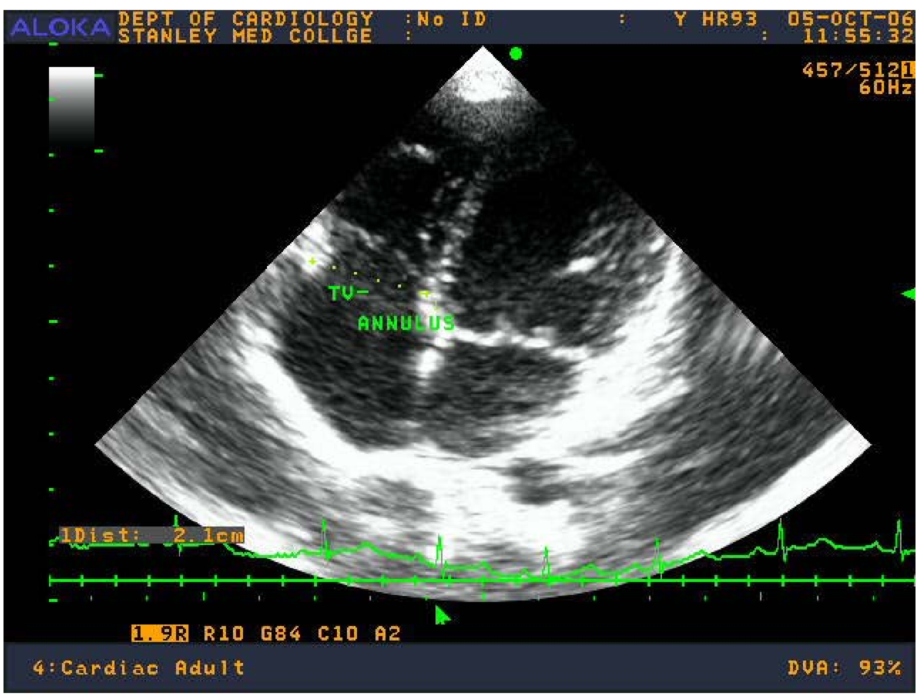
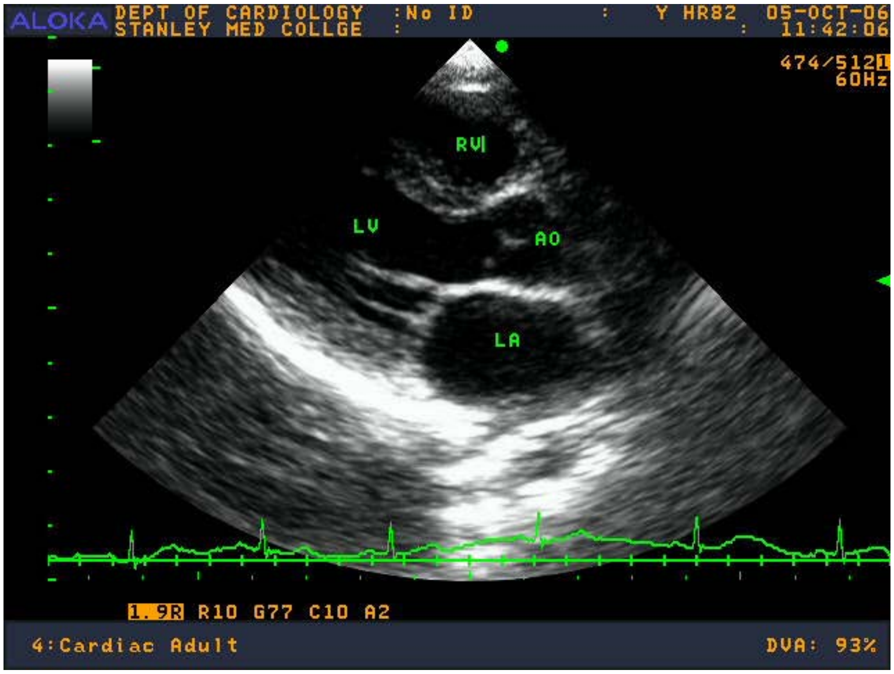
TRICUSPID VALVE ANNULUS



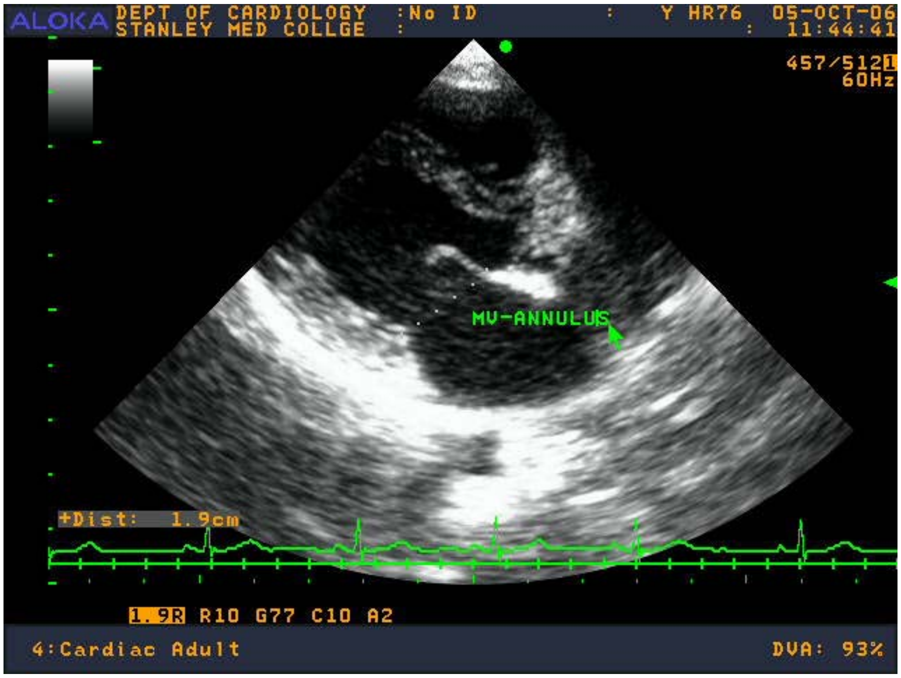
RV - Right Ventricle
TV – Tricuspid Valve
RA – Right Atrium
LV – Left Ventricle
MV – Mitral Valve
LA – Left Atrium



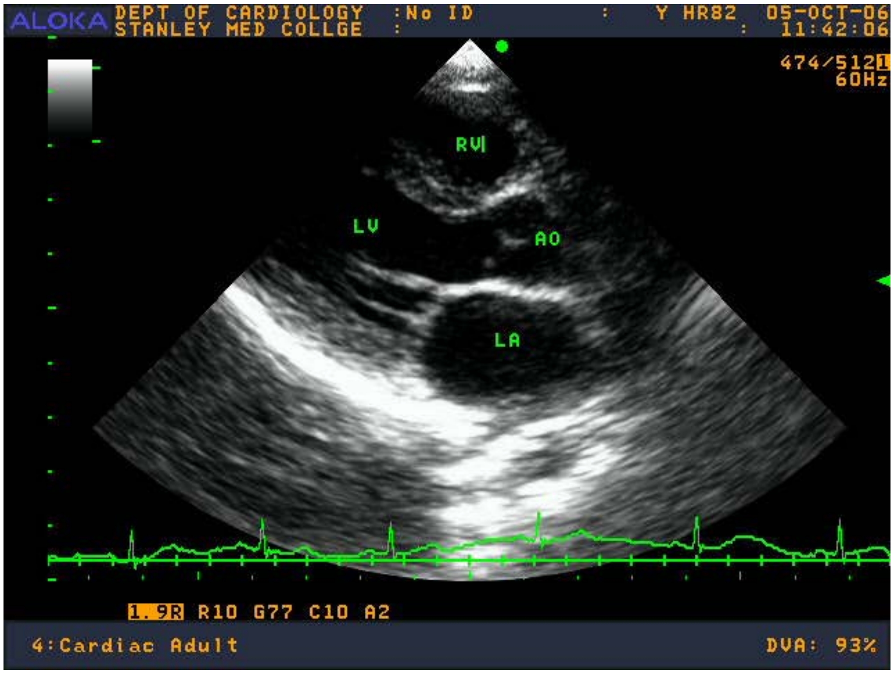
MITRAL VALVE ANNULUS



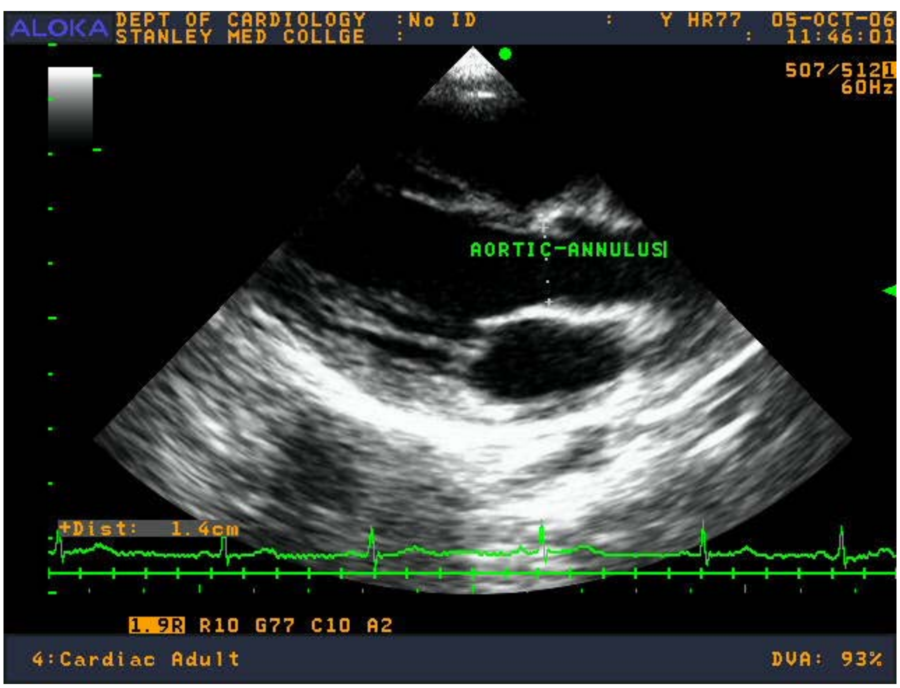
RV - Right Ventricle LV – Left Ventricle
AO - Aorta LA – Left Atrium



AORTIC VALVE ANNULUS



RV - Right Ventricle LV – Left Ventricle
AO - Aorta LA – Left Atrium



PULMONARY VALVE ANNULUS