Dissertation on

ANATOMICAL STUDY OF HUMAN TRICUSPID VALUE

Submitted in partial fulfillment for

M.S. DEGREE EXAMINATION

BRANCH-V ANATOMY

Upgraded Institute of Anatomy

Madras Medical College & Research Institute,

Chennai- 600 003

THE TAMILNADU Dr.M.G.R. MEDICAL UNIVERSITY

CHENNAI – 600 032

TAMILNADU

APRIL 2011

CERTIFICATE

This is to certify that this dissertation entitled **"ANATOMICAL STUDY OF HUMAN TRICUSPID VALUE"** is a bonafide record of the research work done by **Dr.S.SATISH KUMAR.,** Post graduate in the Institute of Anatomy, Madras Medical College and Research Institute, Government General Hospital,Chennai-03, in partial fulfillment of the regulations laid down by The Tamil Nadu Dr.M.G.R. Medical University for the award of M.S. Degree Branch V- Anatomy, under my guidance and supervision during the academic years 2008-2011.

Dr.R.AMUDHA. M.B.B.S.,M.S
Director and Professor,
Institute of Anatomy,
Madras Medical College &
Research Institute,
Chennai – 600003

Dean,
Madras Medical College &
Research Institute,
Govt. General Hospital,
Chennai – 600 003

ACKNOWLEDGEMENT

I would like to place my sincere thanks and gratitude to my most respected teacher and guide **Prof.Dr.Mrs.R.Amudha M.S.,** Director and Professor, Institute of Anatomy, Madras Medical College and **Prof**.**Dr.Christilda Felicia Jebakani M.S.,** Former Director and professor, Institute of Anatomy, Madras Medical College, Chennai – 3, for their invaluable guidance, persistent support for completing my study.

I earnestly thank to **Dr.J.Mohanasundaram,M.D.,Ph.D.,** Dean, Madras Medical College, Chennai-3 for me granting me permission to utilize the facilities in this college for performing this study.

I express my thanks to **Dr.R.Subramaniyam,M.D.,D.M.,** Director, Institute of Cardiology, Govt General Hospital, Chennai-3 for permitting to take echocardiogram images.

My heartful thanks to **Dr.I.Jeyaraj**, Associate Professor, **Tmt.M.S.Thenmozhi, Dr.V.Loganayaki, Dr.V.Sathialakshmi, Dr.M.Vijayalakshmi and Dr.P.Murugesan**, Assistant Professors, Institute of Anatomy, Madras Medical College,Chennai– 3 for their valuable suggestion and encouragement throughout the study.

I sincerely thank **Dr.Radha Bai**, Director, Institute of Obstetrics and Gynaecology, Chennai for helping in the foetal study.

I earnestly thank my seniors **Dr.Rajapriya, Dr.K.Sujatha, Dr.Sangameswaran, Dr.Vijaya** and my juniors **Dr.Kalai.Anbusudar, Dr.Kanagavalli, Dr.Suganya, Dr.Kausalya** for their constant support and encouragement throughout the study.

I extend my heartfelt thanks to my colleagues **Dr.T.Suresh Kumar, Dr.V.Dhanalakshmi and Dr.K.R.Arun Kumar** for their constant encouragement and unstinted co-operation.

I am grateful to my parents and my brother who have helped making this study a reality.

I am thankful to the technicians and all other staff members for helping me in carrying out the study.

CONTENTS

INTRODUCTION

Tricuspid Valve sometimes called the **"Forgotten Valve"** and a **"Second-Class Structure"** in Cardiac Surgery. It can be a potential source of considerable morbidity and mortality , both when it is a primary site of disease and when it is secondarily involved in left heart or pulmonary vascular disease[51].

The Tricuspid valve complex consists of functional units which include **Tricuspid annulus, valve leaflets, chordae tendineae and papillary muscles**(fig.1,2).

The tricuspid valve annulus is a collagenous ring succeeding the orifice, where the bases of the cusps are attached.The annulus is composed of anterior and posterior rims of collagenous tissue.

The leaflets or cusps of tricuspid valve are three in number, named anterior, posterior and septal according to their attachment to the annulus. Anterior leaflet is the largest and septal is the smallest.

The junctions between the leaflets are represented by deep indentation or commissures, which are named as the anteroseptal, posteroseptal and anteroposterior commissures.

The anterior leaflet is attached to the upper margin of the annulus and extends medially across the membranous part of the ventricular septum to meet the septal leaflet at the anteroseptal commissure. The septal leaflet is attached horizontally to the lower

margin of the annulus and extends from antero posterior to postero septal commissures.The septal leaflet extends from the muscular part to the ventricular septum.Each leaflet presents from the free margin to the annulus 3 zones -rough, clear and basal zones.

The chordae tendineae are fibrous collagenous structures supporting the cusps of the atrioventricular valves and consists of 2 types -false and true.

The two major papillary muscles in the right ventricle are located in anterior and posterior positions. A third, smaller muscle has a medial position together with several smaller and variable muscles attached to the ventricular septum.

The anterior papillary muscle is the largest. Its base arises from the right anterolateral ventricular wall below the anteroinferior commissure of the inferior cusp and it also blends with the right end of the septomarginal trabecula.

The posterior or inferior papillary muscle arises from the myocardium below the inferoseptal commissure. It is frequently bifid or trifid. The septal or medial papillary muscle is small but typical and arises from the posterior septal limb of the septomarginal trabecula. All the major papillary muscles supply chordae to adjacent components of the cusps they support.

AIM OF THE STUDY

Normal tricuspid valve function depends upon the anatomical and mechanical integrity of the AV ring, the valve leaflets, chordae tendineae and papillary muscles.

Advances in e**chocardiography, invasive cardiology and surgical reconstruction of Tricuspid valves** necessitate an appreciation of the many variations in the anatomy of the Tricuspid valve for Interventional Cardiologists and Cardiac Surgeons.

The classical description of the tricuspid valve found in the text books of anatomy is inadequate for the need of cardiac surgeon. Similarly the importance of the valvular structures and the myocardium in the mechanism of valve closure requires a new appraisal in view of recent observations.

Numerous variations in the configuration of the cusp tissue and chordal/papillary support of the tricuspid valve,making the interior of the right ventricle as unique to each individual as one's finger print[57].

The aim of the present study is to analyse the morphological and morphometric details of the human tricuspid valve complex.

This study will also be of much help in Tricuspid valve procedures such as **Tricuspid annuloplasty**, **Tricuspid Valve repair (commissurotomy)**, **Artificial chordae tendineae replacement, Tricuspid valve replacement** and **Tricuspid Valvectomy**(fig.3,4,5,6,7).

Present study to be done with the following parameters:

1. Tricuspid Valve Annulus Shape
2. Tricuspid Valve Circumference
3. Number of commissures
4. Length of Commissures
5. Number of Tricuspid Leaflets
6. Shape of Tricuspid Leaflets
7. Height and Length of Tricuspid Leaflets
8. Chordae Tendineae
    a) Types of Chordae Tendineae
    b)Number Of Chordae Tendineae At Origin
    c)Number Of Chordae Tendineae At Insertion
9. Papillary Muscles and its numbers

REVIEW OF LITERATURE

1. Tricuspid Valve Annulus Shape

Keith L .Moore[25] (1980) stated that the oval right atrioventricular orifice is large enough to admit the tips of three average sized fingers.

R . Wayne Alexander et al[35] (1998) quoted that tricuspid annulus is nearly a circular fibrous structure.

Aytac Kocak et al[8] (2004) mentioned that the annular circumference of tricuspid valve was a large oval aperture and enough to admit the tips of 4 fingers.

Susan Standring[52] (2005) stated that the tricuspid valve orifice is best seen from atrial aspect and roughly triangular.

B.N Vijaya Ragawa Rao[9] (2007) stated that tricuspid annulus is nearly circumferential , larger than mitral annulus(fig.24).

2. Tricuspid Valve Circumference

Silver MD et al[42] (1971) stated that the annular circumference of the valve in 27 hearts from men was 11.4 ± 1.1 cm and in the 23 female hearts was 10.8 ± 1.3 cm.

R . Wayne Alexander et al[35] (1998) mentioned that tricuspid valve is larger in circumference and measures 10cm to 12.5cm.

Paulo A et al[19] (2000) stated that the normal tricuspid valve has a complex anatomic structure that can be readily evaluated by 2DE ,

the annular circumference of the valve in men is 11.4±1.1 cm and in females is 10.8±1.3 cm.

Aytac Kocak et al[8] (2004) stated that annular circumference was 12.4 ± 1.1 cm in males and 11.8 ± 1.3 cm in females of non cardiac death origin . Annular circumference for cardiac death origin was 11.2 ± 1.2 cm in males and 10.8 ± 1.1 cm in females.

Seccombe J.F et al[37] (2005) stated that in 24 normal hearts, the mean tricuspid valve length was 11.3 cm ± 0.1 cm.

Susan Standring[52] (2005) stated that tricuspid valve orifice measures 11.4 cm in males and 10.8 cm in females.

Mohamed A . B. Motabagani[33] (2006) stated that total annular length of the human tricuspid valve ranges between 11.3 cm to 13.9 cm.

B.N Vijaya Ragawa Rao[9] (2007) stated that the tricuspid valve circumference is 11.4 cm ± 1.1 cm in males and 10.8 ± 1.3 in females.

3. Number of commissures

Silver MD et al[42] (1971) mentioned that the fan shaped chordae are used to delineate the leaflet commissures. However these chordae are not present in all commissures , and other land marks must be used to define the commissures in some hearts (fig.8,9).

Anteroseptal commissure: The basal attachment of the tricuspid valve reaches its highest level at the membranous interventricular septum , where the anterior and septal walls of right ventricle join. 41 of 50 hearts had a fan shaped chordae at this site.

This chordae which has flattened ribbon like branches and arises either directly from the septal band of the crista supraventricularis or from a small papillary muscle on that band.

Anteroposterior commissure: It forms a deep indentation in the leaflet tissue between the anterior and posterior leaflets. In 47 of the 50 hearts , it was well delineated by a fan shaped chordae and was located roughly at the acute margin of the right ventricle. The anterior papillary muscle , which is usually the largest and has the moderator band attached to it , is another useful landmark.

Posteroseptal commissure: It is a deep indentation in the leaflet tissue at the junction of the posterior and septal walls of the right ventricle has three landmarks: a fan shaped chordae , a papillary muscle and a fold in the septal leaflet of the tricuspid valve.

Rosenquist G.C , Sweeney L J[38] (1975) mentioned that in 39 out of 95 normal specimens , there was either no commissure between the anterior and medial leaflets of tricuspid valve , which resulted in an interrupted valve margin at the center of the membranous ventricular septum or an incompletely formed commissure.

Arthur E . Baue [4] (1996) stated that three commissures anteroseptal, the anteroposterior and posteroseptal are present in tricuspid valve . Posteroseptal has three landmarks , 1) a fan-shaped chorda 2) a papillary muscle on the posterior wall of the ventricle 3) a fold in the tissue of the septal leaflet.

Mohamed A . B. Motabagani[33] (2006) reported that three commissures were observed to intervene between the three leaflets of the human tricuspid valve: anteroposterior , posteroseptal and anteroseptal. The clefts and commissures were grossly identified by the attachment of the fan shaped chordae tendineae.

The anteroposterior and posteroseptal commissures received commissural chordae originating from the medial most apex of the anterior and posterior papillary muscles respectively. The anteroseptal commissure received chordae that arose from one of the masses of the septal papillary muscle or directly from the septal wall of the right ventricle.

B.N Vijaya Ragawa Rao[9] (2007) mentioned that tricuspid valve has three commissures: anteroposterior , posteroseptal and anteroseptal commissure.

4. Length of Commissures

Silver MD et al[42] (1971) reported that the height of anteroseptal commissure was 1.1 ± 0.3 cm in males and 1.0 ± 0.2 cm in females. The height of posteroseptal commissure was 0.8 ± 0.2cm in males and 0.7 ± 0.2 cm in females.The height of anteroposterior commissure was 0.6 ± 0.3 cm in male and 0.6 ± 0.2 cm in female.

Paulo A Ribeiro and muayed Al- Zai bug[19] (2000) stated that the length of the anteroposterior commissure measures an average of 1.1cm ,in the posteroseptal 0.8 cm and in the anteroseptal 0.6 cm.

Skwarek.M et al[46] (2005) stated that commissural length measured as the distance between the attachment of the tricuspid valve and the intercuspidal incisura , ranged from 2 to 15 mm with an average of 6.33 ± 2.59mm.

Mohamed A .B. Motabagani[33](2006) reported that height of anteroposterior commissure ranges between 0.7-1.1cm,for anteroseptal commissure 0.7-1.3cm and for posteroseptal commissure 0.6-1.2 cm.

B.N Vijaya Ragawa Rao[9] (2007) mentioned that length of anteroposterior commissures with a size of 1.1cm , posteroseptal commissures with a size of 0.8cm and anteroseptal commissure with a size of 0.5cm.

5. Number of Tricuspid Leaflets

J.C.B. Grant[22] (1951) stated that, the right atrio ventricular orifice is guarded by the right atrioventricular or tricuspid valve. The three cusps are an inferior , a medial or septal , and an anterior.

Henry Hollinshed[21](1971) quoted that the tricuspid valve is described as consisting of three cusps or leaflets, anterior(infundibular), posterior (marginal or inferior), and septal (medial);the anterior cusp is attached to the anterior wall of the heart;the septal cusp is attached to the interventricular septum and therefore lies both medially and posteriorly; the posterior cusp lies posteriorly and to the right, and in relation to the right margin of the ventricle.

M. Ugarte et al[30] (1976) stated that in an anatomical study of 54 specimens with endocardial cushion defect that the septal tricuspid

leaflet was found to be underdeveloped or absent but not able to find any clefts or divisions in it.

W.J. Hamiltton[58] (1978) mentioned that the right atrioventicular orifice is guarded by the tricuspid valve. It has three cusps and of these the septal cusp is attached at its base to the ventricular septum, and the anterior cusp, which is the largest , is placed between the atrioventricular orifice and the infundibulum ; the third cusp is the posterior.

Keith .L. Moore[25] (1980) stated that the right atrioventricular orifice is guarded by three cusps anterior , septal and posterior cusps, hence the name tricuspid valve. Small secondary cusps may be present which obscure this general arrangement.

Wafae N et al[59] (1990) stated that the tricuspid valve was not consistently tricuspid , but was observed to present 2 , 4 , 5 , or 6 cusps in 72 % of cases .In 64 % of cases commissural cusps were presnt independent of the number of tricuspid cusps.

T. Ikegaya et al[55] (1991) stated that a 59 year old woman died from heart failure associated with tricuspid regurgitation and pulmonary hypertension. Necropsy revealed that had tricuspid valve has 6 leaflets.

Nicholas T.Kouchoukos et al[26] (1993) stated that tricuspid valve , has three leaflets : anterior , posterior and septal. The anterior leaflet is largest of the three leaflets and may have notches creating subdivisions.The posterior leaflet is usually the smallest and commonly scalloped . The septal leaflet is usually slightly larger than the posterior leaflet.

Victor S , Nayak VM[57] (1994) stated that the tricuspid veil of cusp tissue lends itself into neat subdivisions into 2 halves, a septal cusp and mural cusp. Since the mural part of the annulus changes its shape and size during the cardiac cycle , the related mural cusp needs to have clefts which vary in number and split it artificially into two to six segments. It appears logical to label this part of the cusp as "mural cusp" which will include the classical "anterior" and "posterior" cusps and associated commissural scallops.

Sutton J P et al[53] (1995) stated that in the fifty hearts were studied the majority of specimens (62%) had readily identifiable leaflets , but some (30%) could be described as having two leaflets while 8% had four leaflets.

R . Wayne Alexander et al[35] (1998) mentioned that the three leaflets are termed anterior, posterior and septal .

Paulo A Ribeiro and muayed Al- Zai bug[19] (2000) stated that the anterior leaflet is almost always largest , the posterior leaflet may have between one and four scallops.The single septal leaflet is the smallest.

Gerola .L.R et al[20] (2001) stated that the number of cusps varied from two to four.Three cusps was the commonest finding and the fourth cusp , if present, was classified as anterolateral in location.

Aytac Kocak et al[8] (2004) studied that in forty hearts they found two leaflets (20%) ,in 140 hearts (70%) three leaflets and in twenty hearts there were four leaflets (10%) in deaths of non cardiac origin.

They also found two leaflets in 36 hearts (18%),three leaflets in 130 hearts (65%) and there were four leaflets in 34 hearts (17%) in deaths of cardiac origin.

Skwarek.M et al[45] (2004) classified accessory cusps into two types. (1) The more frequent were spurious cusps supported by chordae tendineae arising from one apex of the papillary muscle 58.6% of hearts studied.(2) Less frequent group consisted of real accessory cusps supported by chordae tendineae arising from two apices of papillary muscle 41.3% hearts studied(fig.18,19,20).

Susan Standring[52] (2005) stated that it is usually possible to distinguish three cusps in tricuspid valve.They are located anterosuperiorly , septally and inferiorly .

Chummy S. Sinnatamby[12] (2006) stated that tricuspid valve guards the right atrioventicular orifice and has three cusps .The three cusps are called anterior , posterior and septal.

Skwarek.M et al[48] (2006) classified five types of tricuspid valve(fig.12).Frequency of occurrence of particular types of tricuspid valve in 107 formalin fixed adult hearts of both sexes (30 female and 77 male) were studied.

Type 0 – of tricuspid valve occurred in 2.75%(fig.12).

Type 1 - “Typical” form of tricuspid valve present in 10.09%(fig.13).

Type 2 - four cuspidal form present in 41.28%(fig.14,18).

Type 3 - five cuspidal form present in 34.86%(fig.15).

Type 4 - six cuspidal form present in 8.26%(fig.16).

Type 5 - rarest seven cuspidal form present in 2.75%(fig.17).

B.N Vijaya Ragawa Rao[9] (2007) mentioned that tricuspid valve has 3 leaflets: anterior , posterior and septal.

Lapenna E et al[29] (2008) reported a case of a 52 year old man who was referred to surgery because of severe mitral and tricuspid regurgitations of Barlow's disease.In this, tricuspid valve was a "four leaflet valve" due to the presence of a small accessory leaflet between the septal and posterior leaflets.

6. Shape of Tricuspid leaflets

Silver MD et al[42] (1971) reported that anterior leaflet was the largest, usually semicircular may be quadrangular in shape.The posterior leaflet had several indendation , mostly semicircular in shape but it may vary and the septal leaflet is semi oval in shape.

Keith .L. Moore[25] (1980) stated that the cusps are more or less triangular in outline and are continuous with one another at their bases , which are attached to the fibrous ring that surrounds the atrioventricular orifice.

Stephen C . Yang , Duke .E .Cameron[51] (2004) stated that three leaflets of tricuspid valve are the septal , which is semicircular in shape, the anterior which is largest and nearly quadrangular, and the

posterior which is usually the smallest , somewhat triangular in shape.

Aytac Kocak et al[8] (2004) reported that in non cardiac death cases the anterior leaflet was triangular in 100 case (95%), rectangular in 10 cases.The posterior leaflet was the smallest and it appeared as rectangular in 20 case (10%), square in 20 (10%) , triangular in 160 (80%) cases. The septal leaflet appeared rectangular in 32 cases (16%), square in 12 (6%) and triangular in 156 (78%) cases.

In cardiac death cases the anterior leaflet was the largest component of the tricuspid valve and was triangular in 82 cases (91%), rectangular in 11 (5.5%) and square in 7 (3.5%) cases.The posterior leaflet appeared as rectangular in 16 cases (8%), square in 14 (7%) and triangular in 170(85%)cases.The septal leaflet appeared rectangular in 28 cases (14%), square in 21 (10.5%) and triangular in 151 (75.5%) cases.

Mohamed A.B.Motabagani[33](2006) reported that the gross examination of the human tricuspid valve of 10 hearts showed that, the anterior leaflet was always(100%) the largest , triangular and devoid of clefts. The posterior leaflet was the second in size and also triangular.It had either no cleft in 2 hearts (2%) or a single cleft in the remaining 8 human hearts (80%).

The septal leaflet of the human tricuspid valve was semicircular along its free edge and always (100%) , divided by a cleft into two unequal scallops, of which the larger was located nearer to the antero-septal commissure.

Skwarek. M et al[46] (2005) studied natural foramina located in the leaflets of Tricuspid valve . They introduced the concept of **"True" and "Spurious" Natural foramina** of the tricuspid valve. Those surrounded by valve tissue from each side were regarded as true foramina. Foramina with crossing single fibres of valve tissue were treated as one foramina (fig.22).

Spurious natural foramina is part of musculo-fibrous arcade , with a membranous connection between the papillary muscle and the leaflet of the valve (fig.21).

Presence of foramina may be responsible for the additional jets seen during echocardiography as well as the subclinical insufficiency of the tricuspid valve.

7. Height and Length of Tricuspid Valve Leaflets

Silver MD et al[42] (1971) reported that ,the height of anterior leaflet was 2.4 ± 0.4cm in males, 2.1 ± 0.4cm in females and width was 3.9 ± 0.8cm for males,3.5 ± 0.7cm in females. For posterior leaflet height was 1.8 ± 0.3cm in males, 1.6 ± 0.5cm in females and width was 3.0 ± 0.9 in males, 2.6 ± 0.7 for females. In septal leaflet height was 1.7 ± 0.3cm in males , 1.5 ± 0.3cm in females and width was 3.7 ± 0.8cm in males, 3.5 ± 0.8cm in females.

R.Wayne Alexander et al[35] (1998) mentioned that the anterior leaflet is usually the largest with a width of 2.2 cm. The septal and posterior leaflets measures about 1.5cm and 2.0 cm in width respectively.

Aytac Kocak et al[8] (2004) reported that the height and width of leaflets in non cardiac death cases ,for anterior leaflet height was 2.4 ± 0.3 cm in males, 1.9 ± 0.3 cm in females and width 3.8 ± 0.1 cm in males ,3.4 ± 0.1cm in females.For posterior leaflet height was 1.8 ± 0.2 cm in males,1.6 ± 0.3cm in females and width was 3.1 ± 0.7cm. For septal leaflet height 1.9 ± 0.3 cm in males, 1.7± 0.3cm in females and width was 2.6±0.3 cm.

In cardiac death cases, the height of anterior leaflet was 2.5 ± 0.4cm in males , 2.4 ± 0.3cm in females and width was 4.0 ± 0.3cm for males , 3.6 ± 0.4cm in females. For posterior leaflet height was 1.9±0.3cm in males , 1.7 ± 0.4cm in females and width was 3.3 ± 0.4cm in males , 3.1 ± 0.3cm for females. In septal leaflet height was 1.7 ± 0.3cm in males , 1.5 ± 0.2cm in females and width was 3.4 ± 0.6cm in males, 3.2 ± 0.2cm in females.

John F. Seccombe et al[40] (2005) mentioned that mean length were similar for the anterior , posterior and septal leaflets (38-42 mm).

Skwarek.M et al[48] (2006) stated that the average height of the leaflets were: for anterior leaflet 20.71 ± 5.23mm , for posterior leaflet 18.88 ± 4.66 mm and for the septal leaflet 17.22 ± 4.71mm(fig.11).

Mohamed A . B. Motabagani[33] (2006) reported that annular length of anterior leaflet ranges between 2.7-4.7cm , for posterior leaflet 1.8-3.2cm and for septal leaflet 2.5-3.7cm.

Height of anterior leaflet ranges between 1.9-2.7cm , for posterior leaflet 1.5-2.9cm and for septal leaflet 1.4-1.8cm.

B.N Vijaya Ragawa Rao[9] (2007) mentioned that anterior leaflet is the largest with a width of 2.2cm , septal(medial) leaflet is the smallest with a width of 1.5cm, the posterior leaflet measures 2.0cm in width and may have 1-3 scallops produced by small clefts.

8. Chordae Tendineae

a) Types of Chordae Tendineae

J.C.B. Grant[22] (1951) stated that chordae tendineae are fine tendinous chords which pass to the cusps from conical muscular projections on the wall of the ventricle called the papillary muscles.

Silver MD et al[42] (1971) stated that the chordae of the tricuspid valve are fibrous cords of various lengths. They may originate from a papillary muscle either directly from the apex of the muscle or from small nipples which are usually on its upper third. Alternatively , the chordae may arise directly from the muscle of the posterior or septal walls of the right ventricle. The chordae that insert into the leaflet tissue are called true chordae. False chordae that insert elsewhere. Five different types of chordae tendinae are attached to the tricuspid valve.They are Fan-shaped, rough zone, basal , free edge and deep chordae(fig.24).

Fan-shaped chordae: The morphology of the fan shaped chordae in both the tricuspid and mitral valves is similar , inserted into the commissures between the leaflets and into the clefts in the commissures between the leaflets and into the clefts in the posterior leaflet.

Fan shaped chordae were present at the anteroposterior commissure in 47 hearts , at the posteroseptal commissure in 50 and at the anteroseptal in 41 hearts.

Rough zone chordae: These chordae insert into the “rough zone” on the ventricular aspect of each leaflet.Each chordae splits into three cords soon after its origin. One chord inserts into the free margin of the leaflet , one into the upper limit of the rough zone at the line of closure , and third between the other two.

Rough zone chordae were attached to the anterior leaflet in all 50 hearts , to the posterior leaflet in 41 and to the septal leaflet in 49.

Free Edge Chordae: These single , thread like , often long chordae usually originate from the apex of the papillary muscle, but may come from its base. They insert into a leaflet’s free edge, frequently near its apex , but they may insert between the apex and a commissure or cleft.

Free edge chordae were found attached to 32 in anterior , 24 in posterior and 25 in septal leaflets.

Deep Chordae: Deep chordae are long. They pass deep to a leaflet’s free margin to insert on its ventricular surface either in the upper part of the rough zone or in the clear zone. They may be single or they may branch into two or three chords just before insertion.

Deep chordae were attached to the anterior leaflet in 38 hearts, to the posterior in 29 and to the septal leaflet in 33. One inserted into an anteroposterior commissural area.

Basal Chordae: Basal chordae are usually single. They may be round chords, flattened ribbon-like structures long and slender, short and muscular.They arise directly from the myocardium or from small trabeculae carnae and may flare into thin membranous bands just before their insertion. They insert into a zone approximately 2mm wide extending into the leaflet from the annular region.

Basal chordae were found attached to 23 in anterior , 23 in posterior and 45 septal leaflets.

R.Wayne Alexander et al[35](1998) mentioned that strong chords fibrous tissue,the chordae tendineae spring from the tip of each papillary muscles. The chordae tendineae of the tricuspid valve are made up of five types.Fan shaped, rough zone, basal , free edge and deep.Of these, the free edge and deep chordae are unique to the tricuspid valve.

Paulo A Ribeiro and muayed Al- Zai bug[19] (2000) stated that the chordae tendineae commonly arise from the papillary muscle or from the muscle of the posterior or septal walls of the right ventricle.There are five types of chordae tendineae: Fan-shaped, free edge, rough, deep, basal chordae.

Fan shaped chordae form precise landmarks for the commissures and distinguish clefts from the genuine commissures of the leaflets.

Free Edge Chordae are characteristic of tricuspid valve.They are single and may originate in the apex of papillary muscle from its base and inserted into the leaflets free edge.

Deep and Rough Chordae can be as long as 2.2cm. The deep chordae not present in the mitral valve , appears to provide a second arcade for leaflet attachment to the larger tricuspid valve annulus and leaflets.

Basal Chordae are the shortest and measures an average of 0.6cm.

Aytac Kocak et al[8] (2004) stated that five types of chordae were attached to the tricuspid valve. These were fan-shaped , rough zone , basal , free edge and deep chordae. They originated from a papillary muscle either directly from the apex of the muscle or from small nipples , which were usually on their upper third. The chordae were attached to the ventricular end of the valve leaflets and their apices and margins and then anchored to the muscular ventricular wall.

R. Kobza et al[36] (2004) stated that 13500 echocardiographic studies were reviewed to identify patients with severe unexplained tricuspid regurgitation.10 patients with aberrant tendinous chords tethering one or more tricuspid valve leaflets were identified.There were short non-aberant tendinous chords in seven patients, five of them also had right ventricular or tricuspid annulus dilatation.Tethering of tricuspid valve leaflets by aberrant tendinous chords can be the sole mechanism of congenital tricuspid regurgitation.

Susan Standring[52] (2005) stated that the chordae tendineae are fibrous collagenous structure supporting the cusps of the atrioventricular valves. False chordae connect papillary muscles to each other or to the ventricular wall including the septum or pass directly between points on the wall. They are irregular in numbers and dimensions in the right ventricle.The true chordae usually arise from small projections on the tips or margins of the apical one-third of papillary muscles, but sometimes arise from the bases of papillary muscles or directly from the ventricular aspects or the free margins of the cusps.They have been classified into first, second and third order chordae according to the distance of the attachment from the margins of cusps.

Chummy S. Sinnatamby[12] (2006) stated that the edges and ventricular surfaces of the cusps receive the attachments of the chordae tendineae , collagenous cords which diverge from the papillary muscles and prevent the cusps from being everted when the ventricle contracts.

B.N Vijaya Ragawa Rao[9] (2007) mentioned that chordae tendineae may arise from the papillary muscle or from the muscle of the posterior or septal wall of the right ventricle. Tricuspid valve has five types of chordae tendineae:- fan shaped, rough,deep, basal and free edged. Deep and free edge are unique to tricuspid valve.

Marios Loukas et al[31] (2008) stated that 35 out of 100 specimens containing right ventricular false tendon and classified them into types:

Type 1 – In 21 hearts (47.7%) the RFT was located between the ventricular septum and the anterior papillary muscle.

Type 2 –In 11 hearts (22.9%) located between the ventricular septum and the posterior papillary muscle.

Type 3 – In 7 hearts (14.5%) between the anterior leaflet of the tricuspid valve and right ventricular free wall.

Type 4 – In 5 hearts (10.4%) between the posterior papillary muscle and ventricular free wall.

Type 5 – In 4 hearts (8.3%) between the anterior papillary muscle and ventricular free wall.

The presence of conduction tissue fibres within the RFT was limited to Type 1,3 and 4.

In Type 2 and 5 the RFT resembled fibrous structures in contrast with Type 1 , 3 , 4 which is composed more of muscular fibers , including conduction tissue fibers.

b)Number Of Chordae Tendineae At Origin

G.R. Nigri et al[34] (2001) reported that tendinous cords (TC) varying from 1 to 11 originated in the anterior papillary muscle (mean 4.74), from 1 to 8 TC originated in the posterior papillary muscle (mean 2.67) and from 1 to 5 TC originated in the septal papillary muscle (mean 1.77).

Mohamed A . B. Motabagani[33] (2006) stated that, the number of chordate tendineae at anterior papillary muscle in males was 11 to 13 and ,in females was 9 to 12. Number of chordae tendineae at posterior papillary muscle in males was 5 to 7 and, in females was 4 to 6. Number of chordae tendineae at septal papillary muscle in males was 6 to 11 and , in females was 7 to 12.

c)Number Of Chordae Tendineae At Insertion

Silver MD et al[42] (1971) mentioned that on an average,25 chordae inserted into the tricuspid valve.There is no significant difference in the total number between the two sexes. Of the 25 chordae, seven passes to the anterior leaflet, six to the posterior leaflet, nine to the septal leaflet and three insert into the commissural areas.

Ankara[4] (1992) studied the types and distribution of chordae tendineae attached to each leaflet of valva atrioventricularis sinastra and dextra which were examined in 27 normal hearts obtained during autopsies with the aim of contributing to chordal replacement studies.On an average, 27 chordae tendineae in valva atrioventricularis sinastra, 30 in valva atrioventricularis dextra and 57 in the whole heart were detected.The rough zone chordae tendineae,which connected the leaflets

to the ventricle with its three branches and has a significant role for the leaflet's resistance to the pressure , were found quantitatively more than the other types of chordae tendineae in all the leaflets except cuspis septalis.

Paulo A Ribeiro and muayed Al- Zai bag[19] (2000) stated that on an average, 25 chordae tendineae insert into the tricuspid valve ,7 to the anterior leaflet , 6 to the posterior leaflet , 9 into the septal leaflet and 3 into the commissural areas.

Seccombe J.F et al[40] (2005) stated that the tricuspid valve was served by an average of 170 ± 36 chordae tendineae, 49% inserted on the free edge of the valve , 44% to the undersurface and 7% on the basal region.Chordal density (number of chordae/cm^2) was greater in women than men (9.9±0.5 vs 7.3±0.7 chordae/cm^2).The septal leaflet had the greatest chordal density and the anterior leaflet the lowest (12.7±0.9 vs 5.9±0.7 chordae/cm^2)

B.N Vijaya Ragawa Rao[9] (2007) mentioned that on average there are 25 chordae inserted into the tricuspid valve ,7 chordae are inserted into the anterior leaflet , 6 into the posterior leaflet , 9 into the septal leaflet and 3 into the commissures.

Skwarek.M et al[49] (2007) stated that a group of 96 formalin fixed adult human hearts (78 male ,28 female) was examined. The tendinous chords were counted for the main and accessory leaflets with respect to their position in the leaflet , whether in the margin , ventricular surface or commissural area and their ramifications were connected for the main and accessory leaflets.The total average number of chords was 72.71±13.38.

The number of chords attaching to main leaflets was higher than to accessory ones.The number of marginal chords was very similar in the anterior and septal cusps (CA-12.03±2.09 and CS-11.99 ± 3.35 but statistically higher in the posterior cusps (CP-9.47±1.41).

The anterior leaflet was provided by chords which originated in the anterior and posterior papillary muscles (Anterior papillary muscles 86.19±11.66% , posterior 13.09±1.74%).The posterior leaflet was provided by chords coming from the posterior and septal papillary muscles (posterior 85.67±11.48% , septal 1.83%).The septal cusp was provided by chords from the septal and anterior papillary muscles (septal 19±2.55%, anterior 80.99±10.85%)

9.Papillary Muscles and its numbers

J.C.B. Grant[22] (1951) stated that the papillary muscles of right ventricle are (1) a large anterior muscle from which the chordae passes to the anterior and inferior cusps of the valve.(2) a smaller and more irregular inferior muscle , sometimes represented by 2 or more segments , from which chordae pass to the inferior and medial cusps.(3) a group of small septal muscular cones , varying in size and number , which project from the septum and are united by chordae to the anterior and medial cusps.

Henry Hollinshead[21](1971) quoted that the three cusps of the tricuspid valve are not provided with individual papillary muscles; the large and constant papillary muscle in the right ventricle is the anterior papillary muscle, which sends chordae tendineae to both the anterior and the posterior cusps; there may be one prominent posterior papillary muscle and sends the chordae to the septal and

posterior cusps, and one prominent septal muscle, sometimes known as the papillary muscle of the conus, that arises from the supraventricular crest;otherwise posterior papillary muscles are small and irregular, and septal muscles even smaller, some giving rise to single chordae tendon.

Keith L Moore[25] (1980) stated that the papillary muscles are conical projections which have a number of fibrous threads (chordae tendineae) arising from their apices.There are usually three papillary muscles in the right ventricle.

The anterior papillary muscle ,the largest and most prominent of the three, is attached to the anterior wall and its chordae attached to the anterior and posterior cusps.The posterior papillary muscle is smaller than the anterior papillary muscle and may consist of several parts.It is attached to the inferior wall and its chordae tendineae are attached to the posterior and septal cusps.The septal papillary muscles , small and multiple are attached to the interventricular septum and their chordae tendineae are attached to the anterior and septal cusps.

R .Wayne Alexander et al[35] (1998) mentioned that in the right ventricle there are usually 3 papillary muscles. The largest is the anterior papillary muscle , which is found below the commissure between the anterior and posterior leaflets originating from the moderator band as well as from the anterolateral ventricular wall. The posterior papillary muscle lies beneath the junction of the posterior and septal leaflets. The small septal papillary muscle originated from the wall of infundibulum.

Paulo A Ribeiro and muayed Al- Zai bag[19] (2000) stated that the subvalvular tricuspid apparatus is composed of three papillary muscles.The anterior has a moderator band attached to it, usually readily detected by 2DE.The medial tricuspid papillary muscles may be rudimentary in adults.

Grochowski P[47] (2001) studied papillary muscles of right ventricle and introduced the concept of multi apical and multi-segmental papillary muscles. He classified right ventricular papillary muscle into 14 types (1 to 14) (fig.25).

G.R. Nigri et al[33] (2001) stated that a series of 79 normal human hearts was studied focusing on the morphological characteristics of papillary muscle of the right ventricle.The anterior and posterior papillary muscles(apm, ppm) were present in 100% of the cases.The septal papillary muscle (spm) was absent in 21.5% of the heart.

The APM presented one head in 81% and two heads in 19% and, it was 19.16mm in length.The septal papillary muscles(spm) was one headed in 41.7% and presented two heads in 16.5% the presence of a 3 and 4 heads appeared in 12.7% and 7.6% respectively and the spm was 5.59mm in length.The ppm presented one head in 25.4%,two heads in 46.8% , three heads in 21.5% and four heads in 6.3% of the cases it was 11.53mm in length.

Ekin O. Aktas et al[16] (2004) stated that the papillary muscles were conical projections of ventricular muscle, the apices of which offered attachment to the chordae tendineae.The papillary muscle presented great variability in number , with a minimum of two and a maximum of nine papillary muscles in right ventricle.They were

usually 3 papillary muscles, anterior(apm), posterior (ppm) and septal (spm) papillary muscle.

The single papillary muscle was conical , mamillated , flat topped or saucerized and when there were two bellies they presented a two tiered , interlinked , parallel , arched ,V , Y , H configuration. Papillary muscles with three bellies formed a parallel , interlinked or arched arrangement.When four or five bellies existed , they were parallel or interlinked.

Anterior Papillary Muscle : In non cardiac death cases , the anterior papillary muscle was present in 100% of the hearts. It was the largest papillary muscle and the most prominent of the three.Single anterior papillary muscle found in 80.5% of the cases (161 cases) and double one in 19.5% (39 cases).

In cardiac death cases , the anterior papillary muscle was present in 99.5% of the hearts. Single apm found in 83.5% of cases (167 cases) double ones in 13.5%(27 cases) and nil in 3% (6 cases).

Posterior Papillary Muscle : In non cardiac death cases , the posterior papillary muscle was present in 100% of the hearts. One and two ppm were frequently observed (26.5% and 48.5%). Three and four ppm were found in 34 and 15 cases (17% and 7.5%), five ppm were found in one case (0.5%).

In cardiac death cases , the apm was present in 99.5% of the hearts. One and two ppm were frequently observed (43% and 38%). Three and four ppm were found in 16 and 15 cases (8% and

7.5%), five ppm were found in two case (1%).The ppm was not present in 5 cases (2.5%).

Septal Papillary Muscle : In non cardiac death cases , the septal papillary muscle was present in 170 hearts (85%). The spm was rudimentary, often absent or very small in size. The spm presented one , two , three or four heads. The incidence of the double spm (40%) was more frequent than that of the single one (21.5%). Three or four spm were found in 17% and 6.5% of the cases. In 30 case (15%) no spm was found. In these cases, the chordae tendineae were directly attached to the ventricular wall.

In cardiac death cases , the septal papillary muscle was present in 183 hearts (91.5%).The incidence of the double spm (20%) was more frequently than that of the single one (40%). Three or four spm were found in 23% and 8.5% of the cases. In 17 case (8.5%) no spm was found.

Skwarek.M et al[44] (2005) observed 467 papillary muscles belonging to types 1 to 16 (fig.26).

Susan Standring[52] (2005) stated that the two major papillary muscles in the right ventricle are located in anterior and posterior positions. A third, smaller muscle had a medial position together with several smaller and variable muscles attached to the ventricular septum.

The anterior papillary muscle is the largest, its base arises from the right anterolateral ventricular wall below the anteroinferior commissure of inferior cusp and it also blends with the right end of the septomarginal trabecula.

The posterior or inferior papillary muscle arises from the myocardium below the inferoseptal commissure. It is frequently bifid or trifid.

The septal or medial papillary muscle is small but typical and arise from the posterior septal limb of the septomarginal trabecula.

Mohamed A .B. Motabagani[33] (2006) stated that inspection of the interior of the human right ventricle revealed the presence of three papillary muscles anterior, posterior and septal.

The anterior papillary muscle was always largest in the form of a biapical single based conical belly.The base of the anterior muscle was attached to the sternocostal wall of right ventricle within its lower one-third.

The posterior papillary muscle of the human tricuspid valve complex was the second muscle in size and also in the form of a biapical single belly.It arose from about the middle of the diaphragmatic wall of the right ventricle close to the interventricular septum.

The septal papillary muscle was formed of small conical masses , some uniapical and other biapical. All were tethered to the interventricular septum.

Marios Loukas et al[31] (2008) mentioned that an anatomical study was conducted to identify the morphological topography of the papillary muscle complex (PMC).The study involved 200 formalin fixed adult human hearts. The PMC was present in 82% of the

hearts , while in the remaining 18% specimens, it was replaced by tendinous chords.

The PMC was connected with the septal (59.7%) , anterior (20.7) or both septal and anterior leaflets (19.5%) with single (29.8%) or multiple chordae tendineae (70.1%). The PMC was also found to be present as a single papilla(51.8%) , double papillae (32.9%) or triple papillae (15.2%).

EMBRYOLOGY OF TRICUSPID VALVE

Initially, the atrial myocardium is continuous with the ventricular myocardium through the myocardium of the atrioventricular canal. The atrioventricular canal is characterized by sulcus tissue on the epicardial side and subendocardial cushion on the endocardial side. As the atrioventricular valves develop, the sulcus and cushion tissues fuse at the ventricular margin of the atrioventricular canal. This disrupts the myocardial continuity at this site.

The atrioventricular valves develop as shelf-like projections from the margins of the atrioventricular orifices, directed as almost complete conical sheets towards the ventricles, their advancing edges continuing, initially as trabecular ridges, deep into the ventricular cavity. With continued differential growth and excavation on their ventricular aspects, each sheet develops two (mitral) and three (tricuspid) marginal indentations, defining the principal valve cusps. Minor marginal indentations (clefts) subdivide some cusps into scallops.

Each cusp develops functionally significant regional variations in surface texture. Its core condenses as a collagenous lamina fibrosa. The latter blends, at its atrioventricular base, with the inappropriately named fibroareolar valve 'annulus'-each a part of the complex, functionally crucial, fibrous 'skeleton' of the heart.

The anterior cusp of the tricuspid valve and both the anterolateral and posteromedial cusps of the mitral valve appear at about the time when fusion of the atrioventricular cushions and bulbar ridges takes place. Delamination of the septal cusp of the tricuspid valve occurs after closure of the interventricular foramen during the seventh to eighth week of gestation.

MATERIALS AND METHODS

STUDY MATERIALS

1. Heart from 45 adult cadavers.

2. Fetal heart from 5 dead fetus.

3. Adult 2 dimensional Echocardiogram.

METHODS OF STUDY

A. Dissection method

- Conventional dissection method

B. Radiological study

- Adult 2D Echocardiogram Study.

SPECIMEN COLLECTION

1. Forty five adult embalmed human cadavers were selected from the cadavers allotted to the first MBBS students and first BDS students at the Institute of Anatomy, Madras Medical College, Chennai-3.

2. Five dead unclaimed fetuses were obtained from the Institute of Obstetrics and Gynaecology, Egmore. Fetal embalming was done by injecting 200 ml of embalming fluid consisting of formalin, glycerol, alcohol and thymol, through the aorta.

METHODS OF STUDY

1.Conventional dissection method

Heart is sectioned along its acute margin. The section passed near the antero posterior commissure of the right atrioventricular valve with an incision from the right atrium to the apex of the right ventricle. After opening, the heart is washed under running tap water to remove blood clots.Dissection of myocardium was carried out from the right AV fibrous ring to the origin of papillary muscles,preserving the integrity of the valve apparatus.

Morphological and morphometrical data are obtained from each valve shape,circumference,number and depth of commissure,number of leaflets,thier height,length chordae tendineae,papillary muscles and their relation to the leaflets.These data are studied and measured under magnifying lens.

Dissection of fetal heart specimens was done in the same way as done in adult heart but with utmost gentleness and care to the extremely small structures in the fetus.Findings are measured,noted and photographs were taken.

2.Radiological study

2D Echocardiogram of 10 patients who underwent cardiac evaluation (normal and valvular disease) were selected and the images taken and studied.

The Tricuspid valve is a multi-component complex structure. Unlike the aortic and mitral valve, it is not possible to visualize all TV cusps simultaneously in one cross-sectional view by standard transthoracic two-dimensional echocardiography(2DE), either transthoracic or transesophageal due to the position of TV in the far field.

Currently the state of art in imaging the diagnosis of the tricuspid valve is two dimensional echocardiography(2DE) , complemented with Doppler hemodynamic assessment.These combined noninvasive techniques, that are widely available, achieve a precise and cost-effective anatomic and physiological assessment of tricuspid valve.

OBSERVATION

Specimens of heart from 45 adult human cadavers preserved in formalin were studied. Conventional dissection method was carried out in all the specimens. Dissection was also carried out in five fetuses and their hearts were studied. In each heart a detailed examination was made on the tricuspid annulus , commissures , valve leaflets , chordae tendineae and papillary muscles. The findings observed in 45 hearts are summarized as follows:

1.Shape of Tricuspid Annulus

In the present study tricuspid valve annulus in 39 hearts were circular in shape (pic.1) and in 6 hearts oval in shape(pic.2) [Table no.1].

2.Circumference of Tricuspid Annulus

In the present study, the average circumference of the tricuspid annulus was found to be 11.8cm (range 10.3 to 13.0 cm).

Measurements and statistical analysis are shown in(pic.3) table no.2.

3. Number of commissures

Commissures are junctional areas between the leaflets.Positions of the commissures were observed as anteroposterior, anteroseptal and posteroseptal .

Commissures were identified by the fan shaped attachment of the chordae and these chordae are known as commissural chordae.

In the **present study,** the number of commissures were three namely anteroposterior, anteroseptal and posteroseptal commissures, clearly identifiable in all 36 hearts and accessory commissure were present in 9 hearts[Table no.3,4].

4. Length of commissures

Length of a commissure is defined as the shortest distance between the basic and free margin of a leaflet in an intercuspidal insura[46].The length of the commissures were measured using divider and millimeter scale(pic.4).

In the present study the length of anteroposterior commissure ranged from 0.9-1.4 cm with an average of 1.17 cm. The length of posteroseptal commissure ranged from 0.6-0.9 cm with an average of 0.74 cm and the length of anteroseptal commissure ranged from 0.5-0.9 cm with an average of 0.64 cm [Table no.4].

The length of commissure (Accessory commissure) between main leaflet and accessory leaflet ranged from 0.4-0.8 cm with an average of 0.53 cm[Table no.4].

5. Number of Tricuspid valve leaflet

Anterior leaflet identified between anteroseptal and anteroposterior commissures. Septal or medial leaflet identified between anteroseptal and posteroseptal commissures .Posterior leaflet lies between the anteroposterior and posteroseptal commissures, it received the chordae tendineae mostly from posterior and anterior

papillary muscles.Posterior leaflet had indentations or cleft in its free edge and it gives a scalloped appearance.

In the present study number of leaflets varied from 3 to 6.Three leaflet were found in 36 (80%) of hearts(pic.5) ,4 leaflets were found in 6 (13.3%) hearts (pic.6,7) and 5 leaflets were found in 1 (2.2%) heart (pic.8). 6 leaflets were found in 2 (4.4%) hearts(pic.9,10) [Table no.5].

Two types of accessory leaflets were present in 9 hearts (20%) having 4 , 5 and 6 leaflets. Spurious accessory leaflet receives chordae tendineae arising from single papillary muscle(pic.11). True or real accessory leaflet received chordae tendineae arising from 2 papillary muscle (pic.12).

6.Shape of Tricuspid valve

In the present study, the shape of anterior leaflet appeared largest and triangular in all 45 hearts (100 %). It receives the chordae tendineae from anterior and septal papillary muscles.

The septal leaflet appeared triangular in 42 hearts(93.3%), semicircular in 3 hearts(6.7%), it receives chordae tendineae from posterior and septal papillary muscles.

The posterior leaflet appeared triangular in all 45 hearts (100%), it receives chordae tendineae from posterior and anterior papillary muscle [Table no.6].

The accessory leaflets were present in 9 hearts, they all appeared triangular in shape[Table no.9].

In the present study True natural foramina were present in 3 hearts(pic.13,15) and Spurious natural foramina present in 9 heart specimens(pic.14,15).

7.Height and Length of Tricuspid Valve Leaflets

a) Height of Tricuspid Valve Leaflets

Height of a leaflet measured is the greatest distance between the base and free margin of a leaflet(pic.16).

In the present study the height of the tricuspid valves varied in each heart and the height of the anterior leaflet ranged from 1.9 – 2.5 cm(mean 2.21cm), for septal leaflet 1.4-1.9 cm(mean 1.68cm) and for posterior leaflet 1.7-2.2 cm (mean 1.92cm) [Table no.7].

b) Length of Tricuspid Valve Leaflets

In the present study the length (width) of the anterior leaflet varied from 3.0 – 3.9 cm (mean 3.51cm) for septal leaflet 2.8-3.9cm (mean 3.26cm) and for posterior leaflet 2.0-3.2 cm (mean 2.51cm) (pic.17) [Table no.8].

In the present study the height of the accessory leaflet ranged from 0.6 – 1.4 cm(mean 0.95cm) and length (width) of the accessory leaflet varied from 0.7 – 1.4 cm (mean 1.08cm) [Table no.9].

8. Chordae Tendineae

a) Types of Chordae Tendineae

Ventricular aspect of the tricuspid leaflet was inspected to observe the pattern of insertion and types of chordae tendineae(pic.18).

In the present study following types of chordae tendineae were found:

True and False varieties of **chordae** were observed.True chordae connect the apical third of the papillary muscles to the free margins and ventricular surfaces of tricuspid valve.False chordae extend irregularly connecting the ventricular wall, trabeculae carneae(pic.19).

Rough Zone Chordae were attached to the free margin and adjoining ventricular aspect of three leaflets of the tricuspid valve.Each rough zone chordae on approaching the leaflet splits into three strands. One was attached to the free margin,the other to the junction of rough and clear zones and third to a point between the first and second attachment.This type of rough zone chordae were observed in all 45 hearts(pic.21).

Commissural chordae were inserted into the free margin of the commissural area in a fan shaped manner in all 45 hearts(pic.20).

Similar to commissural chordae fan shaped chordae were observed to insert in the clefts between the scallops of the posterior leaflet.These are called cleft chordae and seen in all the 45 hearts.

Free edge chordae were thread like long chordae originated from apex of the papillary muscle also arise from its base.They inserted into leaflets free edge, mostly near its apex or may insert between the apex and a commissure. Free edge chordae found attached to anterior leaflet in 41 hearts ,to posterior leaflet in 38 hearts and to septal leaflets in 22 hearts(pic.22,23).

Deep chordae were long, arise from the apical part of papillary muscle and pass deep to free margin of leaflet to insert on ventricular surface either at the junction of rough and clear zone or in the rough zone. Deep chordae were attached to anterior leaflet in 40 hearts, to posterior in 32 and septal leaflet in 24 hearts(pic.24,26).

Basal chordae were mostly single,arised directly from the myocardium (ventricular wall) or from trabeculae carneae and insert into the basal zone of leaflet. These chordae were found attached to anterior leaflet in 22 hearts , to posterior leaflet in 20 hearts and to septal leaflet in 24 hearts(pic.25,26).

In the present study I also identified chordae forming a net like pattern (fenestrated appearance) before attaching to septal leaflet in one heart(pic.27).

b). Number Of Chordae Tendineae At Origin

Tendinous chords attached to each papillary muscle were counted at their origin insitu and after removal of the right atrioventricular valve.

In the present study number of tendinous chords originated from anterior , posterior and septal papillary muscles vary in each heart.

The number of chordae tendinae originated from anterior papillary muscle ranges from 3 to 10 (mean 5.73) and from septal papillary muscle ranges from 0 to 8 (mean 3.71). The number of chordae tendineae originated from posterior papillary muscle ranges from 1 to 8 (mean 3.75). In 10 hearts there were no septal papillary muscle and in these 10 hearts chordae tendineae directly arise from ventricular wall [Table no.10,11].

c). Number Of Chordae Tendineae At Insertion

The anterior leaflet received the chordae tendineae from anterior and septal papillary muscles.The septal leaflet received chordae tendineae from posterior and anterior papillary muscles.The posterior leaflet received chordae tendineae from posterior and septal papillary muscles.

In the present study the number of chordeae tendineae inserted into anterior leaflet ranges from 9 to 21(mean 14.2) and in septal leaflet ranges from 8 to 14(mean 10.82).The number of chordae tendineae

inserted into posterior leaflet ranges from 7 to 18 (mean 11.95). 3 to 6 chordae tendineae inserted into the commissures and clefts [Table no.12,13].

9. Papillary Muscles and its numbers

In the present study, the anterior papillary muscles were largest and arose from anterolateral ventricular wall and its chordae tendineae attached to anterior and posterior cusps.

The posterior papillary muscles were smaller compared to anterior papillary muscle ,arose from inferior wall of right ventricle and its chordae attached to posterior and septal cusps.

In the present study the septal papillary muscles were small and multiple arose mostly from interventricular septum and some arose from posterior septal limb of septomarginal trabeculae.In 10 heart specimens there were no septal papillary muscles, where chodae arose directly from ventricular valve.

Number of papillary muscles:

The number of papillary muscles were observed insitu after removal of right atrio ventricular valve.

In the present study the anterior and posterior papillary muscles were present in 45 hearts (100%) .The septal papillary muscles were present only in 35 hearts (77.8%) [Table no.14].

The anterior papillary muscle presented with one head (belly) (pic.28,29) in 37 hearts, 2 heads(pic.30,31) in 7 hearts and 3 heads (pic.32) in 1 heart.

The posterior papillary muscle presented with one head(pic.33) in 17 hearts, 2 heads(pic.34) in 20 hearts ,3 heads(pic.35) in 8 hearts.

The septal papillary muscle was absent in 10 hearts(pic.36) , presented with one head(pic.37) in 7 hearts , 2 heads(pic.38) in 14 hearts, 3and 4 heads(pic.39&40) appeared in 10 and 4 hearts respectively.

Fetal study:

Full term fetal specimens were collected from the institute of Obstetrics and Gynaecology , Egmore , Chennai.

In each heart a detailed examination was made of the tricuspid annulus ,commissures , number , shape of leaflets, chordae tendineae and papillary muscles.

Tricuspid annulus were circular in 3 hearts and oval in 2 hearts (pic.41). Its circumference ranged from 6.2 cm to 7.4cm.

Three commissures , three leaflets and 5 types of chordae were seen in all the 5 hearts (pic.42,43).

Three papillary muscles anterior , septal and posterior papillary muscles were present in all the 5 fetal hearts. In one heart posterior papillary muscles were 2 in number (pic.42) and another fetal heart it was 3 in number (pic.43).

Radiological Study:

Adult 2D Echocardiogram Study:

Currently the state of art in the imaging the diagnosis of the tricuspid valve is two dimensional echocardiography(2DE) , complemented with Doppler hemodynamic assessment.

For assessment of the tricuspid valve leaflets in 2DE , standard 2-Dimensional TV cross-sections, a)Apical 4-chamber view b)Parasternal short axis view c) Parasternal long-axis right ventricular inflow view and d) Sub-xiphoid view were simulated[pic.44,45]

Anterior leaflet is seen in the Apical 4-chamber and right ventricular inflow view[pic.45,46]. Posterior leaflet is assessed in the Parasternal long-axis right ventricular inflow view[pic.45]. Septal leaflet is the smallest and can be imaged from the Apical 4-chamber view[pic.45,46].

Bright echoes indicate that the leaflets are thick or calcified, such as found in rheumatic tricuspid disease.

Tricuspid ring may be represented by a line joining the basal attachments of leaflets in each view. Prolapse is diagnosed if one or more leaflets extend beyond this line in systole[pic.47,50].

In functional tricuspid regurgitation patients the annulus measurement is significantly larger otherwise anatomically normal valve[pic. 48,49]. In pure TR there will be fibrosis, leaflet retraction,

chordal fusion and in some patient with rheumatic heart disease may exhibit commissural fusion.

Although the tricuspid commissures are not readily seen on 2-DE as they are covered by a continuous curtain of valve tissue , the normal motion on the edge of the leaflets indicate that they are anatomically free.

In 2-D echocardiography images the papillary muscles and chordae attachments and can differentiate between normal ,thin chordae and fused and matted chordae that exibits abnormal bright echoes , such as in rheumatic tricuspid heart disease and endomyocardial fibrosis.

In Ebstein’s anamoly, the tricuspid leaflets are attached towards the right ventricular apex and part of the right ventricular cavity becomes atrialized.

DISCUSSION

1.Shape of Tricuspid valve Annulus

Keith L Moore[25] (1980) , R .Wayne Alexander et al[35] (1998) , Aytac Kocak et al[8](2004) ,B.N.Vijaya Ragawa rao[9] (2007) have quoted that the tricuspid valve annulus is circular in shape.

In the **present study** tricuspid valve annulus in 39 hearts were circular in shape (86.7%) and in 6 hearts oval in shape(13.3%). Majority of heart specimens(86.7%) annulus is circular in shape which coincides with the statement of the above authors[Chart.1].

2. Circumference of Tricuspid Annulus

Silver M.D et al[42] (1971) ,Paulo A et al[19] (2000) stated that annular circumference of tricuspid valve for men was 11.4 ± 1.1cm and for female 10.8 ± 1.3 cm.

R .Wayne Alexander et al[35] (1998) stated that tricuspid valve annular circumference varies from 10-12.5cm.

Aytac Kocak et al[8] (2004) found that in non cardiac death origin heart specimen, annular circumference was 12.4 ± 1.1 cm in male and 11.8 ± 1.3cm in female. Annular circumference for cardiac death origin was 11.2 ± 1.2cm in males and 10.8 ± 1.1 cm in females.

Seccombe J.F et al[40] (2005) stated that average tricuspid valve length was 11.3 ± 0.1 cm.

Susan Standring[52] (2005) mentioned that tricuspid valve orifice measured 11.4 cm in men and 10.8 cm in female .

Mohamed A.B Motabugami[33] (2006) found that average tricuspid valve circumference ranged from 11.3cm to 13.9 cm.

In the **present study** the average circumference of the tricuspid valve was found to be 11.8 cm but it ranged from 10.3 cm to 13 cm. The annular circumference varies in each heart do not coincide with any of the authors[Chart.2(a),2(b)].

3.Number of commissure

Silver M.D et al[42] (1971) , Arthur E Baue[5] (1996) , Susan Standring[52] (2005), Mohamed A.B Motabgani[33] (2006), B.N . Vijaya Ragawa Rao[9] (2007) all reported 3 commissures in tricuspid valve namely Anteroposterior , Posteroseptal and Anteroseptal commissures.

Roseuquist G.C. Sweeney LJ[38] (1975) mentioned that in 39 out of 95 normal specimens, there was no commissure between the anterior and medial leaflet.

In the **present study** the 36 hearts show 3 commissures namely Anteroposterior , Posteroseptal , Anteroseptal commissures and this study coincides with the study of Susan Standring[52], Silver M.D et al[42] , Arthur E Baul[5] , Mohamed A .B Motabgani[33].

Accessory commissure were present in 9 hearts which coincides with the study of Skwarek.M et al[46] .

4. Length of Commissures

Silver MD et al[42] (1971) reported that the height of anteroseptal commissures were 1.1 ± 0.3cm in males and 1.0 ± 0.2cm in females. The height of posteroseptal commissures were 0.8 ± 0.2cm in males and 0.7 ± 0.2cm in females.The height of anteroposterior commissures were 0.6 ± 0.3cm in males and 0.6 ± 0.2cm in females.

Paulo A Ribeiro and muayed Al- Zai bug[19] (2000) stated that the length of the anteroposterior commissure measures an average of 1.1cm ,in the posteroseptal 0.8cm and in the anteroseptal 0.6 cm.

Skwarek. M et al[46] (2005) stated that in his study commissural length ranged from 2 to 15mm with an average of 6.33 ± 2.59mm.

Mohamed A.B.Motabagani[33](2006) reported that height of anteroposterior commissure ranges between 0.7-1.1cm ,for anteroseptal commissure 0.7-1.3cm and for posteroseptal commissures 0.6-1.2cm.

B.N Vijaya Ragawa Rao[9] (2007) mentioned that of anteroposterior commissures with a size of 1.1cm , posteroseptal commissures with a size of 0.8cm and anteroseptal commissure with a size of 0.5cm.

In the **present study** the AP commissure ranged from 0.9 -1.4 cm(mean 1.17 cm) ,for PS commissure ranged from 0.6-0.9 cm (mean 0.74 cm) and AS commissure ranged from 0.5 -0.9 cm (mean 0.64 cm) .The length of the AP, PS and AS commissure coincides with the study of Silver MD et al[42] Paulo A Ribeiro and muayed Al- Zai bug[19] [Chart.3].

The length of commissure (Accessory commissure) between main leaflet and accessory leaflet ranged from 0.4-0.8 cm with an average of 0.53 cm ,this value is nearer with the study of Skwarek.M et al[46] .

4. Number Tricuspid valve leaflets

Previous studies by J.C.Boileau Grant[22](1951), Chummy S. Sinnatamby[12] (2006), Keith .L.Moore[25] (1980), Stephen C . Yang, Duke .E .Cameron[51] (2004), R .Wayne Alexander et al[35](1998) , Susan Standring[52] (2005), B.N Vijaya Ragava Roa[9](2007) mentioned that tricuspid valve has 3 valves namely Anterior, Posterior and Septal .

In recent studies authours mentioned that tricuspid valve vary in number of leaflets from 2 to 7 due to prescence of accessory leaflets.

M .Skwarek et al[48] (2006) classified five types of tricuspid valve according to the prescence and position of accessory leaflet in between the main leaflets.

T. Ikegaya et al[55] (1991) stated that during necropsy of a 59 years old women of heart failure he found the tricuspid valve has six leaflets.

Lapenna E et al[29] (2008) reported a case of a 52 year old man of severe mitral and tricuspid regurgitations of Barlow's disease he found that tricuspid valve was "four leaflet valve" due to the presence of a small accessory leaflet between the septal and posterior leaflets.

Sutton J P et al[53] (1995) stated that the fifty hearts were studied the majority of specimens (62%) had readily identifiable leaflets , but some (30%) having two leaflets , 8% had four leaflets.

Aytac Kocak et al[8] (2004) studied that in fourty hearts they found two leaflets (20%) , in 140 hearts (70%) three leaflets and in twenty hearts there were four leaflets (10%) in deaths of non cardiac origin.They also found two leaflets in 36 hearts (18%),three leaflets in 130 hearts (65%) and there were four leaflets in 34 hearts (17%) in deaths of cardiac origin.

Wafae N et al[59] (1990) stated that the tricuspid valve was not consistently tricuspid , but was observed to present 2 , 4 , 5 , or 6 cusps in 72 % of cases .

Victor S , Nayak VM[57](1994) stated that the tricuspid veil of cusp tissue lends itself into a neat subdivisions into 2 halves a septal cusp and the mural cusp vary in number and split artificially into two to six segments.

L.R.Gerola et al[20] (2001) stated that the number of cusps varied from two to four.Three cusps was the commonest finding and the fourth cusp , if present, was classified as anterolateral in location.

In the **present study** number of leaflets varied from 3 to 6.Three leaflet were found in 36 (80%) of hearts ,4 leaflets were found in 6 (13.3%) hearts and 5 leaflets were found in 1 (2.2%) heart. 6 leaflets were found in 2 (4.4%) hearts[Chart.4].

The number of leaflets identified in the present study coincides with the study of Wafae N et al[59] ,T. Ikegaya et al[55] and M .Skwarek et al[48].

5. Shape of Tricuspid valve leaflets

Silver MD et al[41] (1971) reported that anterior leaflet was semicircular, but may be quadrangular in shape. The posterior leaflet had several indendation or clefts, mostly semicircular in shape but it may vary and the septal leaflet is semi oval in shape.

Keith .L. Moore[25] (1980) stated that the cusps were more or less triangular in outline.

Stephen C .Yang , Duke .E .Cameron[51] (2004) stated that three leaflets of tricuspid valve are the septal , which is semicircular in shape. The anterior which is largest and nearly quadrangular , and the posterior which is usually the smallest , somewhat triangular in shape.

Aytac Kocak et al[8] (2004) reported that in non cardiac death cases the anterior leaflet was triangular in 100 case (95%), rectangular in 10 cases.The posterior leaflet was the smallest and it appeared as rectangular in 20 cases(10%), square in 20 (10%) , triangular in 160 (80%) cases. The septal leaflet appeared rectangular in 32 cases (16%) ,square in 12 (6%) and triangular in 156 (78%) cases.

In cardiac death cases the anterior leaflet was the largest component of the tricuspid valve and was triangular in 182 cases (91%), rectangular in 11 (5.5%) and square in 7(3.5%) cases. The posterior leaflet appeared as rectangular in 16 cases (8%) , square in

14 (7%) and triangular in 170 (85%) cases. The septal leaflet appeared rectangular in 28 cases (14%) ,square in 21 (10.5%) and triangular in 151 (75.5%) cases.

Mohamed A . B. Motabagani[33] (2006) reported that the gross examination of the human tricuspid valve of 10 heart showed , the anterior leaflet was always (100%) the largest , triangular . The posterior leaflet was the second in size and also triangular. It had either no cleft in 2 hearts (2%) or a single cleft in the remaining human hearts (80%). The septal leaflet of the human tricuspid valve was semicircular.

In the **present study** all the 45 hearts anterior leaflets were triangular(100%) in shape and the posterior leaflets also triangular in all hearts(100%). The septal leaflets were triangular in 42 hearts(93.3%) and semicircular in 3 hearts(6.7%).It coincides with the study of Aytac Kocak et al[8] , Keith Moore[25] and Mohamed A .B. Motabagani[33][Chart.4(a)] .

6. Height and Length of Tricuspid Valve Leaflets

a)Height of the Tricuspid Valve

Silver MD et al[42] (1971) reported that the height of anterior leaflet was 2.4 ± 0.4cm in males, 2.1 ± 0.4cm in females. For posterior leaflet height was 1.8 ± 0.3cm in males, 1.6 ± 0.5cm in females. In septal leaflet height was 1.7 ± 0.3cm in males, 1.5± 0.3cm in females.

Aytac Kocak et al[8] (2004) reported that the height of leaflets in non cardiac death cases, for anterior leaflet height was 2.4 ± 0.3 in males , 1.9±0.3cm in female. For posterior leaflet height was

1.8±0.2cm in male, 1.6 ± 0.3cm in female.For septal leaflet height 1.9 ± 0.3cm in male , 1.7 ± 0.3cm in female.

In cardiac death cases ,the height of anterior leaflet was 2.5 ±0.4cm in male, 2.4 ± 0.3cm in female. For posterior leaflet height was 1.9 ± 0.3cm in male, 1.7 ± 0.4cm in female. For septal leaflet height was 1.7 ± 0.3cm in males, 1.5 ± 0.2cm in females.

M .Skwarek et al[48] (2006) stated that the average height of the leaflets were, for anterior leaflet 20.71 ± 5.23mm , for posterior leaflet 18.88 ± 4.66 mm and for the septal leaflet 17.22 ± 4.71mm.

Mohamed A .B. Motabagani[33] (2006) reported that height of anterior leaflet ranges between 1.9-2.7cm , for posterior leaflet 1.5-2.9cm and for septal leaflet 1.4-1.8cm.

B.N Vijaya Ragawa Rao[9] (2007) mentioned that anterior leaflet is the largest with a width of 2.2cm , septal(medial) leaflet is the smallest with a width of 1.5cm, the posterior leaflet measures 2.0cm in width.

In the **present study** the height of the anterior leaflet ranges from 1.9-2.5 (mean 2.21cm). The height of the posterior leaflet ranges from 1.7-2.2 (mean 1.92cm) and for septal leaflet height ranges from 1.4-1.9 (mean 1.68cm). In the present study the height of the accessory leaflet ranged from 0.6 – 1.4 cm(mean 0.95cm) [Chart.5] .

The mean height of leaflets in the present study is nearer with the study of above mentioned authors.

b)Length of the Tricuspid Valve

Silver MD et al[42] (1971) reported that, the width (length) of anterior leaflet was 3.9 ± 0.8cm for males, 3.5 ± 0.7cm in females. For posterior leaflet width was 3.0 ± 0.9cm in males , 2.6 ± 0.7cm for females.In septal leaflet width was 3.7 ± 0.8cm in males,3.5 ± 0.8cm in females.

R.Wayne Alexander et al[35] (1998) mentioned that the anterior leaflet is usually the largest with a width of 2.2 cm. The septal and posterior leaflets measures about 1.5cm and 2.0 cm in width respectively.

Aytac Kocak et al[8] (2004) reported that the width (length) of leaflets in non cardiac death cases,width of anterior leaflet was 3.8 ± 0.1cm in males, 3.4±0.1cm in females. For posterior leaflet width was 3.1 ± 0.7cm and for septal leaflet width was 2.6 ± 0.3cm.

In cardiac death cases, the width of anterior leaflet was 4.0 ± 0.3cm for males, 3.6 ± 0.4cm in females. For posterior leaflet width was 3.3 ± 0.4cm in males , 3.1 ± 0.3cm for female and for septal leaflet width was 3.4 ± 0.6cm in males, 3.2 ± 0.2cm in females.

Seccombe J.F et al[40] (2005) mentioned that mean length were similar for the anterior , posterior and septal leaflets (38-42 mm).

Mohamed A . B. Motabagani[33] (2006) reported that annular length of anterior leaflet ranges between 2.7-4.7cm , for posterior leaflet 1.8-3.2cm and for septal leaflet 2.5-3.7cm.

In the **present study** the length of the anterior leaflet ranges from 3.0-3.9 (mean 3.51cm). The length of the posterior leaflet

ranges from 2.0-3.2 (mean 2.51cm) and for septal leaflet height ranges from 2.8-3.9 (mean 3.26cm). The length (width) of the accessory leaflet varied from 0.7 – 1.4 cm (mean 1.08) [Chart.6].

The mean length of leaflets in the present study is nearer with the study of above mentioned authors.

7.Chordae Tendineae

a) Types of Chordae Tendineae

J.C.B.Grant[22] (1951) stated that chordae tendineae are fine tendinous cords which pass to the cusps from conical muscular projections on the wall of the ventricle called the papillary muscles.

Susan Standring[52] (2005) stated that the chordae tendineae are fibrous collagenous structure supporting the cusps of the atrioventricular valves. False chordae connect papillary muscles to each other or to the ventricular wall including the septum.The true chordae usually arise from small projections on the tips or margins of the apical one-third of papillary muscles.

Chummy S.Sinnathamby[12] (2006) stated that the edges and ventricular surfaces of the cusps receive the attachments of the chordae tendineae, collagenous cords which diverge from the papillary muscles and prevent the cusps from being everted when the ventricle contracts.

Silver MD et al[42] (1971) , R .Wayne Alexander et al[35] (1998), Paulo A Ribeiro and muayed Al- Zai bug[19] (2000), Aytac Kocak et al[8] (2004), B.N Vijaya Ragawa Rao[9] (2007) all mentioned that the chordae tendineae of the tricuspid valve had five types of chordae tendineae:-

fan shaped , rough , deep , basal and free edged. Deep and free edge are unique to tricuspid valve.

Silver MD et al[42] (1971) stated that the chordae of the tricuspid valve are fibrous cords of various lengths.

In his study he observed that the fan shaped chordae were present at the anteroposterior commissure in 47 hearts , at the posteroseptal commissure in 50 and at the anteroseptal in 41 hearts. Rough zone chordae were attached to the anterior leaflet in all 50 hearts , to the posterior leaflet in 41 and to the septal leaflet in 49. Free edge chordae were found attached to 32 in anterior , 24 in posterior and 25 in septal leaflets.

Deep chordae were attached to the anterior leaflet in 38 hearts , to the posterior in 29 and to the septal leaflet in 33. One inserted into an anteroposterior commissural area.Basal chordae were found attached to 23 in anterior ,23 in posterior and 45 septal leaflets.

In the **present study** commissural chordae, cleft chordae and rough zone chordae are observed in all 45 hearts . Free edge chordae found attached to anterior leaflet in 41 hearts ,to posterior leaflet in 38 hearts and to septal leaflets in 22 hearts .Deep chordae were attached to anterior leaflet in 40 hearts , to posterior in 32 and septal leaflet in 24 hearts.Basal chordae were found attached to anterior leaflet in 22 hearts , to posterior leaflet in 28 hearts and to septal leaflet in 40 hearts.

Types of chordae tendineae identified in the present study coincides with the study of above authors.

b)Number Of Chordae Tendineae At Origin

G.R. Nigri et al[34] (2001) reported that Tendinous chords (TC) varied from 1 to 11 originated in the anterior papillary muscle (mean 4.74), from 1 to 8 TC originated in the posterior papillary muscle (mean 2.67) and from 1 to 5 TC originated in the septal papillary muscle (mean 1.77).

Mohamed A .B.Motabagani[33] (2006) stated that the number of chordae tendineae at anterior papillary muscle in male 11 to 13,in female 9 to 12. Number of chordae tendineae at posterior papillary muscle in male 5 to 7, in female 4 to 6. Number of chordae tendineae at septal papillary muscle in male 6 to 11 , in female 7 to 12.

In the **present study** the number of chordae tendineae originated from anterior papillary muscle ranges from 3 to 10 (mean 5.73) and from posterior papillary muscle ranges from 1 to 8 (mean 3.75) The number of chordae tendineae originated from septal papillary muscle ranges from 0 to 8 (mean 3.71). In 10 hearts there were no septal papillary muscle and these 10 hearts chordae tendineae directly arises from ventricular wall[Chart.7].

The number of chordae tendineae at origin in the present study nearer with the study of the G.R. Nigri et al[34] .

c)Number Of Chordae Tendineae At Insertion

Silver MD et al[42] (1971), Paulo A Ribeiro and muayed Al- Zai bag[19] (2000), B.N Vijaya Ragawa Rao[9] (2007) stated that on average , 25 chordae tendineae insert into the tricuspid valve, 7 to the anterior leaflet , 6 to the posterior leaflet , 9 into the septal leaflet and 3 into the commissural area.

Ankara[4] (1992) studied 27 normal hearts , on the average 27 chordae tendineae in valva atrioventricularis sinastra , 30 in valva atrioventricularis dextra and 57 in the whole heart were detected.

Seccombe J.F et al (2005) stated that the tricuspid valve was served by an average of 170 ± 36 chordae tendineae , 49% inserted on the free edge of the valve , 44% undersurface and 7% on the basal region. Chordal density (number of chordae/cm^2) was greater in women than men (9.9 ± 0.5 vs 7.3 ± 0.7 chordae/cm^2).The septal leaflet had the greatest chordal density and the anterior leaflet the least (12.7 ± 0.9 vs 5.9 ± 0.7 chordae/cm^2).

M .Skwarek et al[49] (2007) stated that the total average number of chords was 72.71 ± 13.38. The anterior leaflet was provided by chords which originated in the anterior and posterior papillary muscles (Anterior papillary muscles 86.19 ± 11.66%,posterior 13.09 ± 1.74%). The posterior leaflet was provided by chords coming from the posterior and septal papillary muscles (posterior 85.67±11.48%), septal 1.83%).The septal cusp was provided by chords from the septal and anterior papillary muscles (septal 19±2.55%, anterior 80.99±10.85%).

In the **present study** the number of chordae tendineae inserted into anterior leaflet ranges from 9 to 21 (mean 14.22) and into posterior leaflet, it ranges from 7 to 18 (mean 11.95). The number of chordae tendineae inserted into septal leaflet ranges from 8 to 16 (mean 10.82) [Chart.8].

The number of chordae tendineae at insertion in the present study varies from the study of above mentioned authors.

9.Papillary Muscles and its numbers

Keith L Moore[25](1980) , R .Wayne Alexander et al[35] (1998) , Paulo A Ribeiro[19](2000) , Mohamed A.B. Motabagani[33](2006) stated that in right ventricle there are 3 papillary muscles.

Ekin O. Aktas et al[16] (2004) stated that the papillary muscle usually 3 anterior, posterior and septal muscle but presented with great variability in number , with a minimum of two and a maximum of nine papillary muscle in right ventricle.

Susan Standring[52] (2005)stated that the two major papillary muscles in the right ventricle are located in anterior , posterior positions and a third smaller muscle has a medial position together with several smaller and variable muscles attached to the ventricular septum.

Grochowski P[47] (2001) studied papillary muscles of right ventricle and introduced the concept of multi apical and multi-segmental papillary muscles and classified right ventricular papillary muscle into 14 types and M. Skwarek et al[44] observed 467 papillary muscles belonging 1 to 16 types in his study.

G.R. Nigri[34] (2001) et al stated that the apm presented one head in 81% and two head in 19% .The ppm had one head in 25.4%,two heads in 46.8% , three heads in 21.5% and four heads in 6.3%.The eptal papillary muscles(spm) was one headed in 41.7% and presented two heads in 16.5% the presence of a 3 and 4 heads appeared in 12.7% and 7.6% .

In the **present study** the anterior and posterior papillary muscles were present in 45 hearts (100%) .The anterior papillary muscle was presented with one headed (belly) 37 hearts , 2 headed in 7 hearts and 3 headed in 1 heart.

The septal papillary muscle was absent in 10 hearts ,presented with one headed in 7 hearts , 2 headed in 14 hearts ,3 and 4 heads appeared in 10 and 4 hearts respectively.

The posterior papillary muscle presented with one headed in 17 hearts, 2 headed in 20 hearts, 3 headed in 8 hearts [Chart.9(a),9(b),10,11].

The number of papillary muscles in the present study nearer with the study of the G.R. Nigri et al[34].

CONCLUSION

The Tricuspid valve which guards right atrioventricular orifice was studied in detail by conventional dissection and radiological (echocardiogram) method. The shape and circumference of tricuspid valve annulus, number and length of commissures, number, shape, height and length of tricuspid leaflets, types of chordae tendineae, number of chordae tendineae at origin and insertion, papillary muscle and its numbers have been observed and correlated with the findings of already existing studies.

The following conclusions are derived from these parameters:-

- The shape of the Tricuspid annulus were circular in 39 heart specimens (86.7%) and oval in 6 heart specimens (13.3%).
- The circumference of the tricuspid annulus ranged from 10.3cm-13 cm and the mean circumference was found to be 11.8 cm.
- The number of commissures in 36 hearts were 3 in number namely AP ,PS and AS commissure. 9 heart specimens with accessory leaflets presented with accessory commissures.
- The average length of AP commissure was 1.17cm (range 0.9-1.4 cm) and average length of PS commissure was 0.74cm (range 0.6-0.9 cm).The average length of AS commissure was 0.64cm (range 0.5-0.9 cm).

- The number of leaflets in tricuspid valve of 36 hearts were found to be 3 in number (80%). 4 leaflets were found in 6 hearts (13.5%), 5 leaflets in one heart (2.2%) and 6 leaflets in 2 hearts (4.4%).

- The shape of the anterior , posterior leaflets were triangular in all the 45 hearts (100%). The septal leaflets were triangular in 42 hearts (93.3%) and semicircular in 3 hearts (6.7%).

- Accessory leaflets found in 9 hearts (20%) having 4 , 5 and 6 leaflets and all were triangular in shape. Two types of accessory leaflets, spurious and true accessory leaflet were identified.

- Two types of foramina were found in tricuspid valves. True natural foramina were present in 3 hearts and spurious foramina in 9 hearts.

- The height of the anterior leaflet ranged from 1.9 – 2.5 cm (mean 2.21 cm), septal leaflet 1.4-1.9cm (mean 1.68 cm) and posterior leaflet 1.7-2.2 cm (mean 1.92 cm).

- The length (width) of the anterior leaflet varied from 3.0 – 3.9 cm (mean 3.51cm), septal leaflet 2.8-3.9cm (mean 3.26 cm) and posterior leaflet 2.0-3.2 cm (mean 2.5 cm).

- The height of the accessory leaflet ranged from 0.6 – 1.4 cm (mean 0.95 cm) and length (width) of the accessory leaflet varied from 0.7 – 1.4 cm (mean 1.08 cm).

- All 5 types of chordae namely Rough Zone Chordae, Commissural chordae, Free edge chordae, Deep and Basal chordae were present in the present study.

- The number of chordae tendineae originated from APM ranged from 3 to 10 (mean 5.7) and from SPM ranged from 0 to 8 (mean 3.71). The number of chordae tendineae originated from PPM ranged from 1 to 8 (mean 3.75). In 10 hearts there were no SPM and in these 10 hearts the chordae tendineae directly arose from ventricular wall.

- The number of chordae tendineae inserted into anterior leaflet ranged from 9 to 21 (mean 14.2) and in septal leaflet the number ranged from 7 to 18 (mean 11.95).The number of chordae tendinae inserted into posterior leaflet ranged from 8 to 16 (mean 9).3to6 chordae tendinae were inserted into the commissures and clefts.

- The anterior and posterior papillary muscles were present in all the 45 hearts (100%).The septal papillary muscles presented only in 35 hearts (77.8%).

- The APM was presented with one head (belly) in 37 hearts, 2 heads in 7 hearts and 3 heads in 1 heart.

- The SPM were absent in 10 hearts ,presented with one head in 7 hearts , 2 heads in 14 hearts ,3 heads in 10 hearts and 4 heads appeared in 4 hearts.

- The posterior papillary muscle presented with one head in 17 hearts, 2 heads in 20 hearts, 3 heads in 8 hearts.

Based on this study, I hereby conclude that the **"Anatomical study of Human Tricuspid Valve "** is composed of variations in the shape,circumference of tricuspid annulus, number and length of commissures, number, shape, height and length of tricuspid valve leaflets ,chordae tendineae and papillary muscle .

Hence I hope that this study would be of great use to the cardiologist and cardiac surgeons, in echocardiography, interventional cardiology and in surgical reconstruction of Tricuspid valves.

The morphometric analysis of the valve is useful for the cardiac surgeons to determine the size of the prosthetic valves in valve replacement, annuloplasty, commissurotomy, and artificial chordae tendineae replacement.

LEGEND

2DE	-	2 Dimensional Echo
3DE	-	3 Dimensional Echo
Acc COM	-	Accessory Commissure
AP COM	-	Antero-posterior Commissure
APM	-	Anterior Papillary Muscle
AS COM	-	Antero-septal Commissure
ATVL	-	Anterior Tricuspid Valve Leaflet
C Ac	-	Cusp Accessory
CA	-	Cusp Anterior
CP	-	Cusp Posterior
CS	-	Cusp Septal
CT	-	Chordae Tendineae
IVS	-	Inter-Ventricular Septum
PPM	-	Posterior Papillary Muscle
PS COM	-	Postero-septal Commissure
PTVL	-	Posterior Tricuspid Valve Leaflet
SPM	-	Septal Papillary Muscle
STVL	-	Septal Tricuspid Valve Leaflet
TR	-	Tricuspid Regurgitation
TV	-	Tricuspid Valve

BIBLIOGRAPHY

1. **A.C Wenink**. The medial papillary complex .Br Heart J 1977; 39:1012-1018.

2. **Acar C, Perier P, Fontaliran F, Deloche A, Carpentier A**. Anatomical study of the tricuspid valve and its variations. Surg Radiol Anat 1990; 12: 29-30.

3. **Allen K .Brown, Valerie Anderson**. Two dimensional echocardiography and the tricuspid valve .Br Heart J 1983; 49: 495-500.

4. **Ankara.** The types and distribution of chordae tendineae attached to each leaflet of valve atrioventricularis sinistra and dextra. Turk J Med Res 1992; 10(3):126-9.

5. **Arthur E. Baue, MD:** Glenn's Thoracic and Cardiovascular Surgery; Sixth Edition, Volume II, 1996: 1931-1980.

6. **Ashraf M.Anwar , Marcel L. Geleijinse , Osama I.I.Soliman**.Assessment of normal tricuspid valve anatomy in adults by real- time three-dimensional echocardiography.The International Journal of Cardiovascular Imaging 2007;23(6): 717-724.

7. **Asim Kumar Datta** .Essentials of Human Anatomy, Part-I; 8th Edition, 2008:62-97.

8. **Aytac Kocak, MD, Figen Govsa, MD , Ekin O .Aktas , M.D , Bahar Boydak, M.D , Ismail C. Yavuz, M.D.** Structure of the human tricuspid valve leaflets and its chordae tendineae in unexpected death. Saudi Med J 2004; Vol.25 (8): 1051-1059.

9. **B.N Vijay Raghawa Rao**: Clinical Examination in Cardiology; 1st Edition, 2000:20-27.

10. **Begum JA, Khalil M, Rahman H, Adiluzzaman AA**. A morphological and morphometric study of the right ventricular papillary muscles of autopsied heart of Bangladeshi people. Mymensingh Med J.2006 Jul; 15(2):131-4.

11. **Carpentier. A**: Cardiac Valve Surgery – "French Correction" J.Thorac Cardiovasc Surg, 1983; 86: 323.

12. **Chummy S. Sinnathamby**: Last's Anatomy Regional and Applied; Eleventh Edition, 2006: 207-209.

13. **Constantine Mavroudis**: Pediatric Cardiac Surgery; Second Edition, 1994: 413-416.

14. **David C. Sabiston. JR** : Atlas Of Cardiothoracic Surgery ;1st Edition,1995 : 232-236.

15. **David C. Sabiston. JR**: Text Book of Surgery. The Biological Basis of Modern Surgical Practice; Fifteenth Edition, 1997: 2143-2155.

16. **Ekin O. Aktas, Figen Govsa, Aytac Kocak, Bahar Boydak, Ismail C Yavuz**. Variations in the papillary muscles of normal tricuspid valve and their clinical relevance in medicolegal autopsies . Saudi Med J 2004; Vol.25 (9): 1176-1185.

17. **Eric J.Topol,** Textbook Of Cardiovascular Medicine; Third Edition, 2007:389-399.

18. **Frater,R.W.M., Vetter ,H.O., Zussa ,ac., and Dahm,M** : Chordal replacement in mitral valve repair. Circulation, 82: IV-125, 1990.

19. **Gerald M. Pohost, Daniel S. Berman, Robert A. O Rourke, Pravin M. Shah**: Imaging in Cardiovascular Disease; 1st Edition, 2000: 603-614.

20. **Gerola L R, Wafe N , Hayashi H, , Vieira M C, Juliano , R Smith , J C Prates**.Anatomic study of the human tricuspid valve in children. Surg Radiol Anat, 2001; 23(3): 149-153.

21. **Henry Hollinshead**. **W**: Anatomy for Surgeons. Volume 2, Second edition, 1971:128-9

22. **J .C .Boileau Grant.** A Method of Anatomy Descriptive and Deductive; Sixth Edition, 1958: 164-170.

23. **J.C. Brash**. Cunningham's Text Book of Anatomy; Ninth Edition, 1951: 1231-1235.

24. **Kay J H, Mendez AM, Zubiate P:** A Further Look at tricuspid Annuloplasty.Ann Thorac Surg 1976 ; 22:498.

25. **Keith L .Moore** : Clinically oriented Anatomy. 1980; pages 71-73.

26. **Nicholas T.Kouchoukos,M.D., Eugene H.Blackstone,M.D., Donald B.Doty,M.D., Frank L.Hanley,M.D.,Robert B.Karp,M.D**. Kirklin/Barratt-Boyes: Cardiac Surgery ; Volume 1,Third Edition, 2003 : 20-26.

27. **Lamers WH , Viragh S, Wessels A, Moorman AFM, Anderson RH** (1995) Formation of the tricuspid valve in the human heart. Circulation, 91:111-121.

28. **Lam JHC ,Ranganathan N, Wigle ED,et al** : Morphology of the human Mitral Valve: I. Chordae tendineae : A new classification. Circulation. 1970; 41:449.

29. **Lapenna E, De Bonis M, Maisano F , Crescenzi G , Torracca L, Grimaldi A, Alfieri O**. 'Four-leaflet clover repair' of severe tricuspid valve regurgitation due to complex lesions. J Cardiovasc Med 2008 Aug; 9(8): 847-849.

30. **M .Ugarte ,F Enriquez de Salamanca ,M Quero**.Endocardial cushion defects: an anatomical study of 54 specimens. British Heart Journal 1976; 38: 674-682.

31. **Marios Loukas , Christopher T. Wartmann ,R. Shane Tubbs , Robert G. Louis Jr. ,Nihal Apaydin , Brandie Black and Robert Jordan**. Right ventricular false tendons a cadaveric approach . Surg Radiol Anat 2008; 30: 317-322.

32. **Marios Loukas , R. Shane Tubbs , Robert G. Louis Jr. ,Nihal Apaydin , Artur Bartczak , Vefali Huseng , Nada Alsaiegh and Martin Fudalej**. An endoscopic and anatomical approach to the septal papillary muscle of the conus. Surg Radiol Anat 2009 ;31:701-706.

33. **Mohamed A.B. Motabagani**. Comparative Anatomical, Morphometric and Histological Studies of the Tricuspid Valve-Complex in Human and Some Mammalian Hearts. J.Anat.Soc. India 2006 ; 55 (1): 1-23.

34. **Nigri GR, Di Dio LJA, Baptista CAC**. Papillary muscles and tendinous cords of the right ventricle of the human heart: Morphological characteristics. Surg Radiol Anat 2001 ;23:45-49.

35. **R. Wayne Alexander, Robert C . Schlant , Valentin Fuster** : Hurst's the Heart Arteries and Veins; Ninth dition ,1998: 34-35.

36. **R Kobza,D J Kurz ,E N Oechslin, R Pretre,M Zuber,P Vogt , R Jenni**. Aberrant tendinous chords with tethering of the tricuspid leaflets: a congenital anomaly causing severe tricuspid regurgitation. Heart 2004; 90(3):319-323.

37. **Recep Acar, Murat Kacmaz, B.Ufuk, Akul,A. Kerim Turkaslan, Alaittin Elhan.** The types and distribution of chordae tendineae attached to each leaflet of valve atrioventricularis sinastra and dextra.Turk J Med Res 1992, 10 (3).

38. **Roseuquist GC, Sweeney LJ.** Normal variations in tricuspid valve attachments to the membranous ventricular septum: a clue to the etiology of left ventricle-to-right atrial communication. Am Heart J. 1975 Feb; 89(2):186-8.

39. **Sadler TW.** Langman's Medical Embryology,11th edition 2009. p 174-177.

40. **Seccombe JF, Cahill DR, Edwards WD.**Quantitative morphology of the normal human tricuspid valve autopsy study of 24 cases. Clin Anat 1993; 6: 203-212.

41. **Siaresh Khonsari, Colleen Flint Sintek**: Cardiac Surgery Safegaurds and Pitfalls in Operative Technique;Third Edition,2003:108-115.

42. **Silver MD, Lam JHC ,Ranganathan N** .Morphology of the human tricuspid valve .Circulation 1971; 43:333-348.

43. **Sir John Bruce ,Robert Walmsley , James A Ross:** Manual of Surgical Anatomy; 1964 :267-270.

44. **Skwarek M , Hreczecha J, Grzybiak M, Kosinski A**. Remarks on the morphology of the papillary muscles of the right ventricle. Folia Morphol,2004; 64: 176-182.

45. **Skwarek M, Grzybiak M, Kosinski A, Hreczecha J**.Notes on the morphology of the tricuspid valve in the adult human heart. Folia Morphol,2004; 63: 319-324.

46. **Skwarek M, Hreczecha J, Grzybiak M, Kosinski A.** Unusual anatomical features of the right atrioventricular valve . Folia Morphol, 2005 ; 64: 183-187.

47. **Skwarek M, Dudziak M, Hreczecha J, Grzybiak M**.The connection between the papillary muscles and leaflets of the tricuspid valve.Folia Morphol,2006; 65: 322-328.

48. **Skwarek M, Dudziak M, Hreczecha J, Grzybiak M .**The morphology of right atrioventricular valve in the human adult heart. Folia Morphol,2006; 65: 200-208.

49. **Skwarek M, Dudziak M, Hreczecha J, J.Jerzemowski , Grzybiak M .**The morphology and distribution of the tendinous chords and their relation to the papillary muscle in the tricuspid valve of the human heart. Folia Morphol,2007; 66: 314-322.

50. **Skwarek M, Dudziak M, Hreczecha J, J.Jerzemowski ,B.Wilk , Grzybiak M .**The morphometry of the accessory leaflets of the tricuspid valve in a four cuspidal model. Folia Morphol,2007; 66: 323-327.

51. **Stephen C . Yang , Duke .E .Cameron**: Current therapy in thoracic and cardiovascular surgery; 2004 :637-640.

52. **Susan Standring** : Gray's Anatomy 39th Edition, 2005;1002-1007.

53. **Sutton JP, Ho SY, Vogel M, Anderson RH**. Is the morphologically right atrioventricular valve tricuspid ?. J Heart Valve Dis 1995;4(6): 571-575.

54. **Tandler J**: Anatomie des Herzeens. In Handbuch der Anatomie der Menschen, edited by K.Bardeleben. Ed I ,Vol 3 ,Jena, Gustav Fischer ,1913 , p 88.

55. **T.Ikegaya, Chi Kurata, H. Hayashi,A.Kobayashi,H.Muro and N.Yamazaki. A.** Case of congenital tricuspid valve abnormality showing six leaflets. European Heart Journal 1991; Vol 12: 94-95.

56. **Timothy J Gardner , Thomas L Spray** : Operative Cardiac Surgery ; Fifth Edition ,2004 : 540-551.

57. **Victor S, Nayak VM**. The tricuspid valve is bicuspid. J Heart Valve Dis 1994; 3 :27-36.

58. **W.J. Hamilton.** Text Book of Human Anatomy ; Second Edition, 1976: 230-236.

59. **Wafe N ,Hayashi H,Gerola LR, vieira MC**.Anatomical study of the human tricuspid valve. Surg Radiol Anat. 1990;12: 37-41.

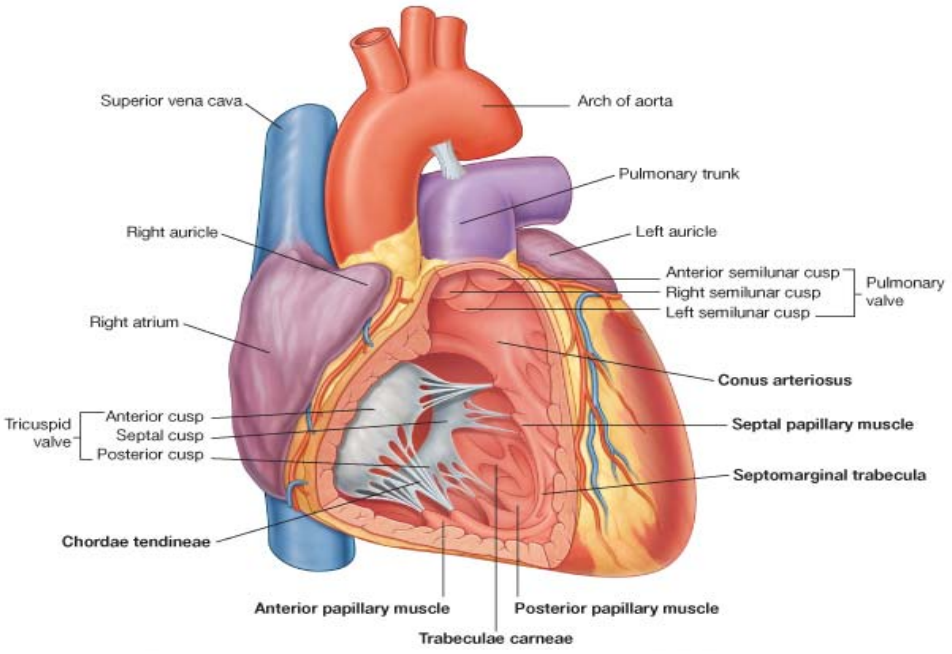


Fig 1: Internal view of the right ventricle showing Tricuspid Valve.

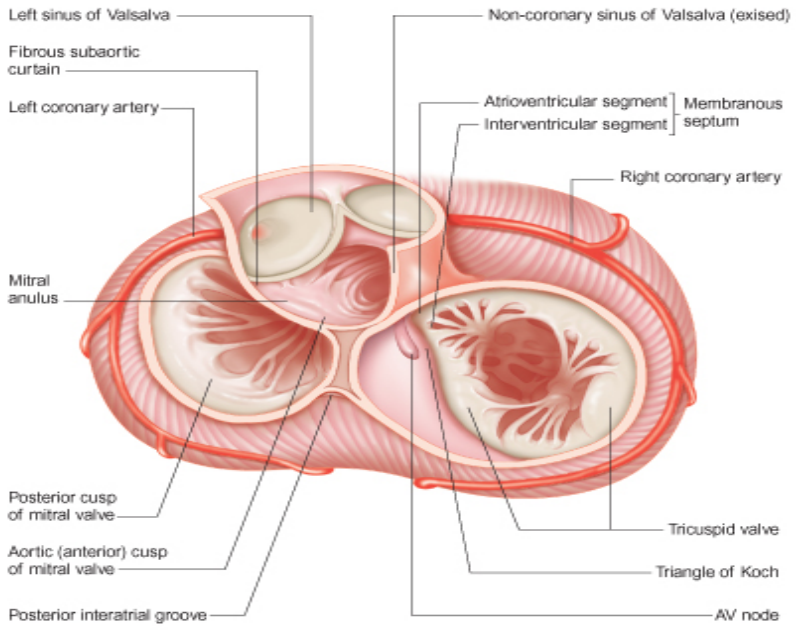


Fig 2: Ventricular Inlet components showing Tricuspid Valve.

Fig.3 : Tricuspid Valve Commissurotomy.

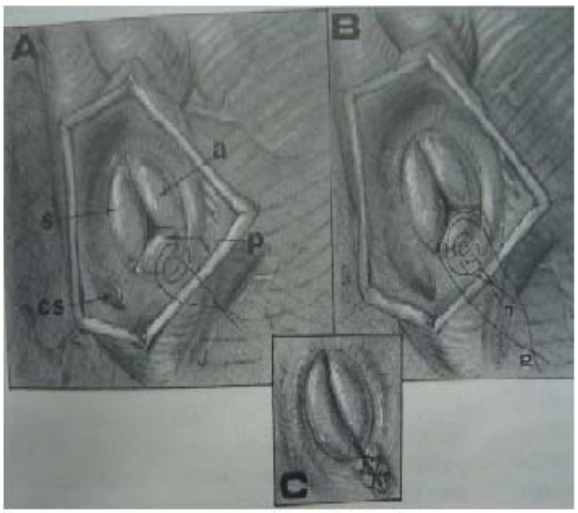


Fig.4 : Bicuspidizing the Tricuspid Valve.

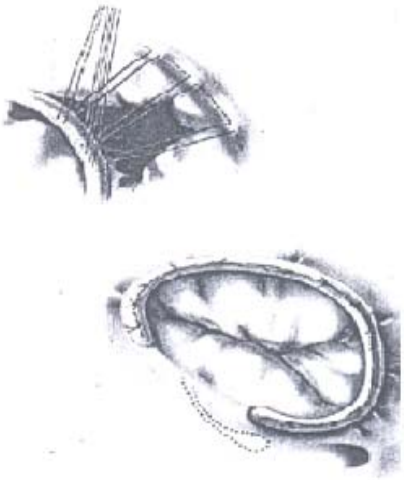


Fig.5: Tricuspid semicircular valvuloplasty.

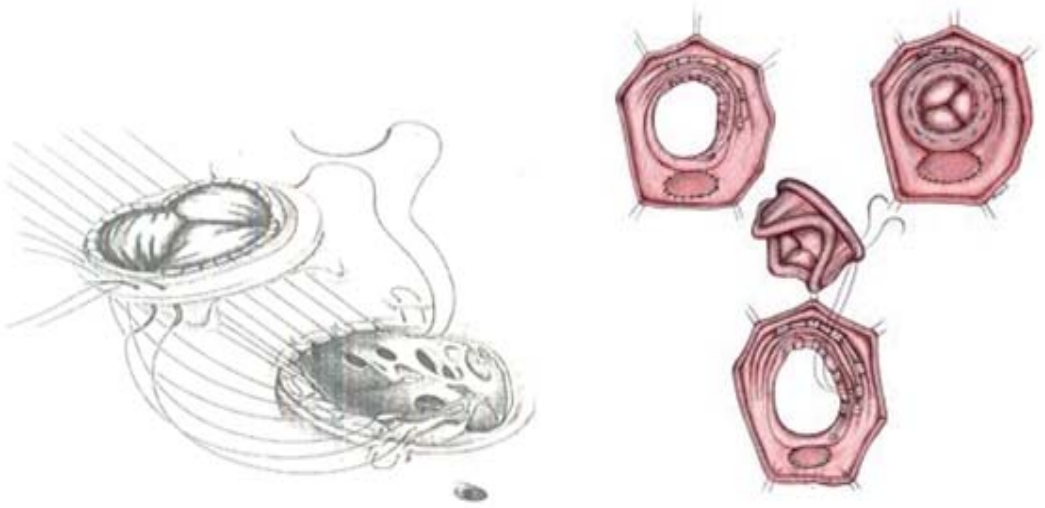


Fig.6 : Tricuspid Valve Replacement.

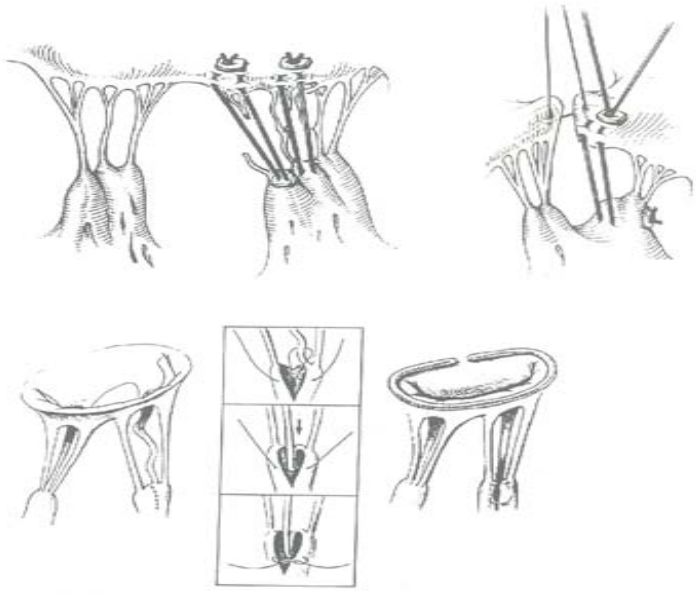


Fig.7 : Artificial Replacement of Chordae Tendineae.

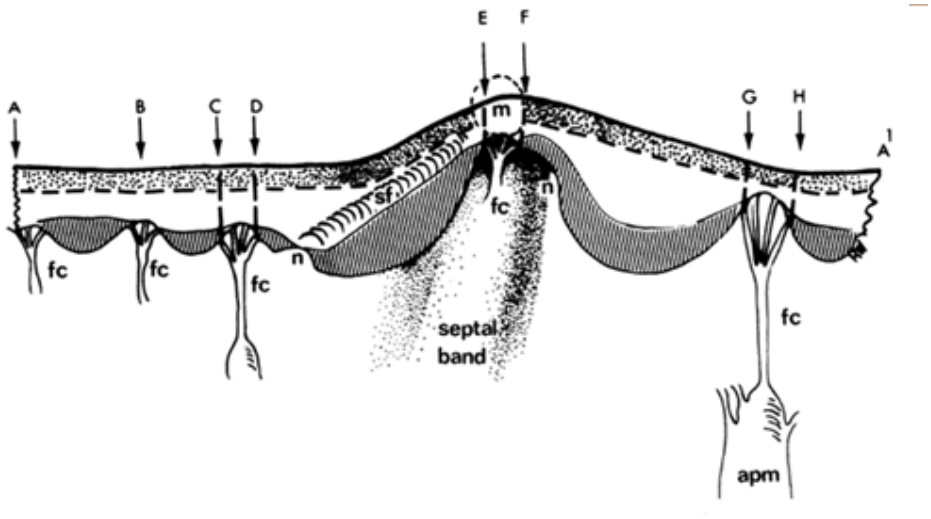


Fig.8: Diagrammatic representation of the tricuspid valve opened through the acute margin of the right ventricle.A-B,B-C, and H-A1 = the middle,posteroseptal commissural, and antero-posterior commissural scallops of the posterior leaflet, A or A1 and B- clefts;C-D= the posteroseptal commissure;D-E=the septal leaflet;E-F=the anteroseptal commissure related to the membranous interventricular septum;F-G=the anterior leaflet; G-H= the anteroposterior commissure[42].

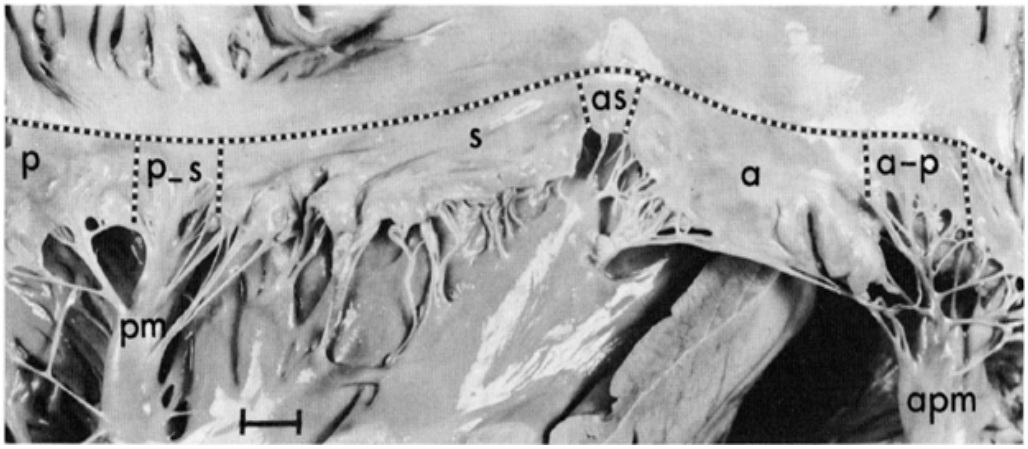


Fig. 9 : Tricuspid valve opened at the acute (lateral) margin of the right ventricle.The annular attachment of the tricuspid valve is indicated by the dashed line.The apex of the anterior papillary muscle(apm) points towards the anteriorposterior commissure(a-p)[42].

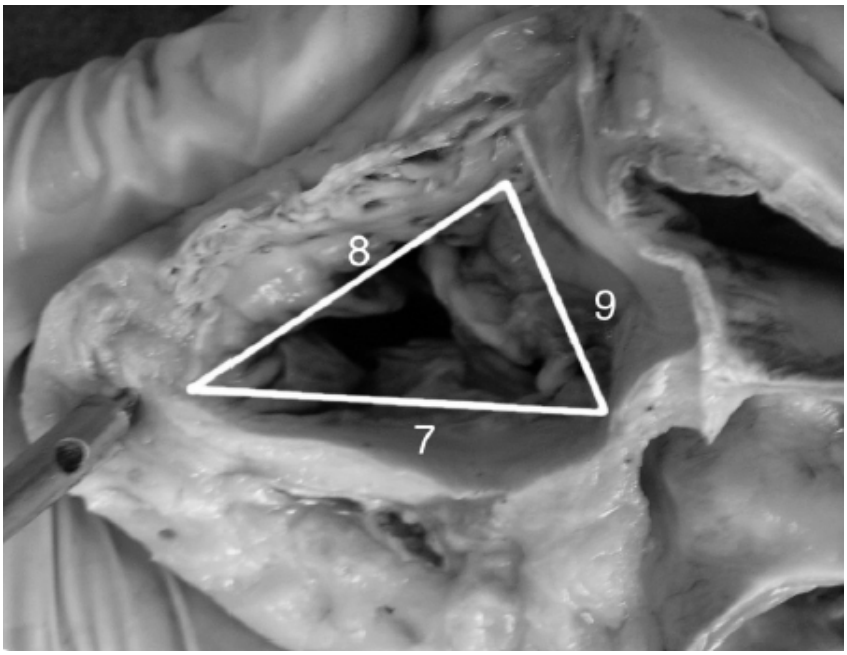


Fig 10 : Tricuspid valve attachment in particular walls of the right ventricle anterior (7), posterior (8),and septal (9).

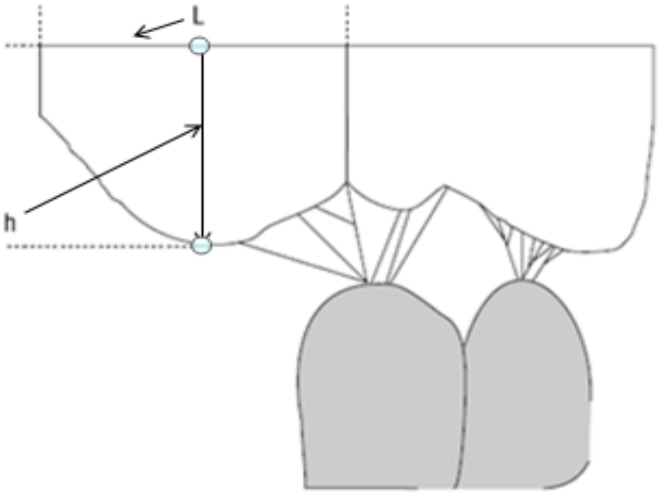


Fig 11: Scheme of the length and height of a leaflet. "L" marks the length of the leaflet and "h"the height.

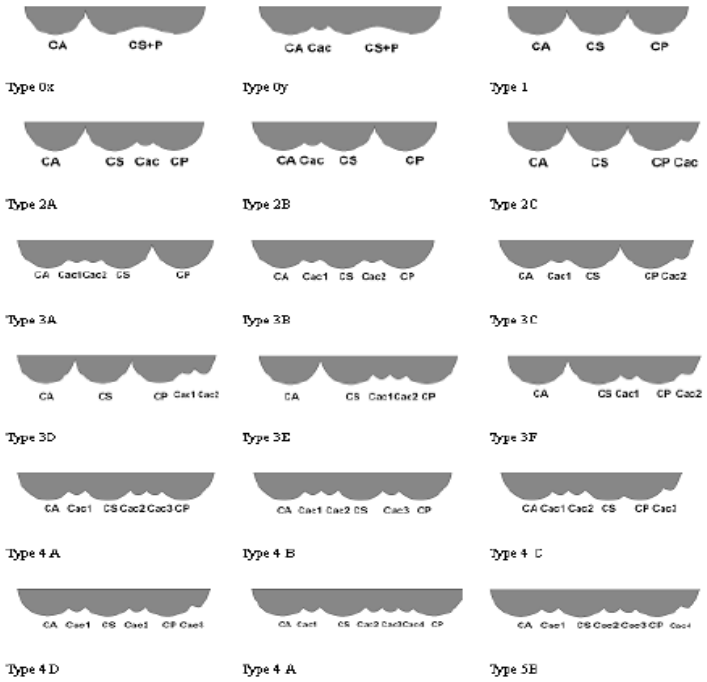


Fig 12: Classification of Tricuspid Valve according to Kosinski A et al (2000) and Skwarek M et al (2004,2005)

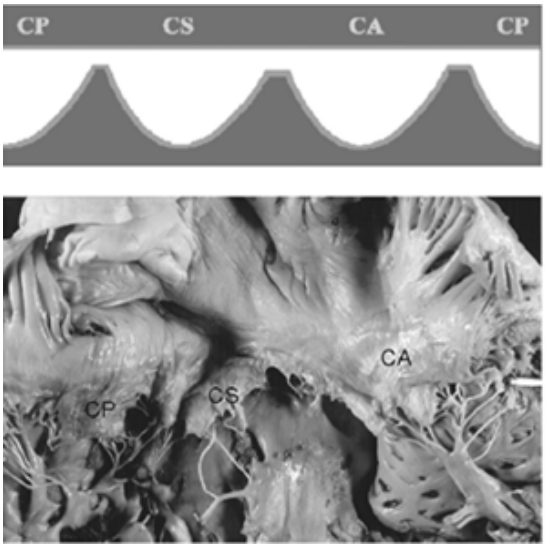


Fig 13: Typical (3 cusp) form of Tricuspid Valve.

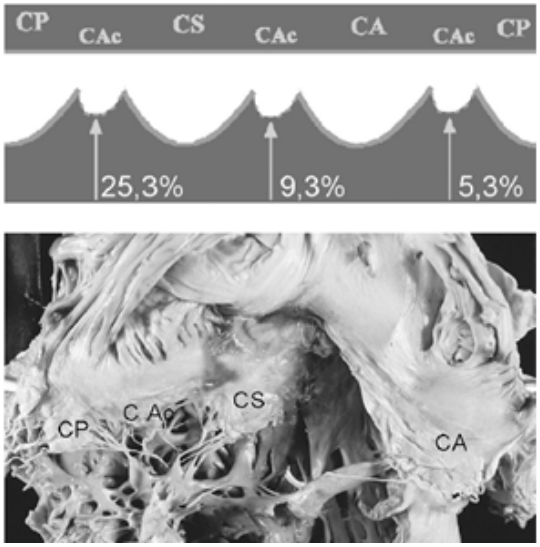


Fig 14: 4-Cuspidal form of Tricuspid valve.

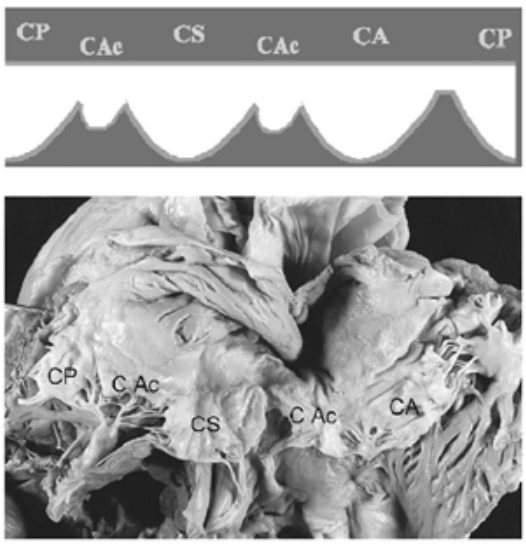


Fig 15: 5- Cuspidal form of Tricuspid Valve

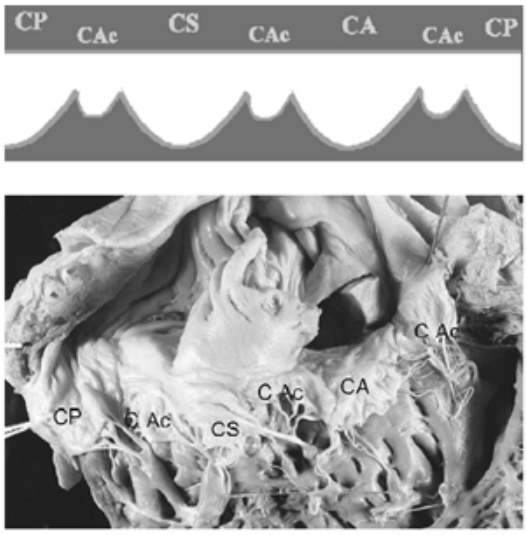


Fig 16: 6-Cuspidal form of TC Valve

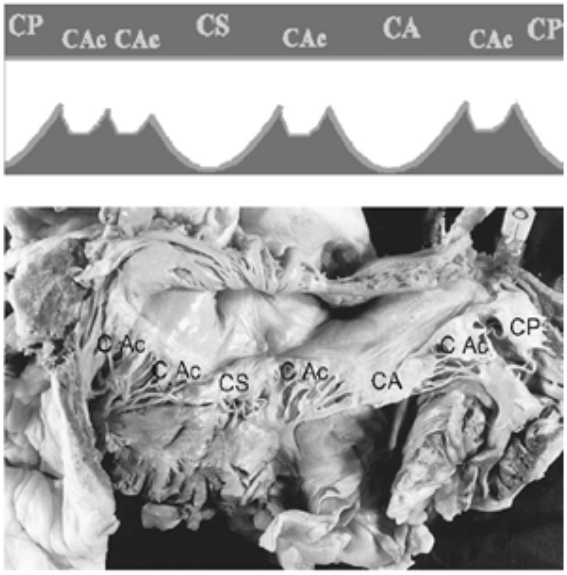


Fig 17: 7-Cuspidal form of Tricuspid Valve.

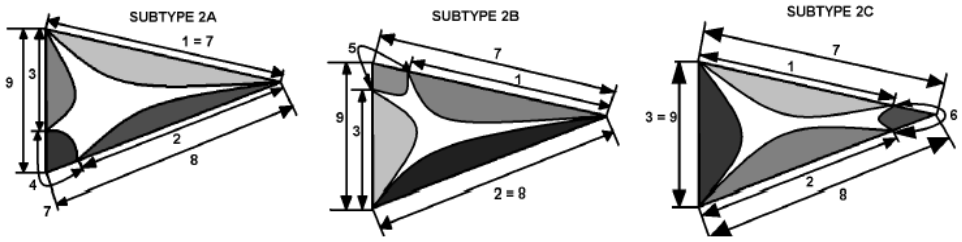


Fig 18: Location of accessory cusps in Four-Cuspidal form(Type 2) of Tricuspid Valve.

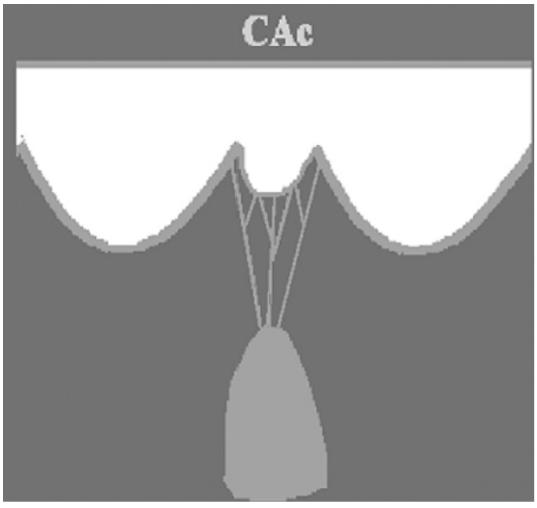


Fig 19: Spourious Accessory Cusp.

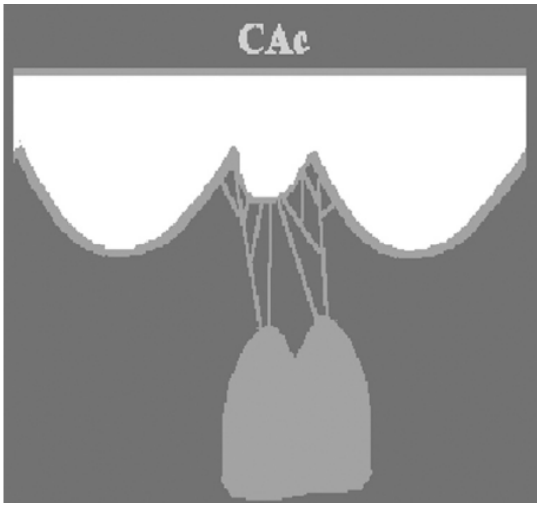


Fig 20: True (Real) Accessory Cusp.

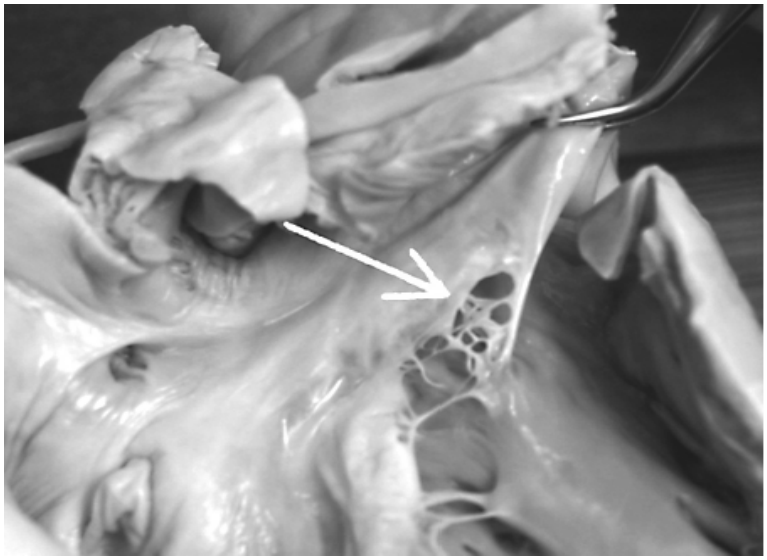
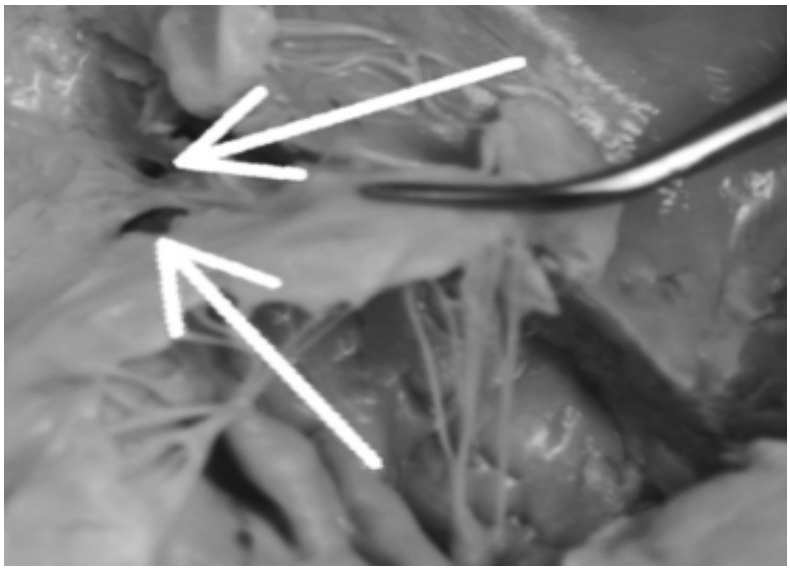


Fig.21: Spurious Foramina of the Tricuspid Valve



Pic.22: Two Natural Foramina of the Tricuspid Valve

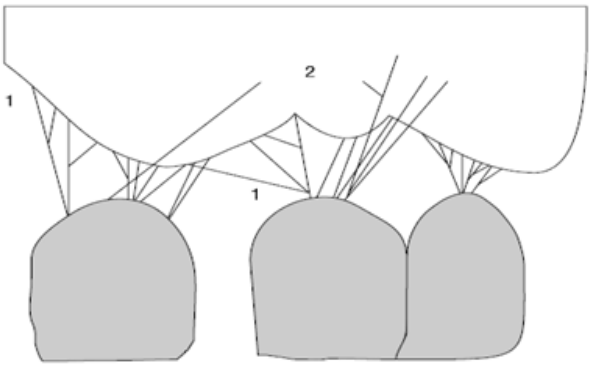


Fig 23: Primary(1) and secondary(2) tendinous chords.The primary chords are attached to the margin of the leaflet and the secondary to the ventricular surface of the valve[47].

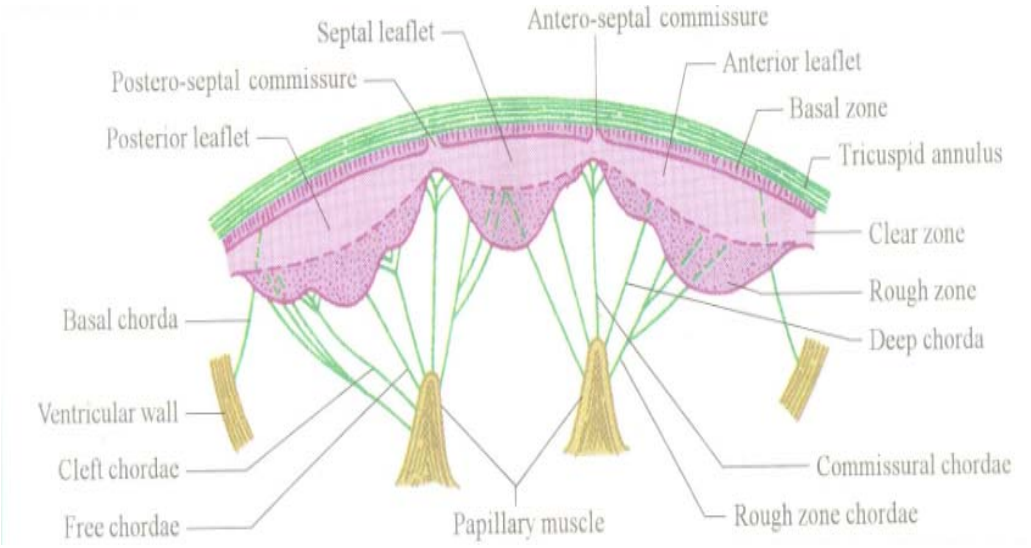


Fig 24: Tricuspid valve complex showing types of Chordae Tendineae.

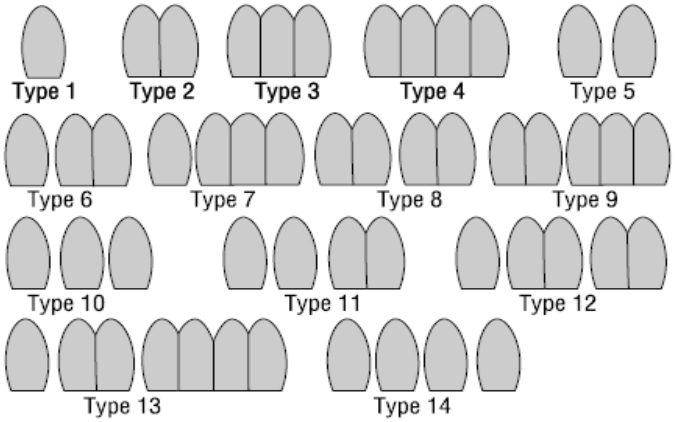


Fig 25:Classification of the Papillary muscles according to Grochowski et al[47] (2001).

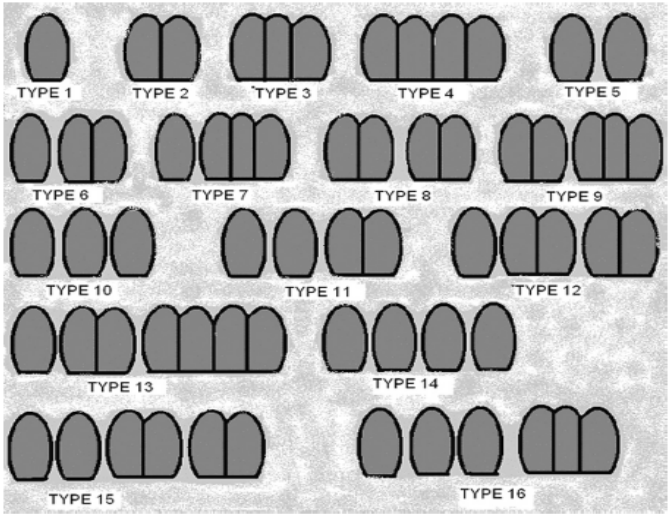


Fig 26: Classification of the Papillary muscles (Type 15 &16) of Right Ventricle according to Skwarek et al (2005).

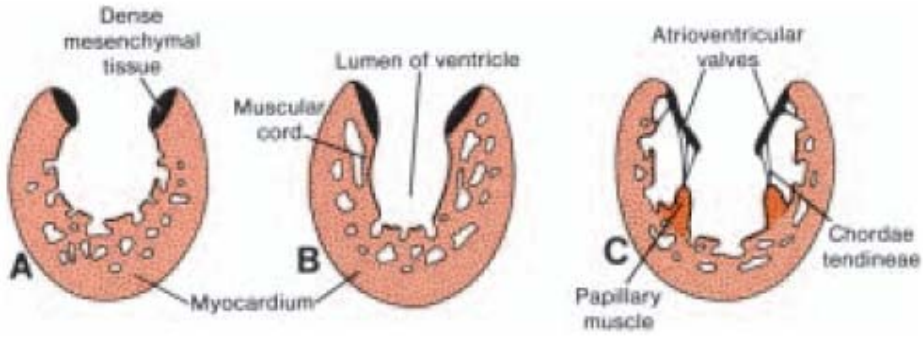
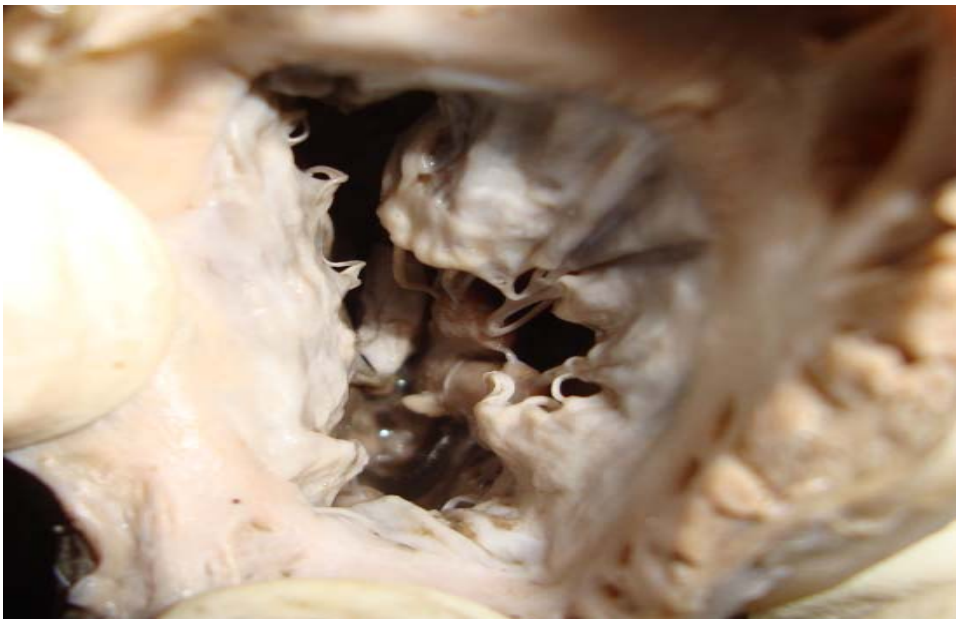
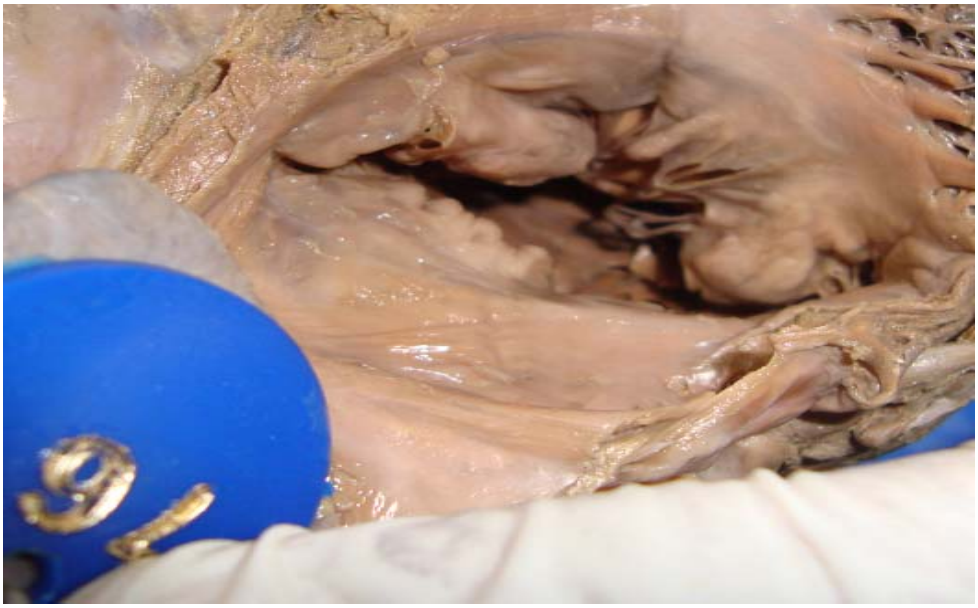


Fig 27: Formation of the atrioventricular valves and chordate tendineae.The valves are hollowed out from the ventricular side but remain attached to the ventricular wall by the chordae tendineae[39].



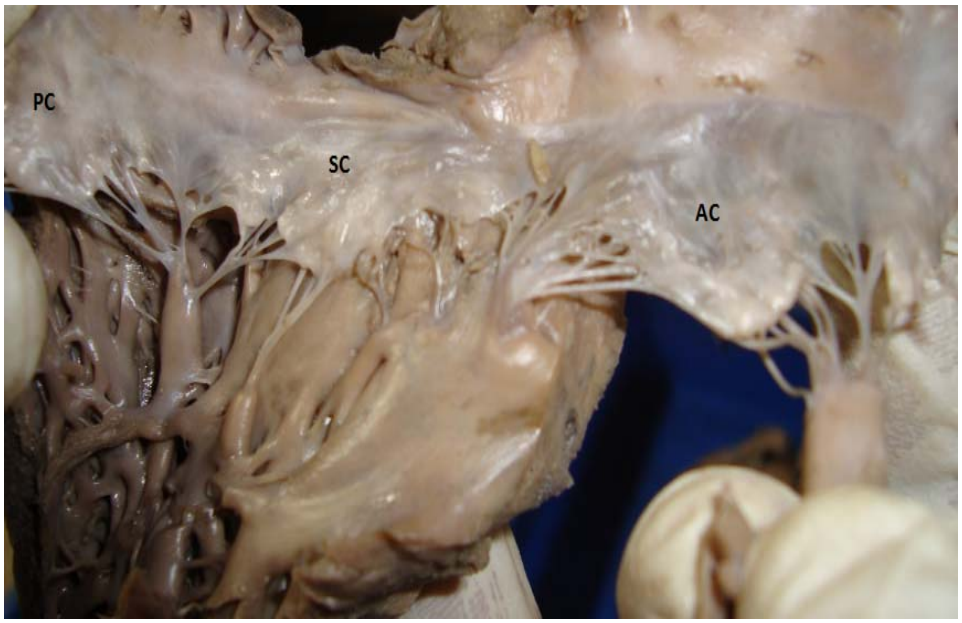
Pic.1: Tricuspid Annulus (circular) Viewed from Right Atrium.



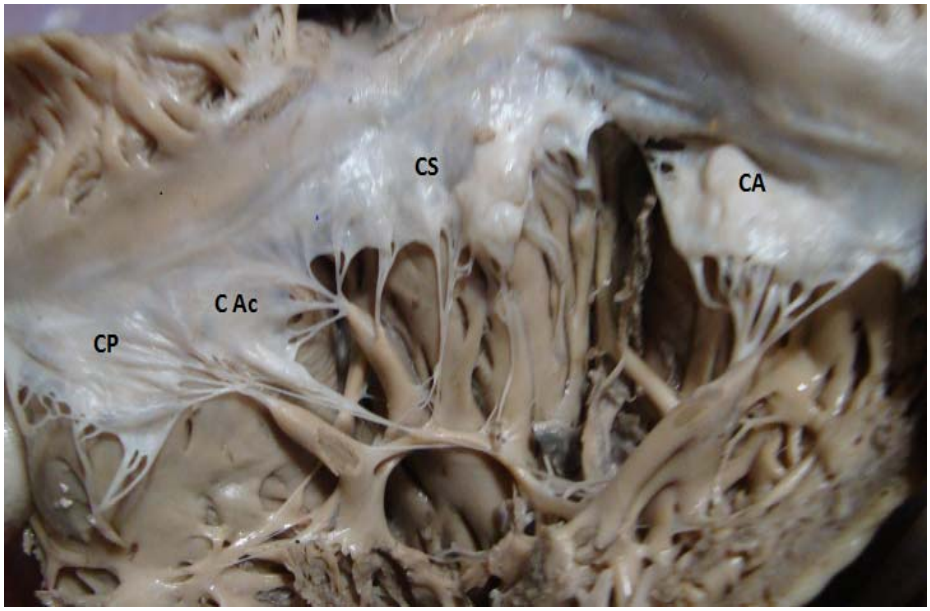
Pic.2: Tricuspid Annulus (oval) Viewed from Right Atrium.

Pic.3: Measurement of circumference of Tricuspid Annulus.

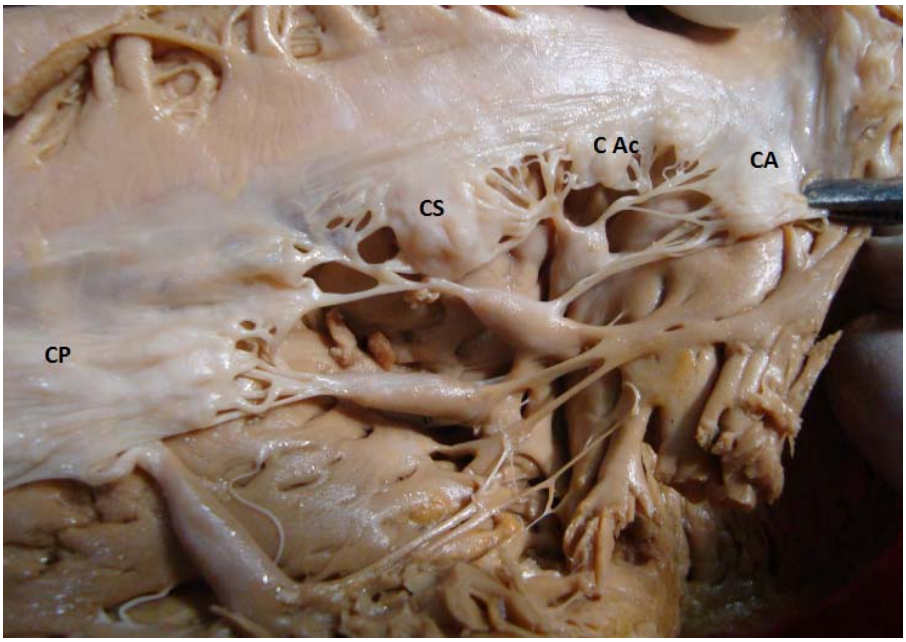
Pic.4: Measurement of Commissural Length.



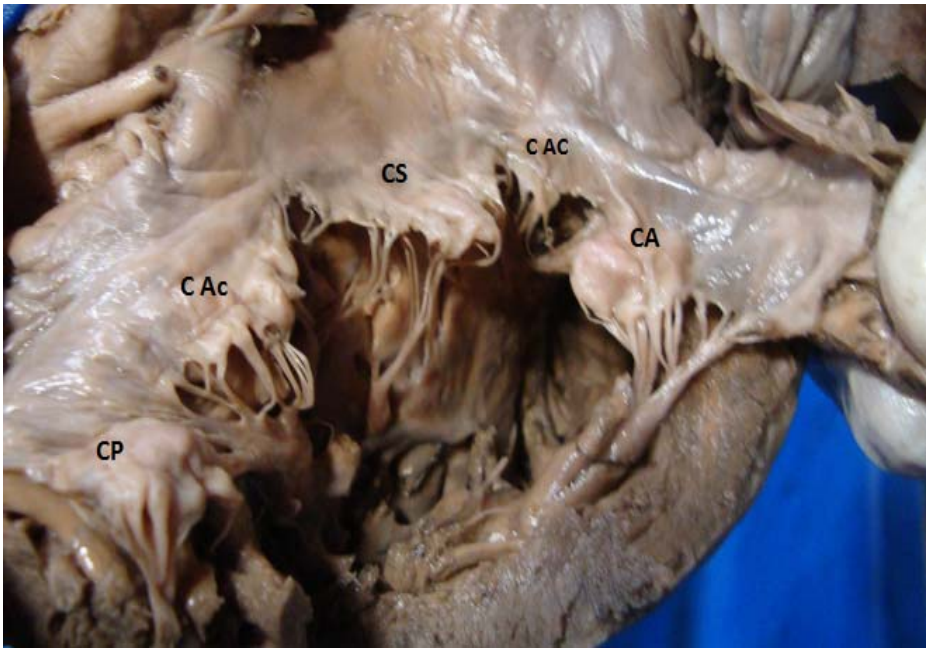
Pic.5: Typical three cuspidal form of Tricuspid Valve.



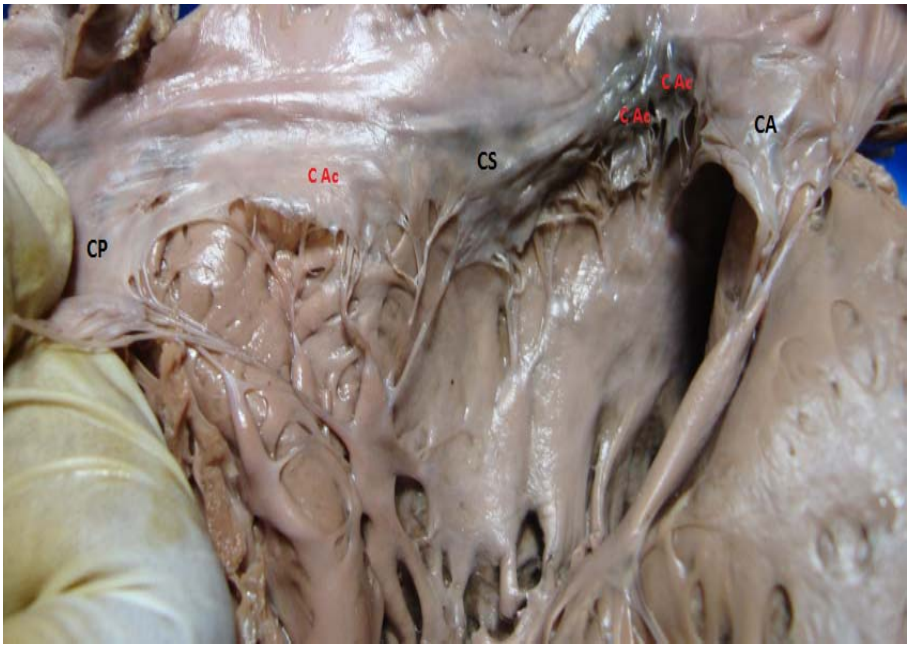
Pic.6: Tricuspid Valve with Four cusps.



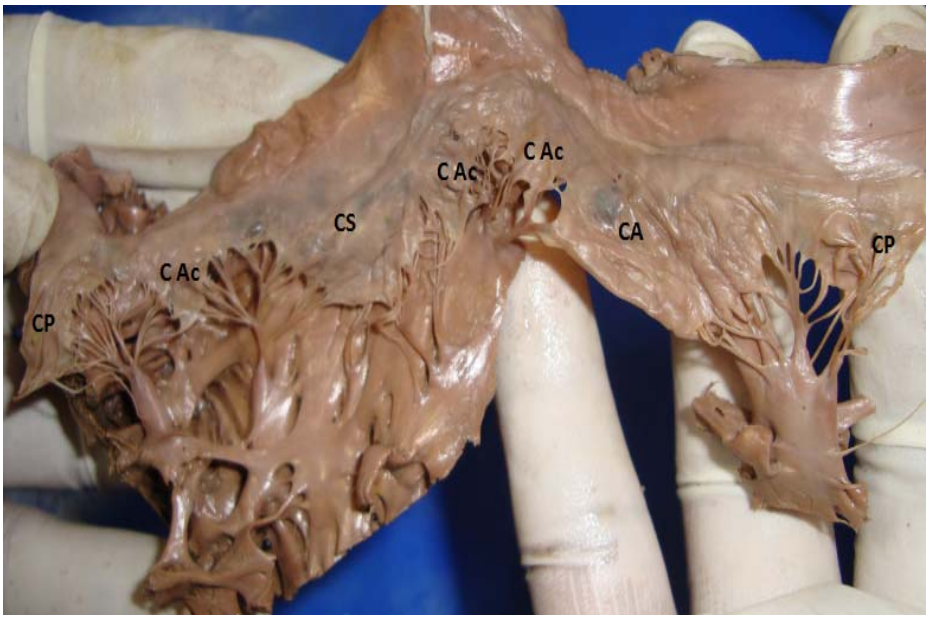
Pic.7: Tricuspid Valve with Four cusps.



Pic.8 : Tricuspid Valve with Five cusps.

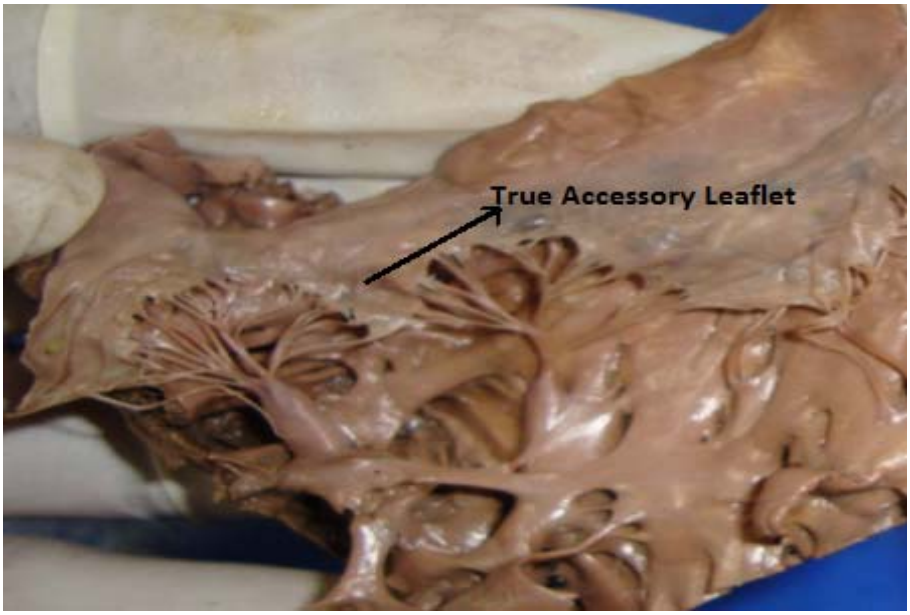


Pic.9 : Tricuspid Valve with six cusps.

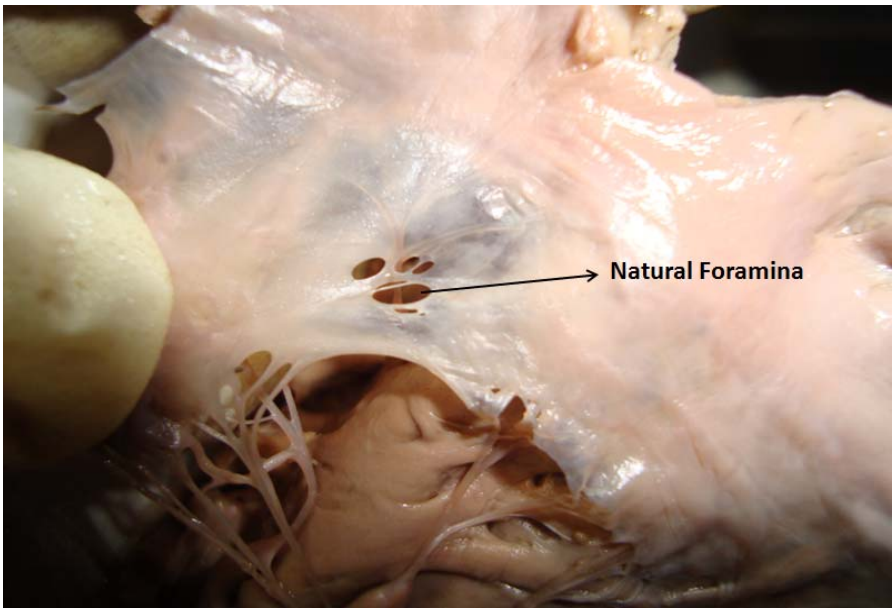


Pic.10: Tricuspid Valve with six cusps.

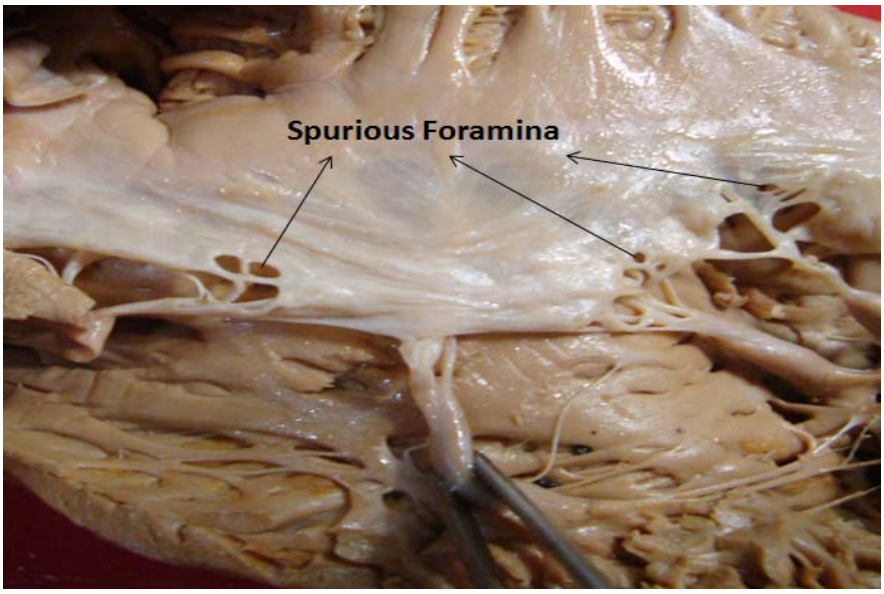
Pic.11: Spurious Accessory Leaflet-receiving Chordae Tendinae from only one Papillary muscle.



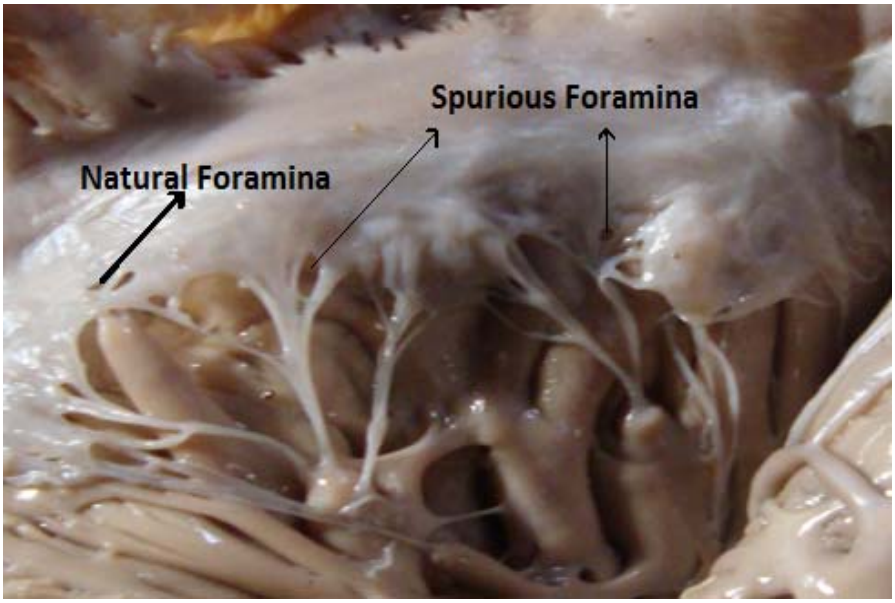
Pic.12: True Accessory Leaflet-receiving Chordae Tendinae from 2 Papillary Muscle.



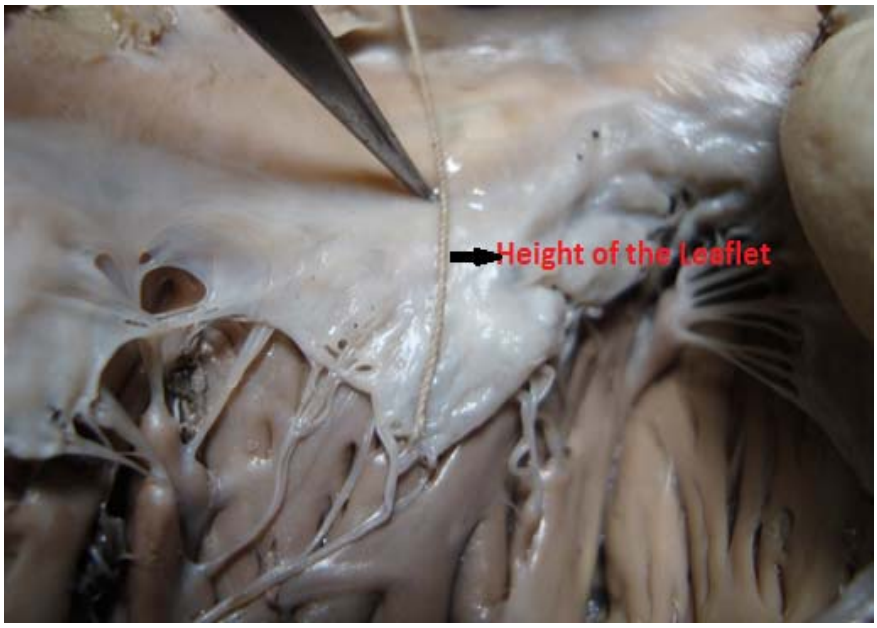
Pic.13: Natural Foramina of the Tricuspid Valve between Posterior and Septal Cusps.



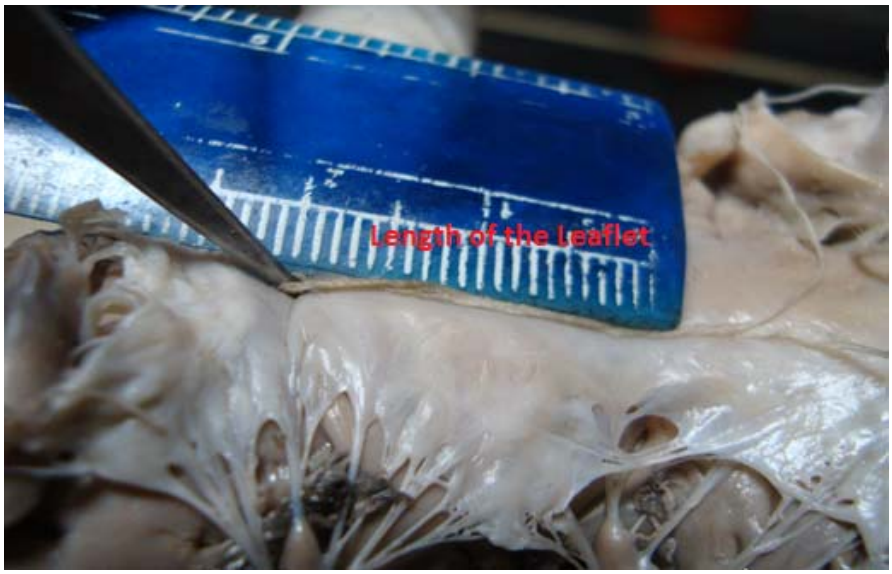
Pic.14: Spurious Foramina of the Tricuspid Valve.



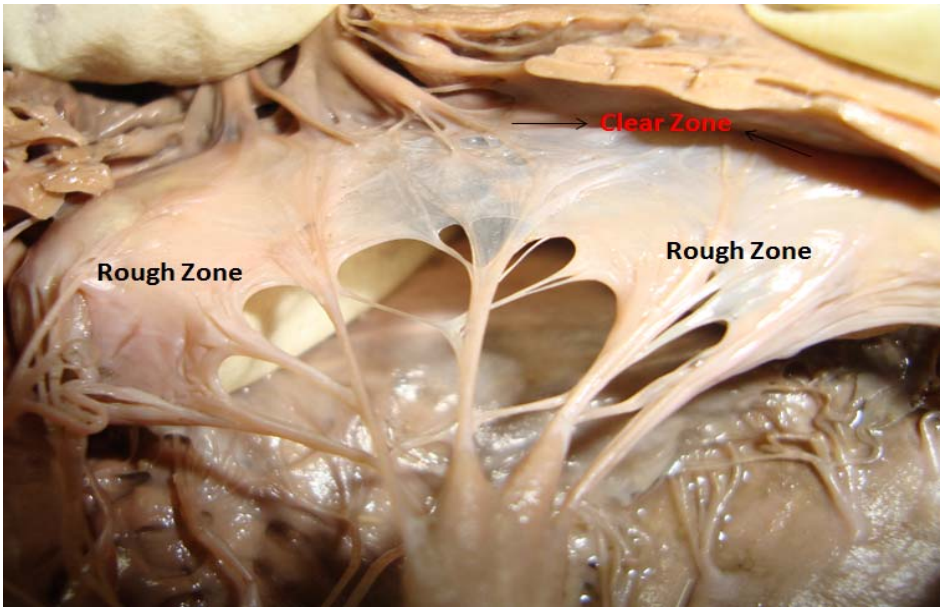
Pic.15: Natural and Spurious Foramina of the Tricuspid Valve.



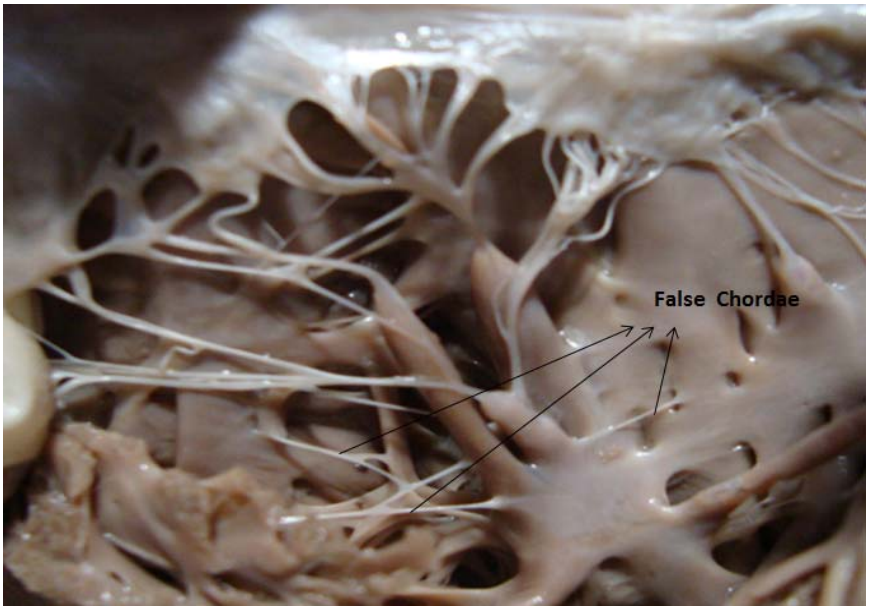
Pic.16: Measurement of height of the Leaflet. (septal)



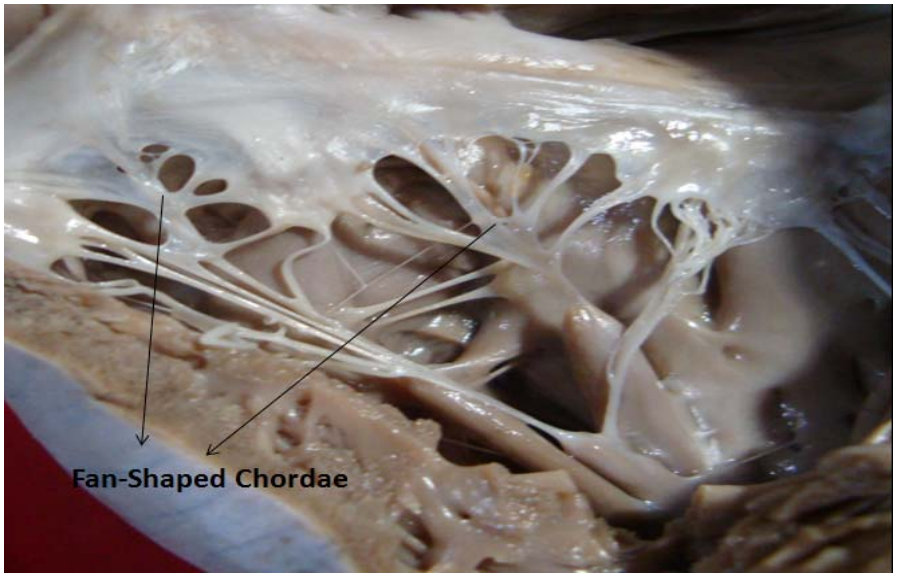
Pic.17: Measurement of length of the Leaflet. (Posterior)



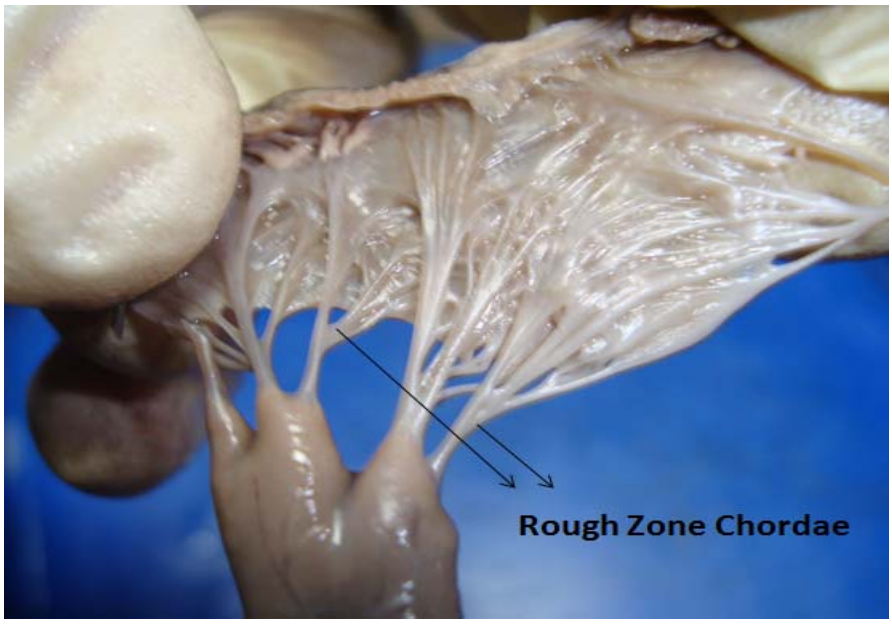
Pic.18: Ventricular surface of Tricuspid Valve Showing Rough Zone and Clear Zone.



Pic.19: False Chordae Connecting papillary Muscle and Ventricular Walls.



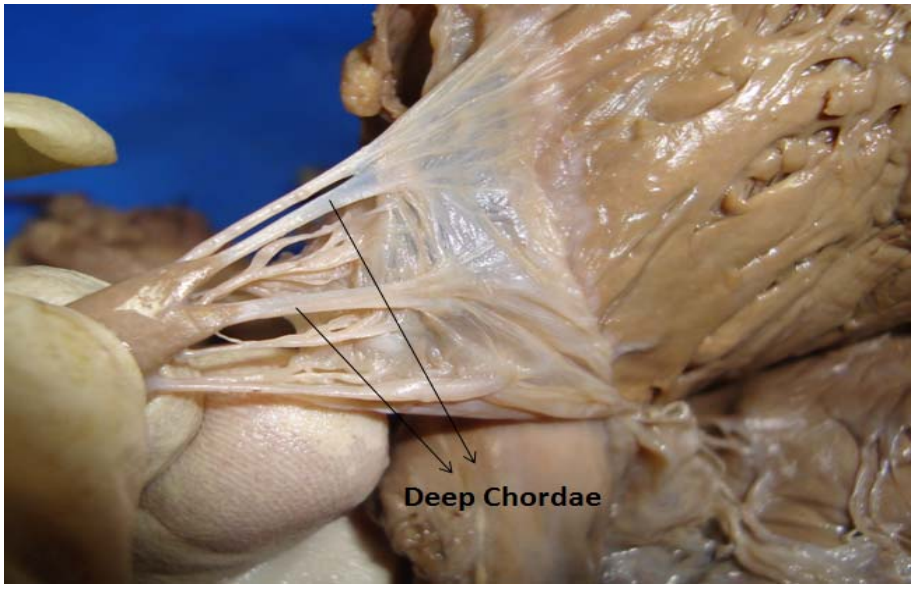
Pic.20: Fan-Shaped Chordae(commissural) inserted in AP and PS commissure.



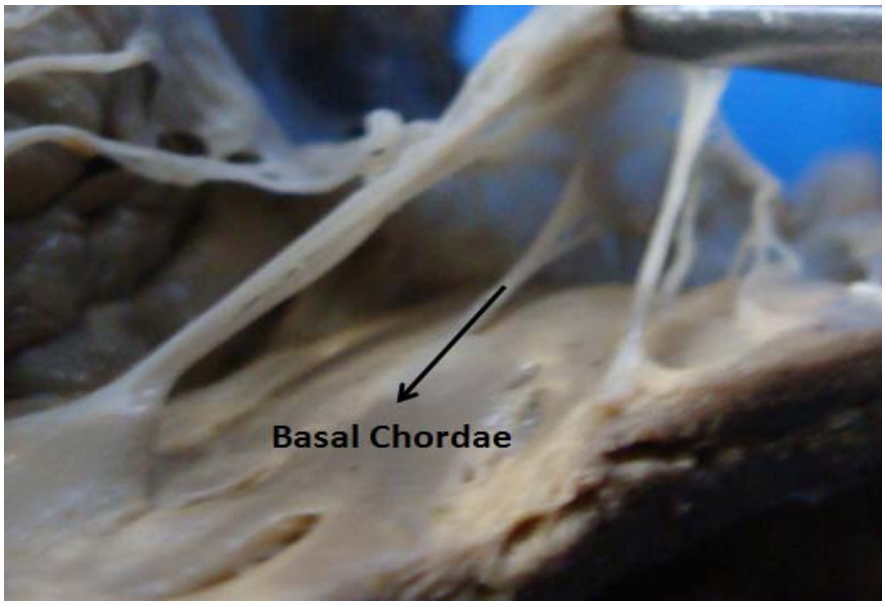
Pic.21: Rough Zone Chordae attached to Anterior Leaflet (ventricular surface).

Pic.22: Free Edge Chordae attached to Septal Leaflet.

Pic.23: Free Edge Chordae attached to Septal Leaflet.

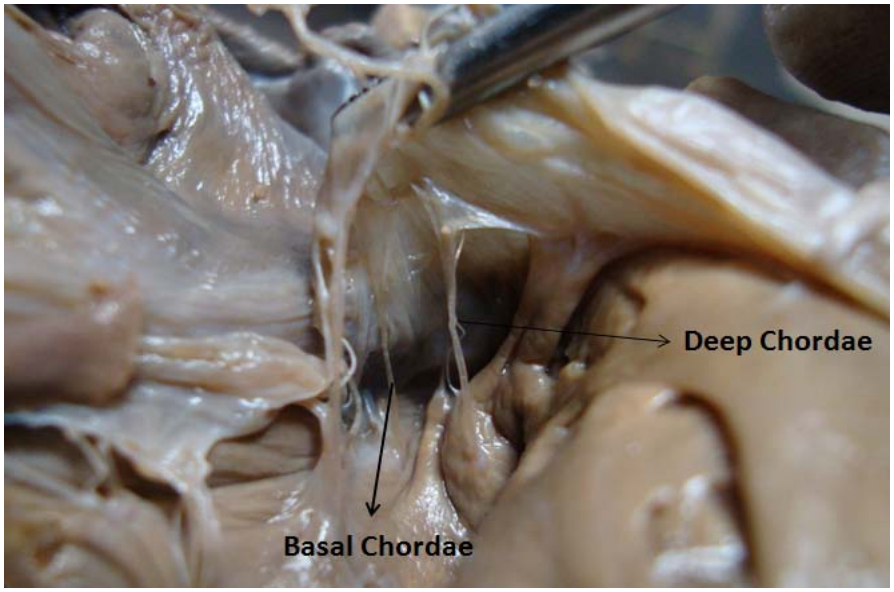


Pic.24: Deep Chordae attached to Anterior Leaflet. (ventricular surface)



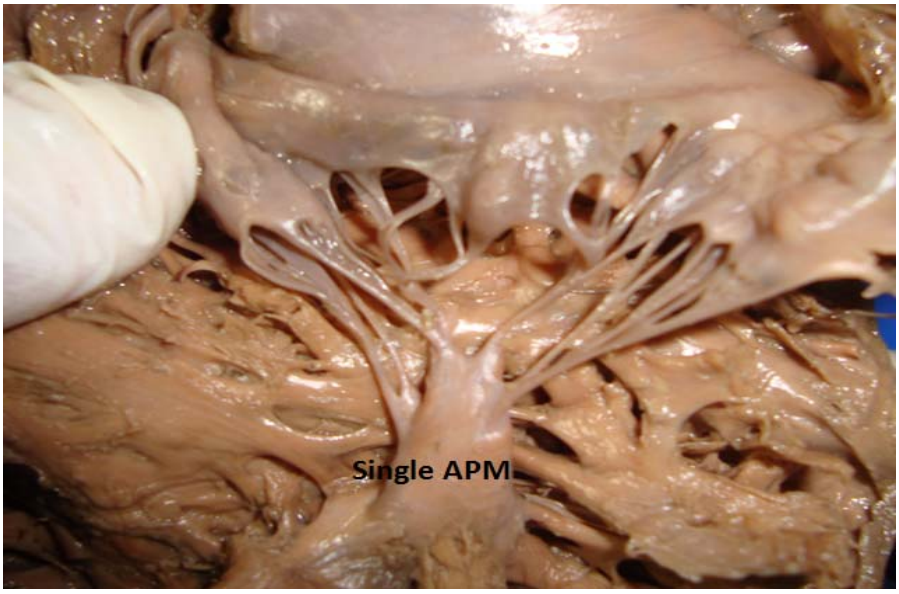
Pic.25: Basal Chordae attached to clear Zone of Anterior Leaflet.

(ventricular surface)

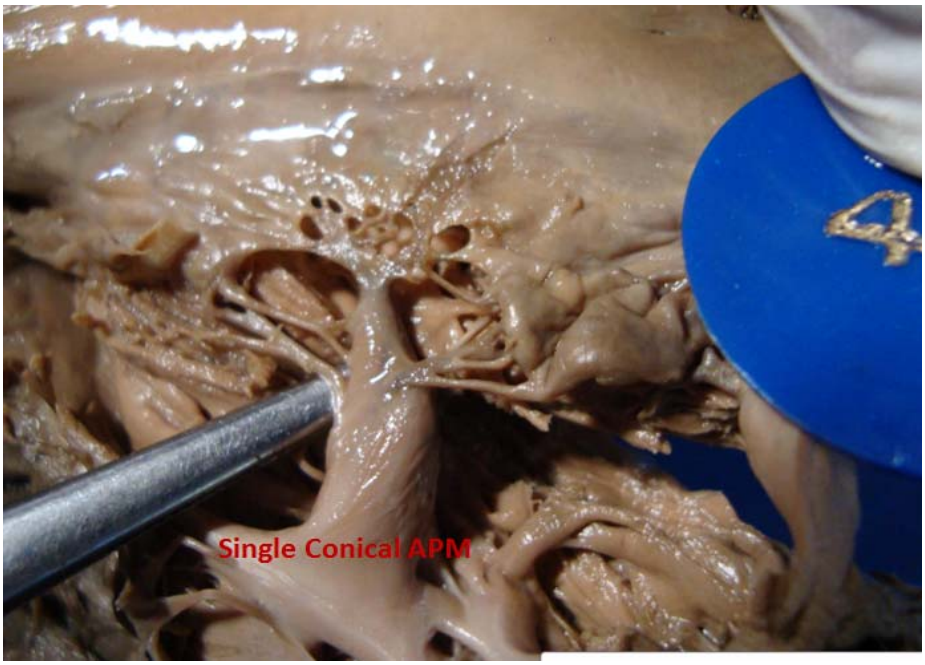


Pic.26: Deep and Basal Chordae arising from Ventricular Wall.

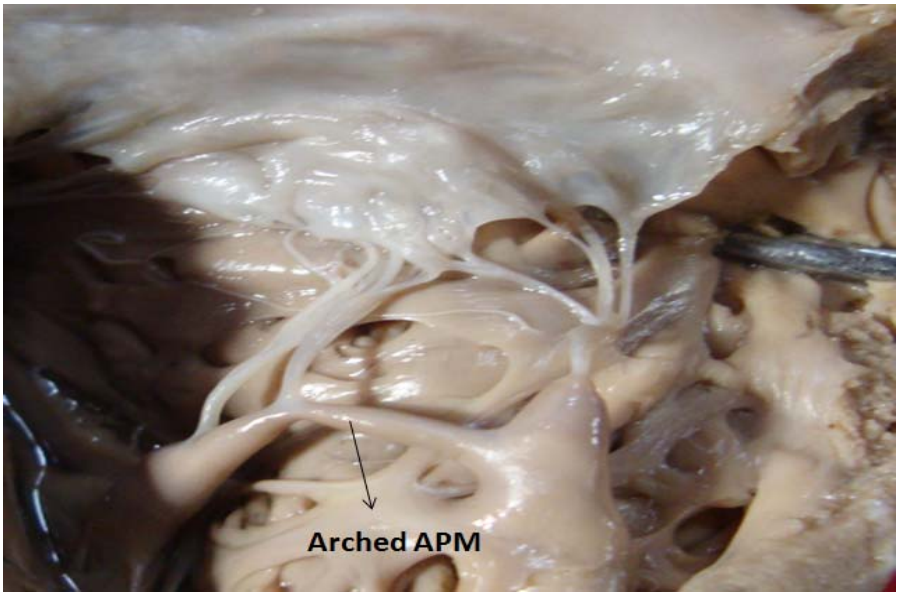
Pic.27: Chordae forming net like pattern before attaching to Septal Leaflet.



Pic.28: Single Mamillated Muscle Belly of Anterior Papillary Muscle.



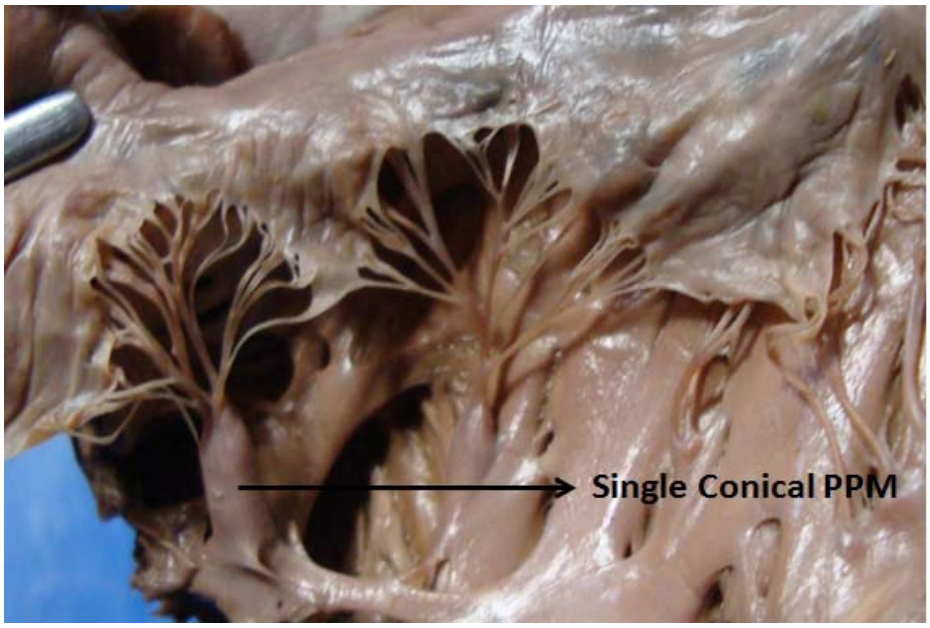
Pic.29: Single Conical Muscle Belly- Anterior Papillary Muscle.



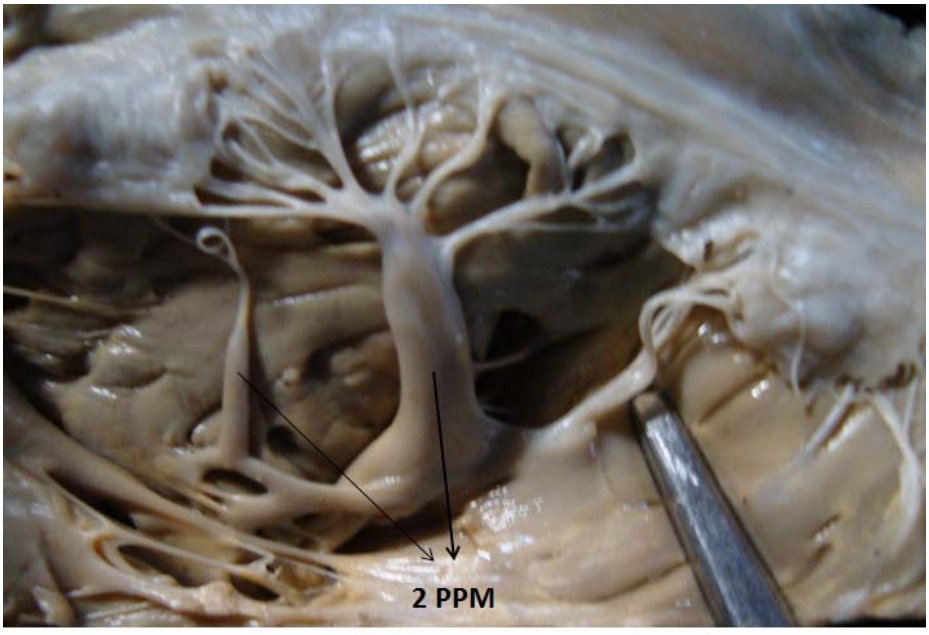
Pic.30: Arched Configuration of 2 Muscle Bellies in Anterior Papillary Muscle.

Pic.31: H Shaped Configuration of 2 Muscle Bellies in Anterior Papillary Muscle.

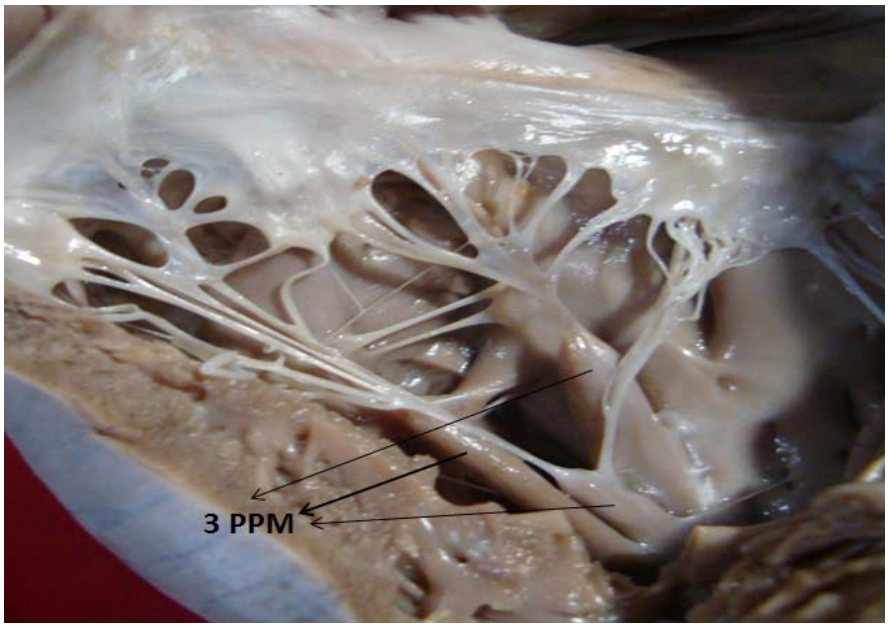
Pic.32: 3 Interlinked Muscle Bellies in Anterior Papillary Muscle.



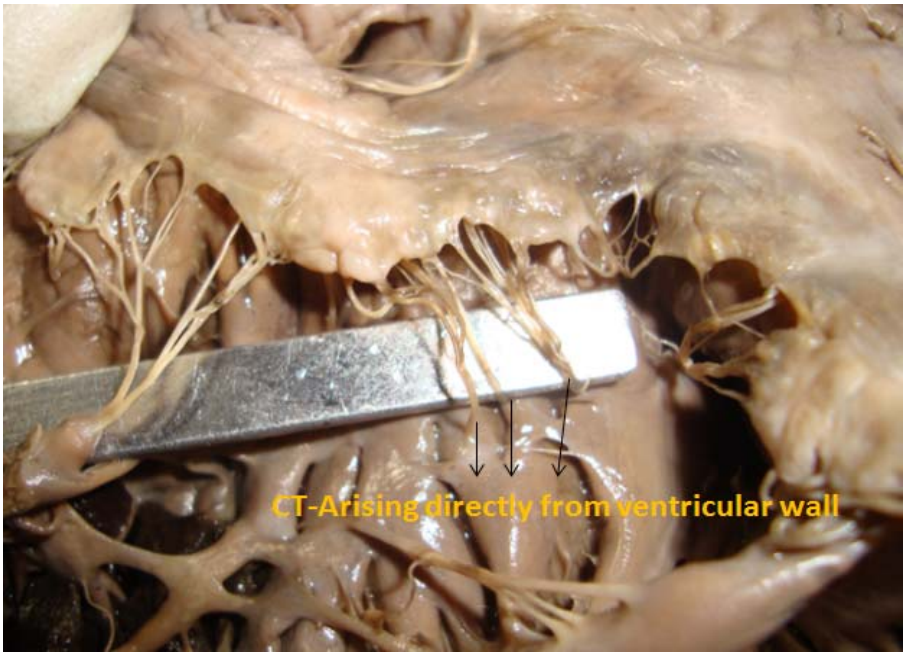
Pic.33: Single Conical Muscle Belly in Posterior Papillary Muscle.



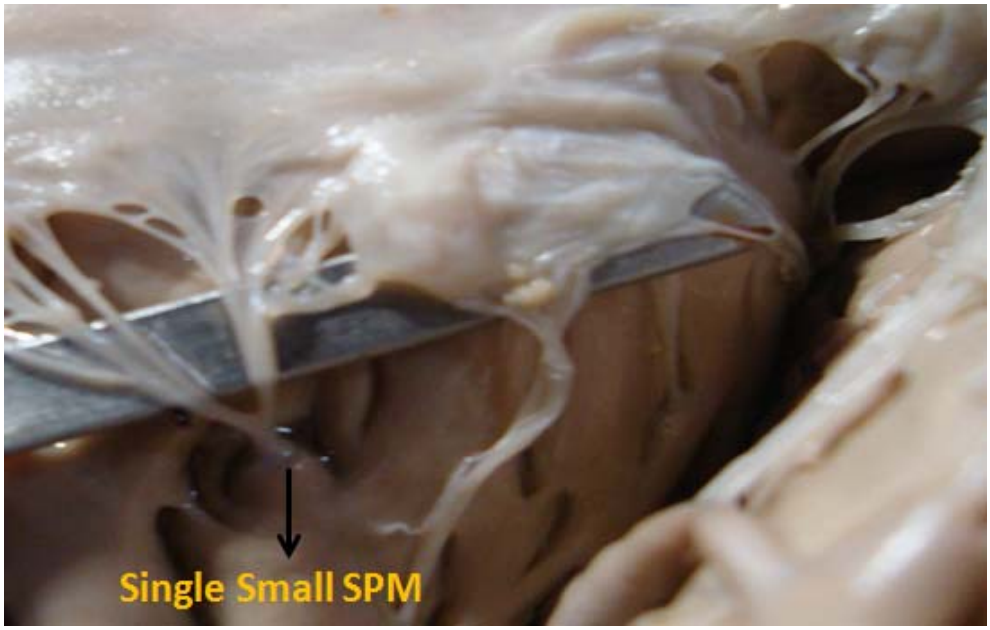
Pic.34: 2 Muscle Bellies in Posterior Papillary Muscle.



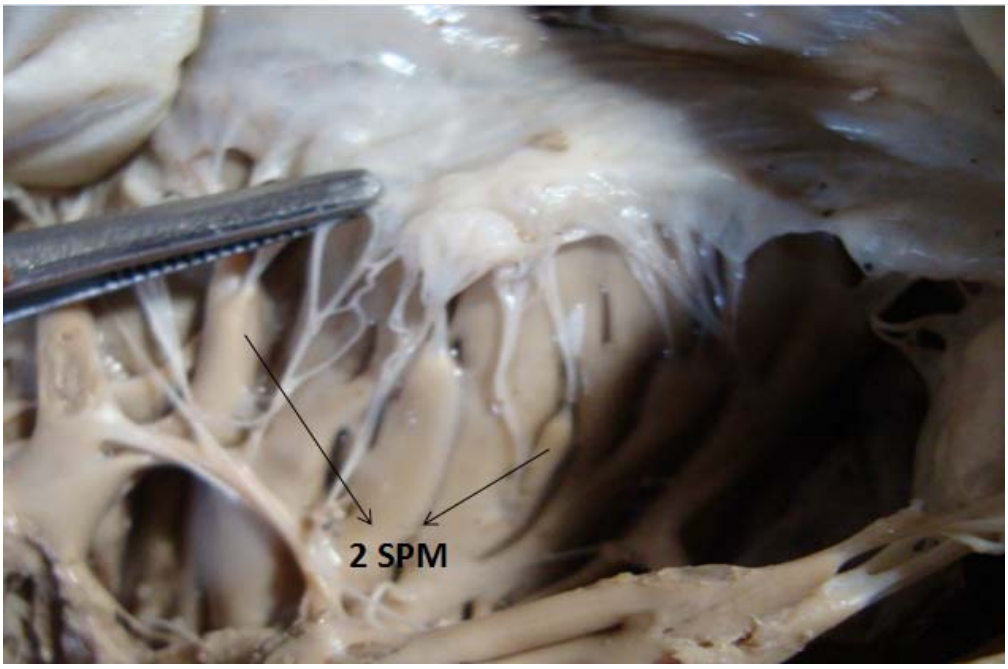
Pic.35: 3 Muscle Bellies in Posterior Papillary Muscle.



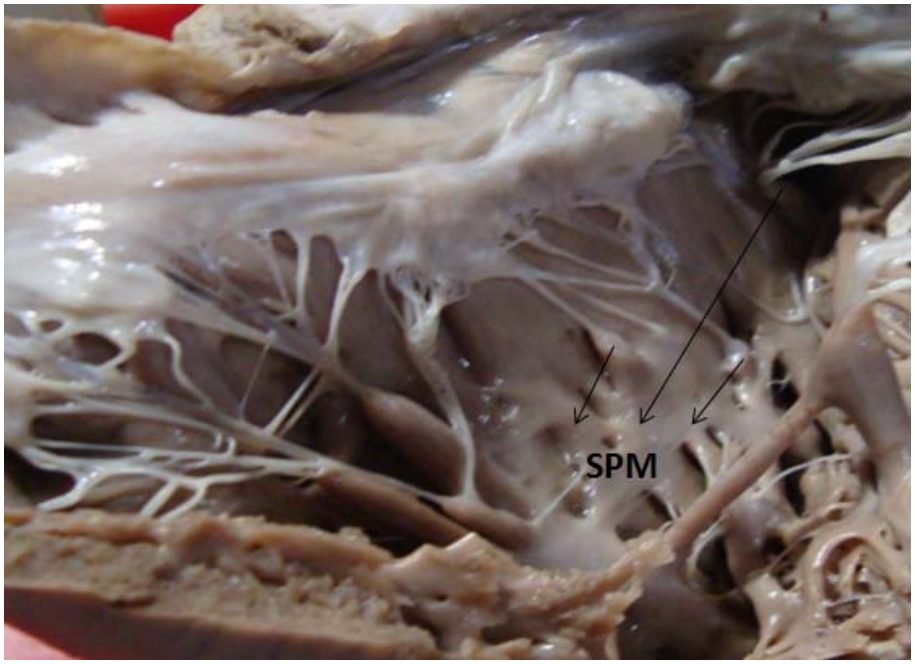
Pic.36: Absent Septal Papillary Muscle-Chordae Tendinae directly arising from ventricular wall.



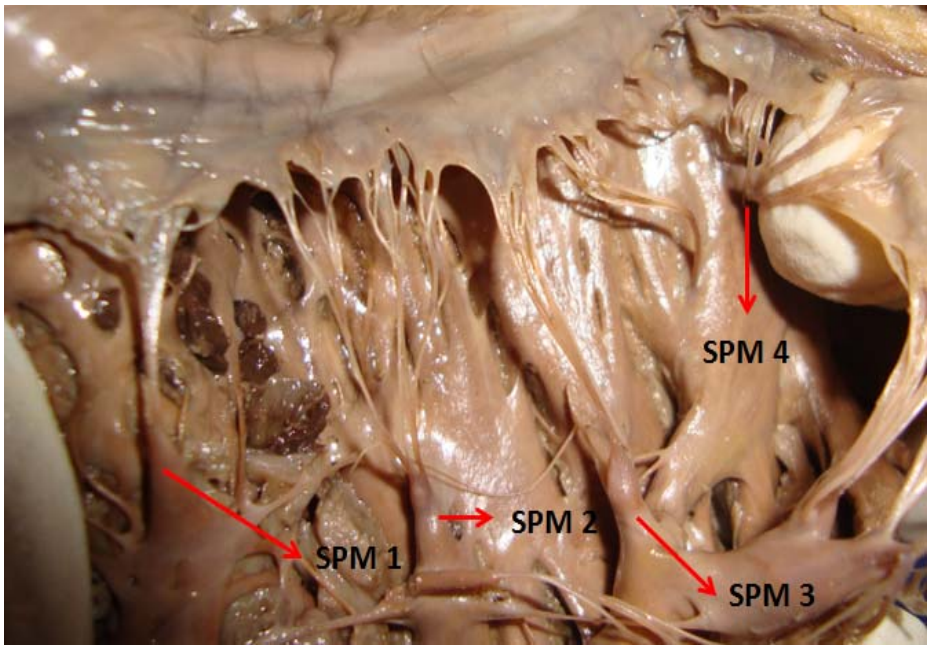
Pic.37: Single Small Septal Papillary Muscle.



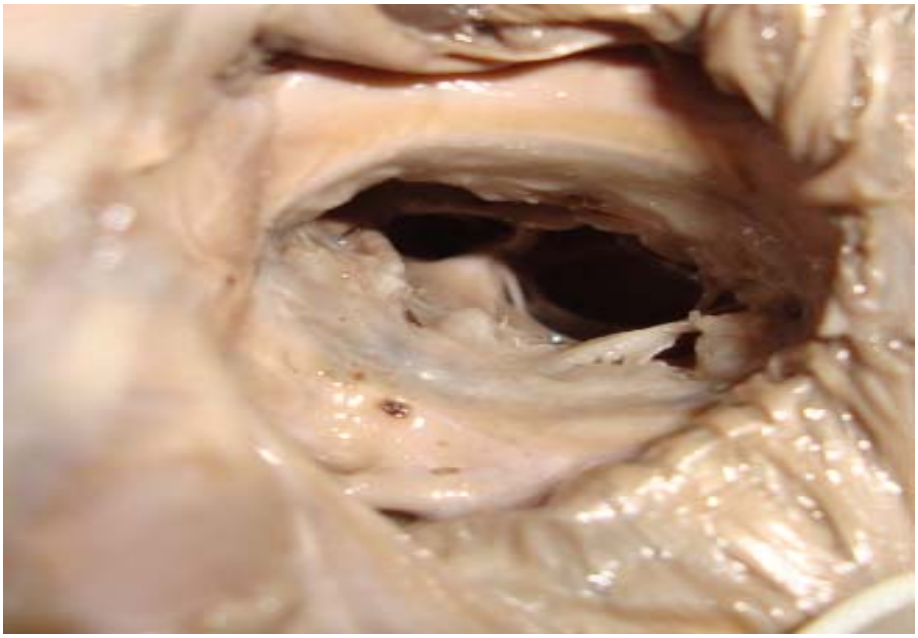
Pic.38: Two Septal Papillary Muscle.



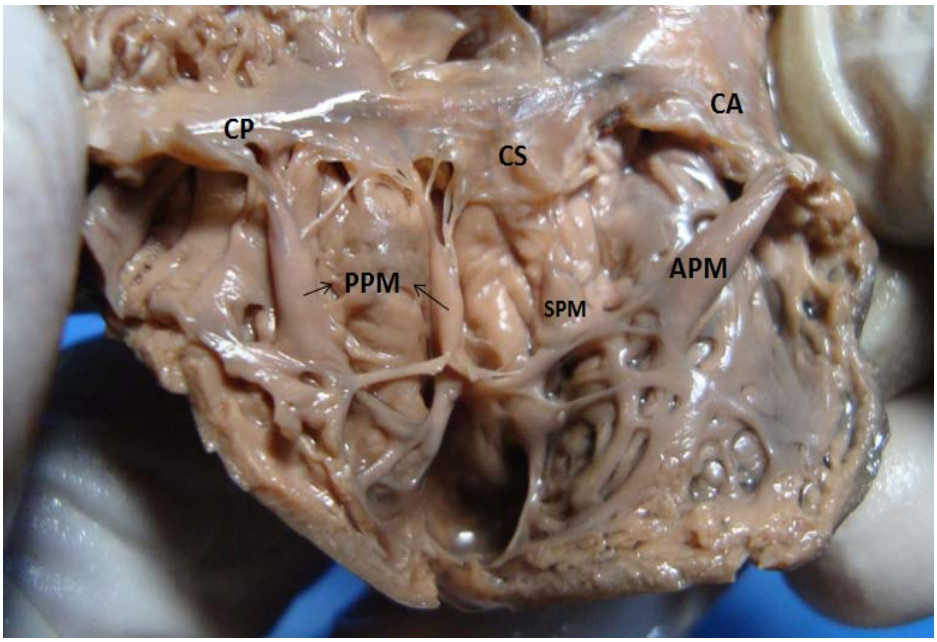
Pic.39: Three Small Septal Papillary Muscle.



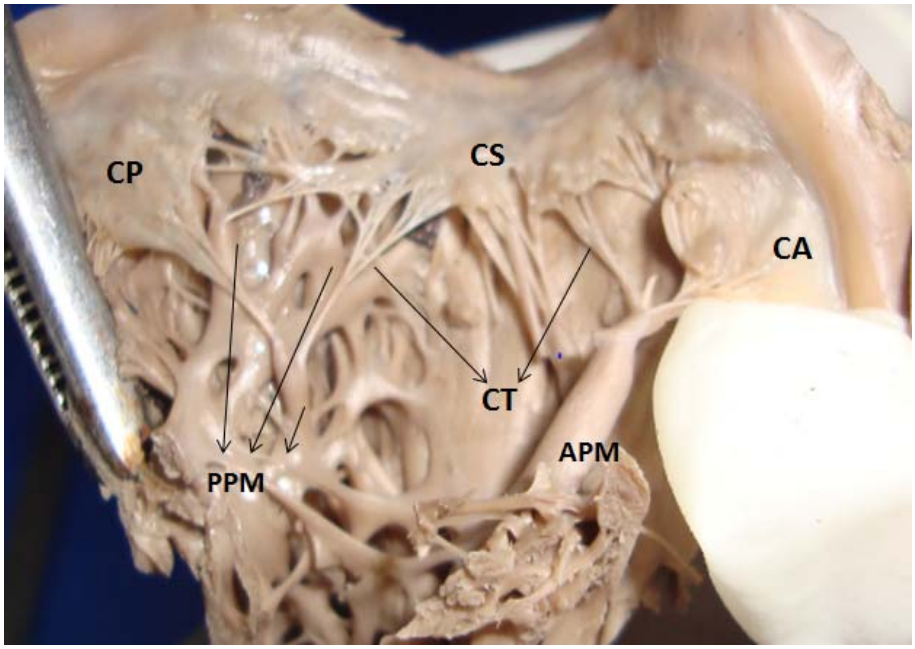
Pic.40: Four Small Septal Papillary Muscle.



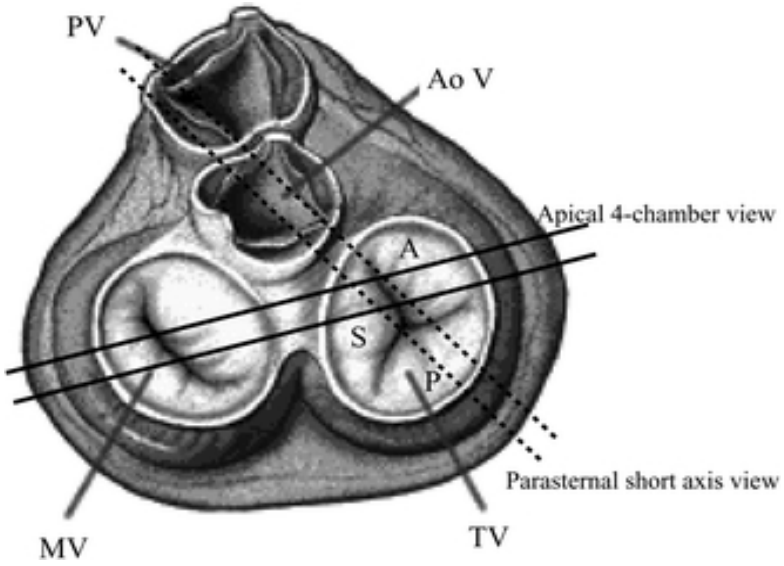
Pic.41: Fetal Heart - Tricuspid Annulus Viewed from Right Atrium.



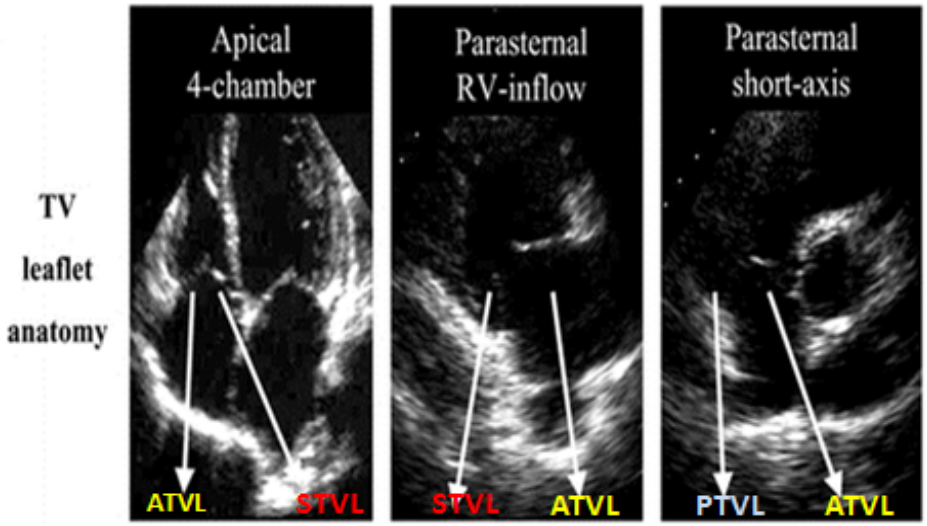
Pic.42: Fetal Heart showing leaflets and papillary muscles.



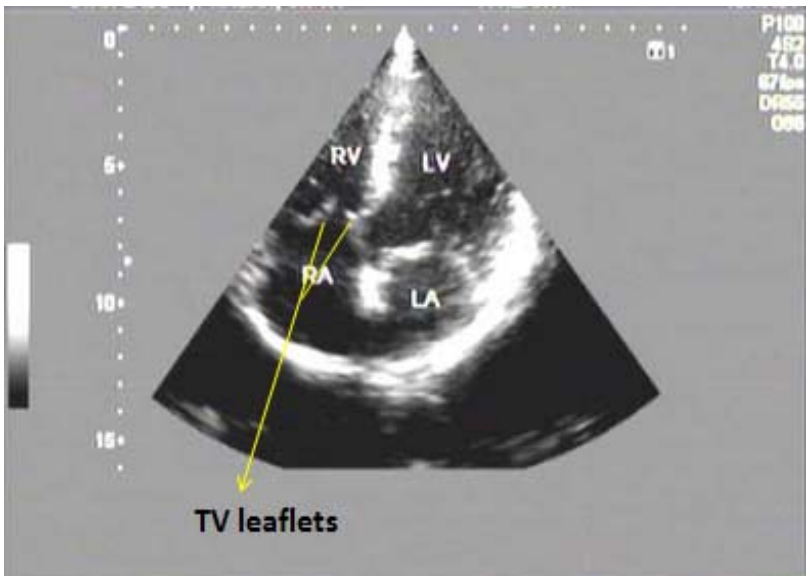
Pic.43: Fetal Heart showing leaflets, papillary muscles and chordae tendineae.



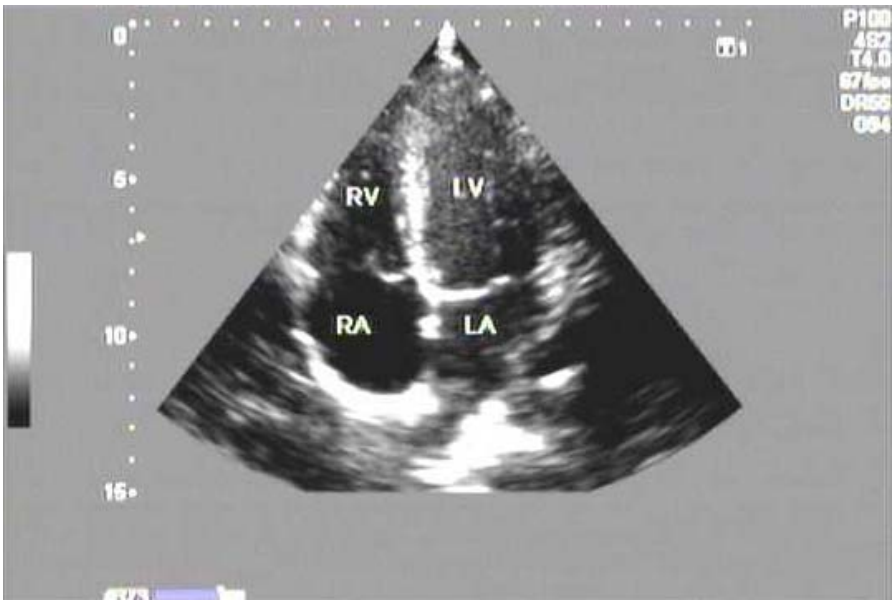
Pic.44: Surgical view of the heart valves demonstrating the range of the 2D echocardiographic 4-chamber and short axis planes.



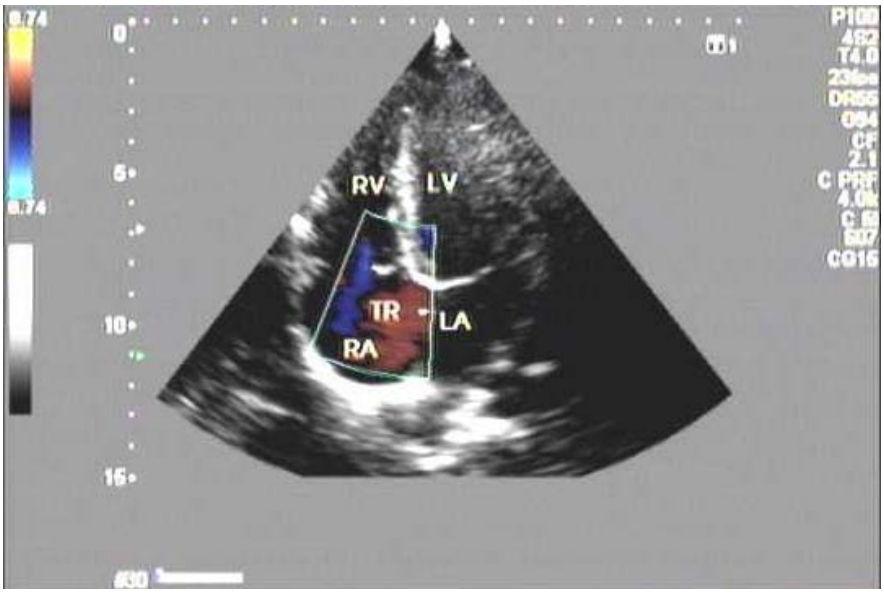
Pic.45:Tricuspid Valve leaflets seen on 2-dimensional imaging.



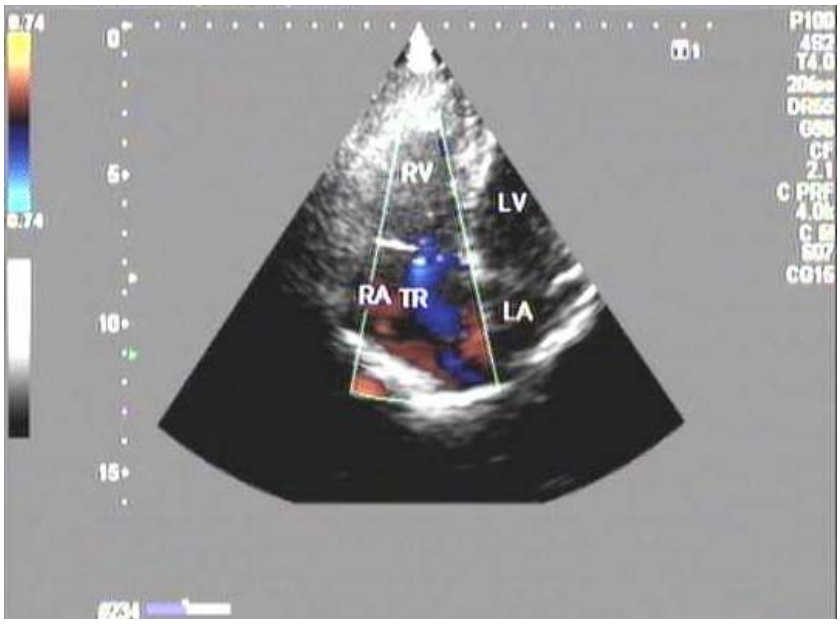
Pic.46: 2-D Echo image of 56 years male old male showing Tricuspid valves.



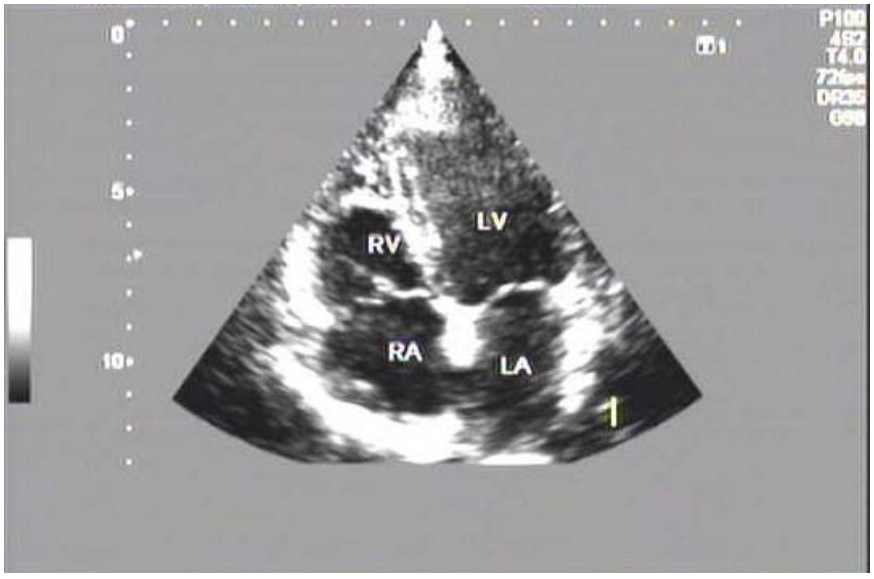
Pic.47: 2-D Echo image of 21 years male showing Tricuspid valve Prolapse.



Pic.48: 2-D Echo with Doppler of 21 years male showing Tricuspid valve Prolapse with Tricuspid regurgitation.



Pic.49: 2-D Echo with Doppler of 60 years male old showing Tricuspid valve Prolapse with Tricuspid regurgitation.



Pic.50: 2-D Echo image of 40 years female showing Tricuspid valve Prolapse.

Table No.1

Shape of Tricuspid Valve Annulus

Specimen Number	Shape of Tricuspid Annulus	Specimen Number	Shape of Tricuspid Annulus
1	Circular	**24**	Oval
2	Circular	**25**	Circular
3	Circular	**26**	Circular
4	Circular	**27**	Circular
5	Circular	**28**	Oval
6	Circular	**29**	Circular
7	Circular	**30**	Circular
8	Circular	**31**	Circular
9	Circular	**32**	Circular
10	Oval	**33**	Oval
11	Circular	**34**	Oval
12	Oval	**35**	Circular
13	Circular	**36**	Circular
14	Circular	**37**	Circular
15	Circular	**38**	Circular
16	Circular	**39**	Circular
17	Circular	**40**	Circular
18	Oval	**41**	Circular
19	Circular	**42**	Circular
20	Circular	**43**	Circular
21	Circular	**44**	Circular
22	Circular	**45**	Circular
23	Circular		

Table No.2

Circumference of Tricuspid Annulus

Specimen Number	Circumference(cm)	Specimen Number	Circumference(cm)
1	11.9	24	10.8
2	12.7	25	11.4
3	11.9	26	12.9
4	12.3	27	13.0
5	12.5	28	12.3
6	12.0	29	12.3
7	11.4	30	11.1
8	10.8	31	13.0
9	10.7	32	11.1
10	11.1	33	12.4
11	10.7	34	10.5
12	12.1	35	10.7
13	12.4	36	11.7
14	11.3	37	11.8
15	10.3	38	11.0
16	10.5	39	12.9
17	12.9	40	12.3
18	12.0	41	12.8
19	12.5	42	11.2
20	12.5	43	12.8
21	11.3	44	11.9
22	11.3	45	12.4
23	10.5		

Mean Circumference = 11.8 cm

Mean $\pm$ SD = 11.8 $\pm$ 0.81 cm

Table No.3

Number of Commisures

Specimen Number	Number of Commisures	Specimen Number	Number of Commisures
1	3	24	3
2	3	25	3
3	3	26	3
4	4	27	3
5	3	28	4
6	3	29	6
7	3	30	3
8	3	31	3
9	3	32	3
10	3	33	3
11	6	34	4
12	3	35	3
13	3	36	3
14	4	37	3
15	4	38	3
16	3	39	3
17	3	40	3
18	3	41	4
19	3	42	3
20	5	43	3
21	3	44	3
22	3	45	3
23	3		

Table No.4

Length of commissures

Sp. No	Commissure Length(cm)						Sp. No	Commissure Length(cm)					
	AP	PS	AS	Acc Com1	Acc Com2	Acc Com3		AP	PS	AS	Acc Com1	Acc Com2	Acc Com3
1	1.3	0.7	0.5	-	-	-	24	1.2	0.7	0.5	-	-	
2	1.1	0.6	0.6	-	-	-	25	1.0	0.6	0.5	-	-	-
3	1.0	0.6	0.7	-	-	-	26	0.9	0.9	0.6	-	-	-
4	1.1	0.8	0.5	0.4	-	-	27	1.0	0.9	0.6	-	-	-
5	1.4	0.7	0.6	-	-	-	28	0.9	0.8	0.5	0.4	-	-
6	0.9	0.8	0.5	-	-	-	29	1.4	0.7	0.7	0.7	0.4	0.6
7	1.3	0.7	0.7	-	-	-	30	1.4	0.6	0.7	-	-	-
8	1.3	0.7	0.5	-	-	-	31	1.4	0.8	0.9	-	-	-
9	1.4	0.7	0.7	-	-	-	32	1.4	0.9	0.9	-	-	-
10	1.4	0.6	0.5	-	-		33	1.4	0.8	0.8	-	-	-
11	1.1	0.8	0.7	0.4	0.8	0.5	34	1.0	0.9	0.9	0.4	-	-
12	1.0	0.7	0.6	-	-	-	35	1.3	0.8	0.8	-	-	-
13	1.3	0.6	0.5	-	-	-	36	1.0	0.8	0.7	-	-	-
14	1.3	0.9	0.8	0.6	-	-	37	1.3	0.6	0.6	-	-	-
15	1.1	0.8	0.5	0.7	-	-	38	1.0	0.9	0.6	-	-	-
16	1.3	0.8	0.7	-	-	-	39	0.9	0.7	0.5	-	-	-
17	1.0	0.6	0.7	-	-	-	40	1.4	0.7	0.9	-	-	-
18	0.9	0.7	0.6	-	-	-	41	1.4	0.8	0.5	0.5	-	-
19	1.3	0.7	0.8	-	-	-	42	1.0	0.9	0.7	-	-	-
20	1.4	0.8	0.6	0.7	0.4	-	43	1.0	0.6	0.7	-	-	-
21	1.2	0.9	0.5	-	-	-	44	1.4	0.9	0.8	-	-	-
22	1.0	0.7	0.5	-	-	-	45	1.0	0.8	0.8	-	-	-
23	0.9	0.7	0.6	-	-	-							

Mean Length of AP com = 1.17 **Mean Length of PS com = 0.74** **Mean Length of AS com = 0.64**

Mean $\pm$ SD = 1.17 $\pm$ 0.13 **Mean $\pm$ SD = 0.74 $\pm$ 0.19** **Mean $\pm$ SD = 0.64 $\pm$ 0.10**

Table No.5

Number of Tricuspid valve Leaflets

Specimen Number	Number valve Leaflets	Specimen Number	Number valve Leaflets
1	3	24	3
2	3	25	3
3	3	26	3
4	4	27	3
5	3	28	4
6	3	29	6
7	3	30	3
8	3	31	3
9	3	32	3
10	3	33	3
11	6	34	4
12	3	35	3
13	3	36	3
14	4	37	3
15	4	38	3
16	3	39	3
17	3	40	3
18	3	41	4
19	3	42	3
20	5	43	3
21	3	44	3
22	3	45	3
23	3		

Table No.6

Shape of Tricuspid valve Leaflets

Sp. No	Shape valve Leaflets			Sp. No	Shape valve Leaflets		
	Anterior	Septal	Posterior		Anterior	Septal	Posterior
1	Triangular	Triangular	Triangular	24	Triangular	Triangular	Triangular
2	Triangular	Triangular	Triangular	25	Triangular	Triangular	Triangular
3	Triangular	Triangular	Triangular	26	Triangular	Semicircular	Triangular
4	Triangular	Triangular	Triangular	27	Triangular	Triangular	Triangular
5	Triangular	Triangular	Triangular	28	Triangular	Triangular	Triangular
6	Triangular	Triangular	Triangular	29	Triangular	Triangular	Triangular
7	Triangular	Triangular	Triangular	30	Triangular	Triangular	Triangular
8	Triangular	Triangular	Triangular	31	Triangular	Triangular	Triangular
9	Triangular	Triangular	Triangular	32	Triangular	Triangular	Triangular
10	Triangular	Triangular	Triangular	33	Triangular	Semicircular	Triangular
11	Triangular	Triangular	Triangular	34	Triangular	Triangular	Triangular
12	Triangular	Triangular	Triangular	35	Triangular	Triangular	Triangular
13	Triangular	Triangular	Triangular	36	Triangular	Triangular	Triangular
14	Triangular	Triangular	Triangular	37	Triangular	Triangular	Triangular
15	Triangular	Triangular	Triangular	38	Triangular	Triangular	Triangular
16	Triangular	Triangular	Triangular	39	Triangular	Triangular	Triangular
17	Triangular	Triangular	Triangular	40	Triangular	Triangular	Triangular
18	Triangular	Semicircular	Triangular	41	Triangular	Triangular	Triangular
19	Triangular	Triangular	Triangular	42	Triangular	Triangular	Triangular
20	Triangular	Triangular	Triangular	43	Triangular	Triangular	Triangular
21	Triangular	Triangular	Triangular	44	Triangular	Triangular	Triangular
22	Triangular	Triangular	Triangular	45	Triangular	Triangular	Triangular
23	Triangular	Triangular	Triangular				

Table No.7

Height of Tricuspid valve Leaflets

Sp.No	Height of Leaflets(cm)			Sp.No	Height of Leaflets(cm)		
	Anterior	Septal	Posterior		Anterior	Septal	Posterior
1	2.2	1.7	2.1	24	2.3	1.9	1.7
2	2.1	1.7	2.1	25	2.2	1.4	1.7
3	2.1	1.6	2.2	26	2.2	1.5	1.7
4	2.5	1.7	2.1	27	2.5	1.7	1.8
5	2.2	1.4	1.9	28	2.4	1.8	2.0
6	2.4	1.5	2.1	29	1.9	1.8	1.7
7	2.0	1.6	2.2	30	2.1	1.9	1.9
8	2.4	1.7	1.7	31	2.3	1.6	1.9
9	2.4	1.8	1.7	32	2.0	1.7	1.8
10	1.9	1.9	1.7	33	2.1	1.6	2.2
11	2.1	1.7	1.8	34	2.2	1.6	1.8
12	2.1	1.8	1.7	35	2.2	1.7	2.0
13	2.0	1.9	1.9	36	2.4	1.7	1.7
14	2.5	1.8	1.8	37	2.2	1.9	1.7
15	1.9	1.4	2.2	38	2.5	1.5	1.8
16	2.0	1.9	2.1	39	1.9	1.7	2.2
17	2.0	1.7	2.1	40	2.1	1.6	1.7
18	2.4	1.4	2.2	41	2.3	1.9	1.9
19	2.4	1.5	2.2	42	2.4	1.8	2.2
20	2.4	1.5	1.9	43	2.1	1.4	1.9
21	2.5	1.8	1.8	44	1.9	1.8	1.9
22	2.4	1.7	1.7	45	2.0	1.6	2.2
23	2.3	1.9	1.8				

Mean Ht. of Ant Leaflet = 2.21cm **Mean Ht. of Septal Leaflet = 1.68cm** **Mean Ht. of Post Leaflet = 1.92cm**

Mean $\pm$ SD = 2.21 $\pm$ 0.19cm **Mean $\pm$ SD = 1.68 $\pm$ 0.16cm** **Mean $\pm$ SD = 1.92 $\pm$ 0.19cm**

Table No.8

Length of Tricuspid valve Leaflets

Sp.No	Length of valve Leaflets(cm)			Sp.No	Length of valve Leaflets(cm)		
	Anterior	Septal	Posterior		Anterior	Septal	Posterior
1	3.5	3.0	2.3	24	3.3	2.8	3.0
2	3.1	3.6	2.6	25	3.7	2.9	2.1
3	3.4	3.5	2.1	26	3.3	3.2	2.5
4	3.9	2.8	2.6	27	3.8	2.9	2.1
5	3.8	3.8	2.1	28	3.7	3.2	3.0
6	3.8	3.8	2.6	29	3.4	3.0	2.1
7	3.7	2.9	2.3	30	3.8	3.0	2.1
8	3.8	3.9	2.2	31	3.0	3.3	2.7
9	3.9	3.8	2.8	32	3.6	3.0	2.4
10	3.5	3.4	2.7	33	3.9	2.8	2.1
11	3.6	3.4	2.5	34	3.5	3.1	3.2
12	3.0	3.0	2.0	35	3.9	2.9	2.0
13	3.3	3.8	2.6	36	3.1	3.5	2.4
14	3.8	3.9	3.2	37	3.2	3.7	2.1
15	3.6	3.7	2.8	38	3.4	3.6	2.3
16	3.4	3.0	3.0	39	3.2	3.5	2.0
17	3.4	3.3	2.1	40	3.0	3.6	3.1
18	3.7	2.9	2.4	41	3.3	2.8	3.2
19	3.9	3.0	2.3	42	3.2	3.0	2.4
20	3.9	2.8	2.9	43	3.7	3.8	3.1
21	3.3	3.2	2.3	44	3.3	3.1	3.2
22	3.7	3.2	2.1	45	3.4	3.6	2.9
23	3.4	3.0	2.4				

Mean Length of Ant Leaflet = 3.51cm Mean Length of septal Leaflet = 3.26cm Mean Length of post Leaflet = 2.51cm

Mean $\pm$ SD = 3.51 $\pm$ 0.27 **Mean $\pm$ SD = 3.26 $\pm$ 0.36** **Mean $\pm$ SD = 2.51 $\pm$ 0.39**

Table No.9

Shape, Length, Height of Accessory Leaflets of Tricuspid valve

Sp.No	Shape	Length of Accessory Leaflets(cm)			Height of Accessory Leaflets(cm)		
		Acc-1	Acc-2	Acc-3	Acc-1	Acc-2	Acc-3
4	Triangular	1.2	-	-	0.8	-	-
11	Triangular	1.2	0.7	1.0	1.0	0.7	0.6
14	Triangular	1.2	-	-	0.9	-	-
15	Triangular	1.1	-	-	0.8	-	-
20	Triangular	1.0	1.2	-	0.7	1.2	-
28	Triangular	0.9	-	-	1.4	-	-
29	Triangular	1.4	1.1	1.0	1.2	1.4	1.2
34	Triangular	1.0	-	-	0.8	-	-
41	Triangular	1.1	-	-	0.6	-	-

Table No.10

Number of Chordae Tendineae at Origin from the Papillary Muscle

Sp.No	Number of Chordae Tendineae at Origin(Papillary Muscle)			Sp.No	Number of Chordae Tendineae at Origin(Papillary Muscle)		
	Anterior	Septal	Posterior		Anterior	Septal	Posterior
1	5	7	4	24	5	0	2
2	6	6	1	25	6	6	5
3	5	8	5	26	3	6	2
4	7	0	3	27	9	7	2
5	5	7	5	28	3	3	2
6	6	1	3	29	4	1	8
7	4	0	5	30	6	0	5
8	7	4	4	31	4	1	6
9	4	5	5	32	6	8	4
10	6	2	6	33	4	0	2
11	7	0	2	34	5	6	2
12	3	8	3	35	7	7	6
13	9	1	2	36	8	3	5
14	8	4	1	37	3	0	2
15	9	5	2	38	6	1	5
16	3	4	5	39	4	7	4
17	7	5	5	40	7	8	4
18	6	7	3	41	9	5	7
19	5	0	6	42	3	4	5
20	5	3	2	43	7	3	1
21	8	0	3	44	6	2	6
22	7	8	5	45	8	4	2
23	3	0	2				

Mean from APM = 5.73 **Mean from SPM = 3.71** **Mean from PPM = 3.75**

Mean $\pm$ SD = 5.73 $\pm$ 1.85 **Mean $\pm$ SD = 3.71 $\pm$ 2.89** **Mean $\pm$SD = 3.75 $\pm$ 1.77**

Table No.11

Number of Chordae Tendineae at Origin from Papillary Muscle

No of Chordae Tendineae at origin	APM	SPM	PPM
0	-	10	-
1-2	-	7	15
3-5	20	13	21
6-8	21	15	7
9-10	4	-	-

Table No.12

Number of Chordae Tendineae at Insertion in Leaflets

No of Chordae Tendineae at Insertion	ANTERIOR LEAFLET	SEPTAL LEAFLET	POSTERIOR LEAFLET	COMMISSURE
3-6	-	8	-	45
7-9	6	28	6	-
10-12	12	7	26	-
13-15	24	2	10	-
16-18	8	0	3	-
19-21	5	0	-	-

Table No.13

Number of Chordae Tendineae at Insertion in Leaflets

Sp. No	Number of Chordae Tendineae at Insertion(Leaflets)				Sp. No	Number of Chordae Tendineae at Insertion(Leaflets)			
	Anterior	Septal	Posterior	Commissure		Anterior	Septal	Posterior	Commissure
1	15	12	14	3	24	14	10	10	3
2	11	10	8	3	25	15	8	8	3
3	21	8	10	4	26	11	10	13	5
4	16	9	8	4	27	9	14	9	3
5	17	11	16	3	28	9	11	9	3
6	13	13	18	3	29	20	9	12	6
7	16	10	10	3	30	18	10	10	3
8	13	9	12	5	31	10	13	15	3
9	19	11	18	3	32	18	9	11	3
10	16	11	9	3	33	9	13	18	6
11	16	12	14	3	34	15	8	7	3
12	17	9	8	3	35	20	13	14	5
13	16	11	13	6	36	13	8	15	3
14	12	12	16	3	37	19	10	11	3
15	17	10	11	4	38	9	12	17	3
16	13	13	13	3	39	12	8	13	4
17	11	14	10	3	40	9	11	12	3
18	13	8	12	4	41	14	10	9	3
19	12	10	15	3	42	16	16	15	4
20	13	14	9	4	43	17	8	12	4
21	15	16	9	3	44	11	8	12	3
22	12	12	17	5	45	15	12	7	3
23	13	11	9	3					

Mean CT at Anterior leaflet = 14.22 **Mean CT at septal leaflet = 10.82** **Mean CT at Posterior leaflet = 11.95**

Mean + SD = 14.22 + 3.25 **Mean + SD = 10.82 + 2.14** **Mean + SD = 11.95 + 3.16**

Table No.14

Number of Bellies present in each Papillary Muscle

No. of Bellies	Anterior Papillary Muscle	Septal Papillary Muscle	Posterior Papillary Muscle
Absent	0	10(22.2%)	0
Single	37(82.2%)	7(15.6%)	17(37.8%)
Two	7(82.2%)	14(31.1%)	20(44.4%)
Three	1(2.2%)	10(22.2%)	8(17.8%)
Four	0	4(8.9%)	0

Chart No:1

Shape of Tricuspid Valve Annulus

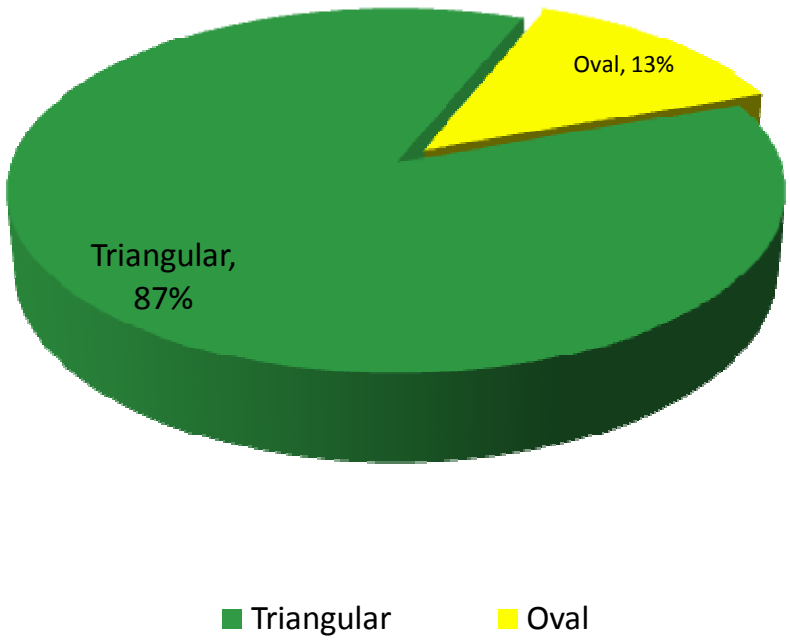


Chart No: 2(a)

Circumference of Tricuspid Valve Annulus

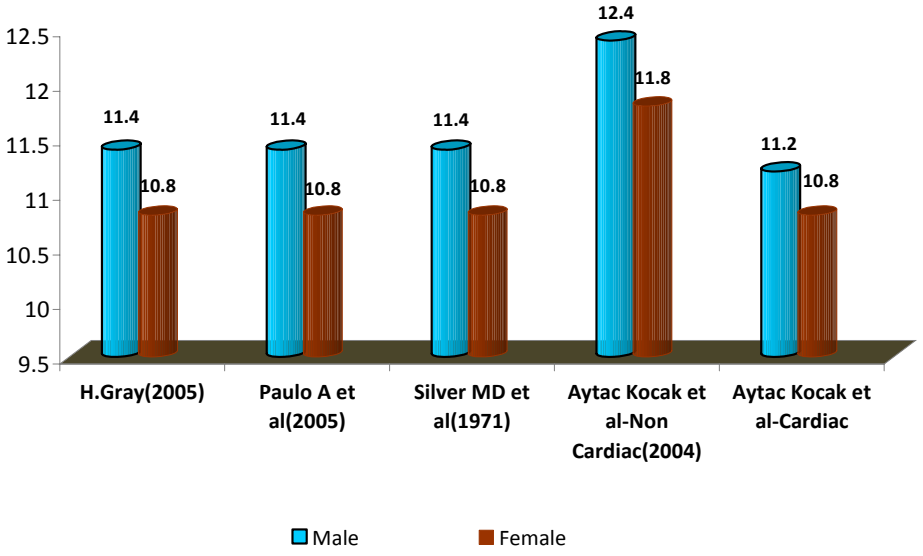


Chart No: 2(b)

Circumference of Tricuspid Valve Annulus

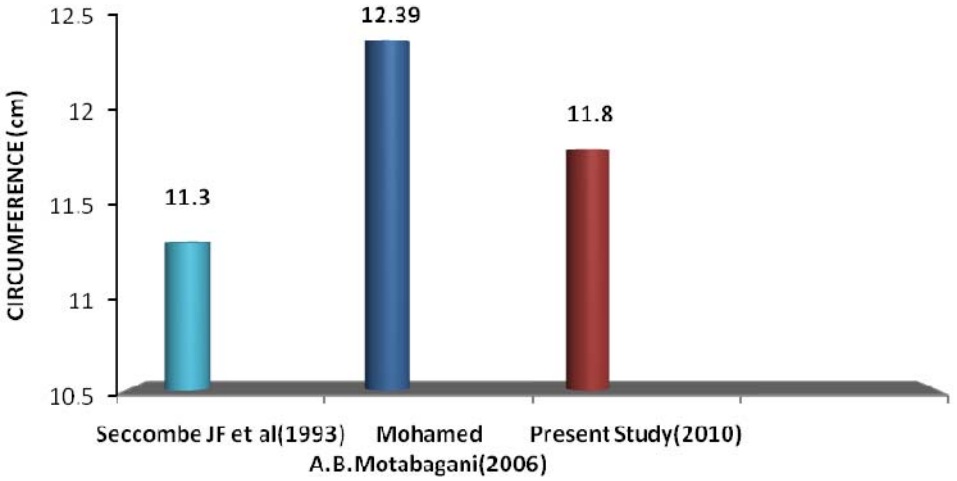


Chart No: 3

Length of commissures

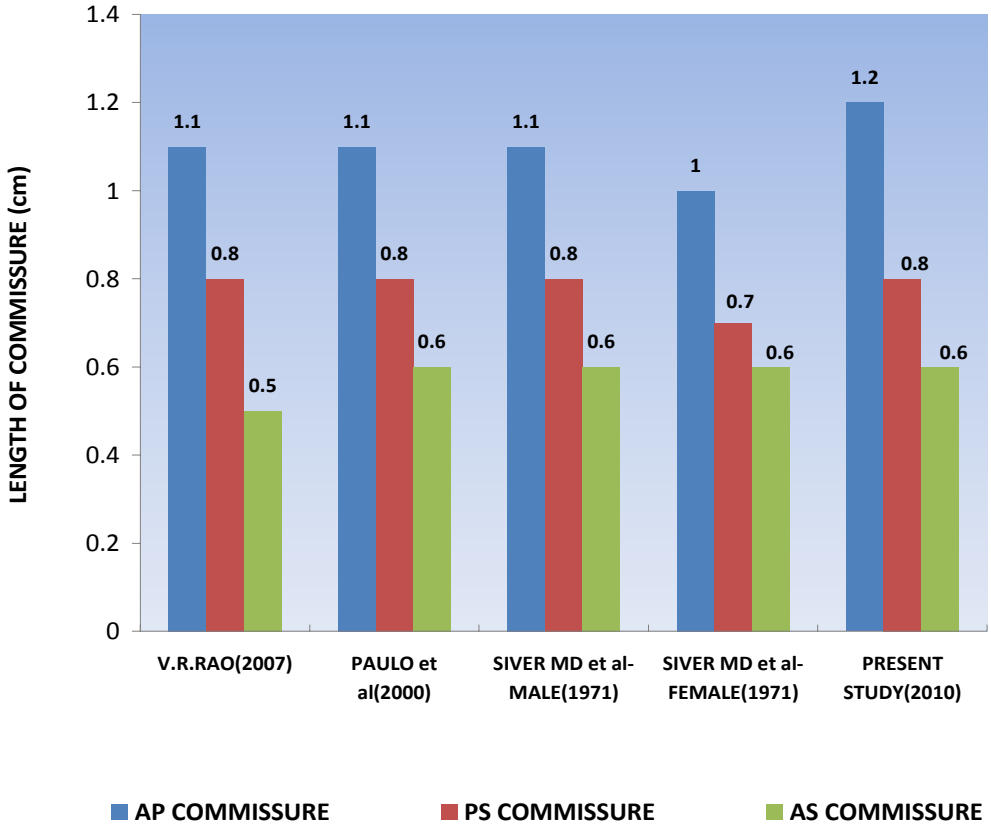


Chart No: 4

NUMBER OF TRICUSPID VALVES IN PRESENT STUDY

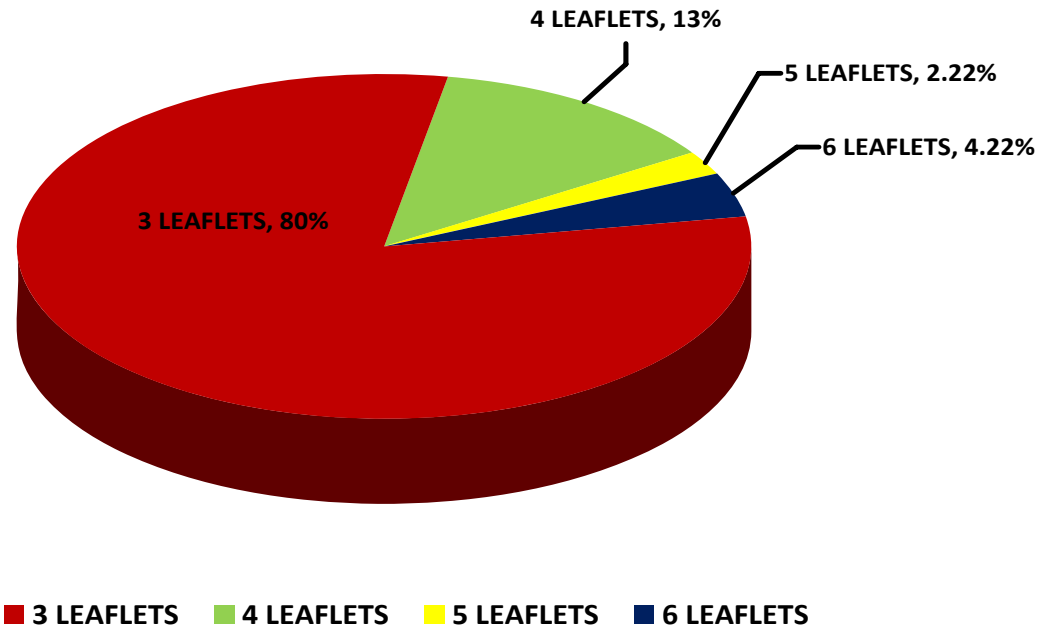


Chart No: 4(a)

Shape of Tricuspid Valve Leaflets

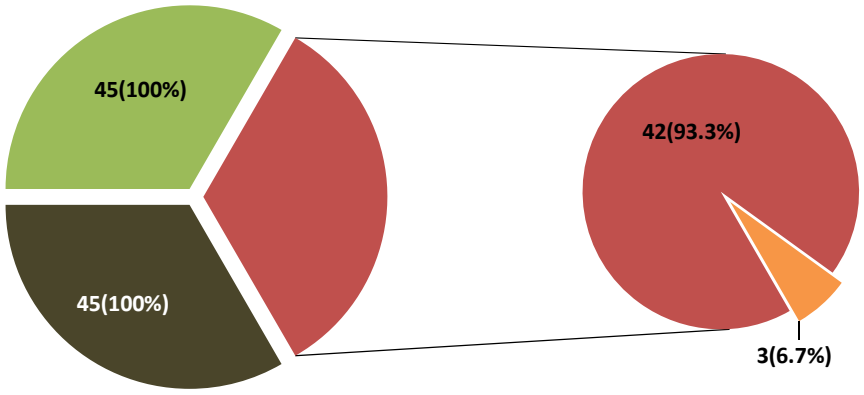


Chart No: 5

Height of Tricuspid valve Leaflets

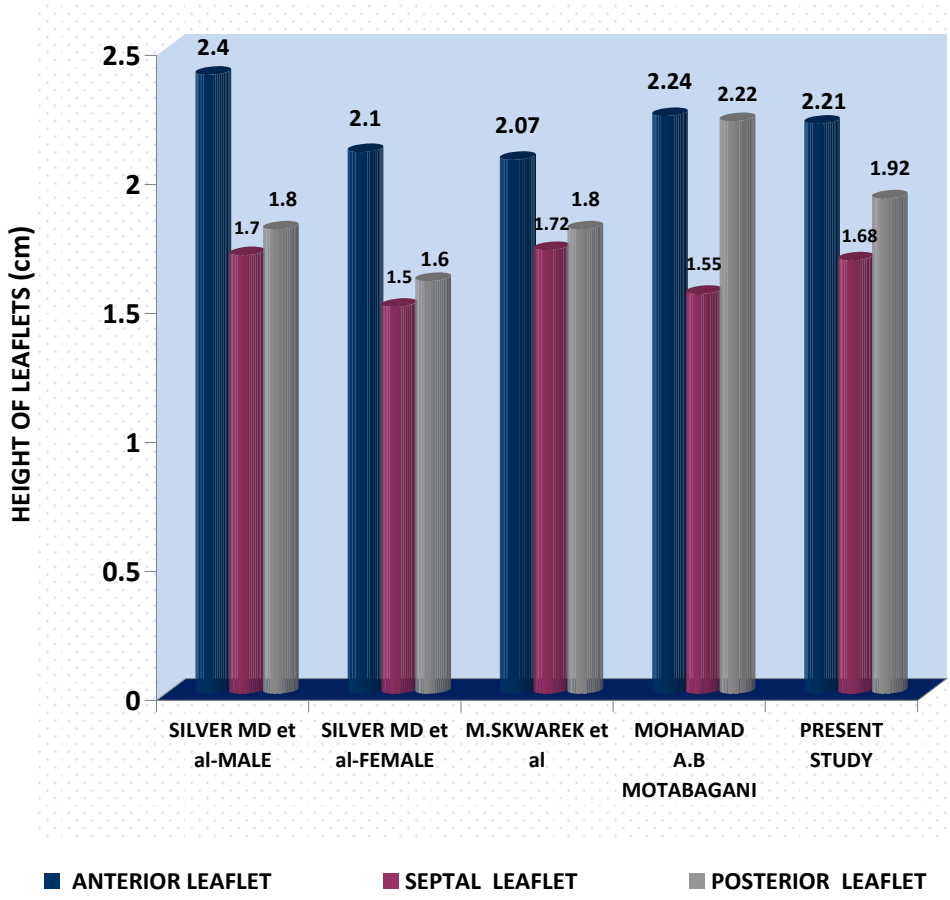


Chart No: 6

Length of Tricuspid valve Leaflets

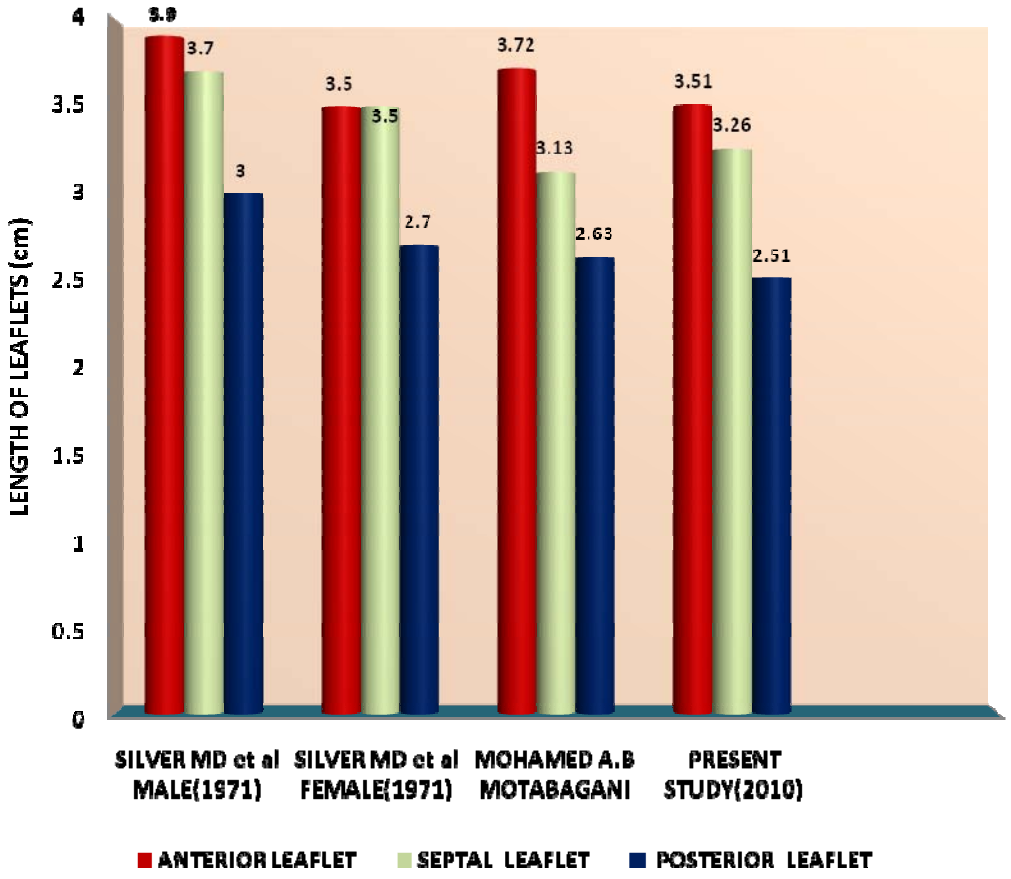


Chart No: 7

Number of Chordae Tendineae at Origin from Papillary Muscles

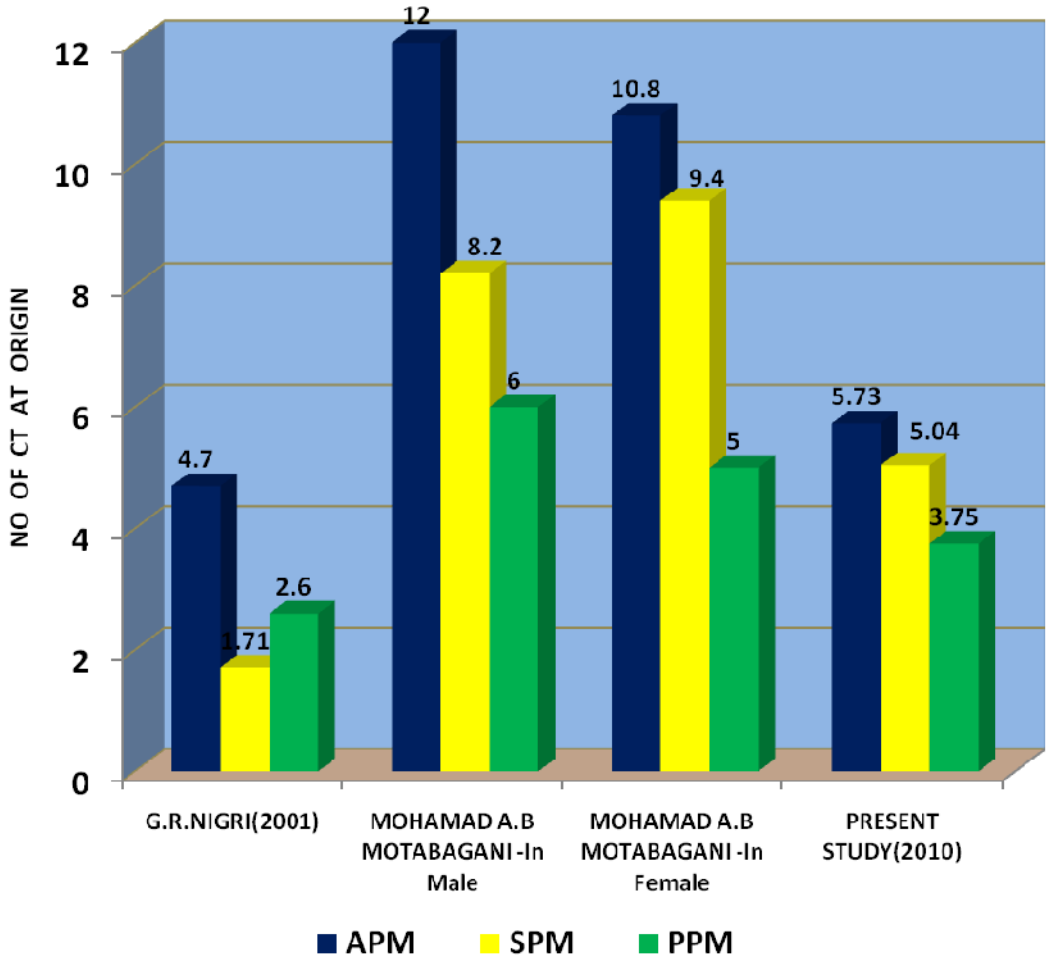


Chart No: 8

Number of Chordae Tendineae at Insertion in Leaflets

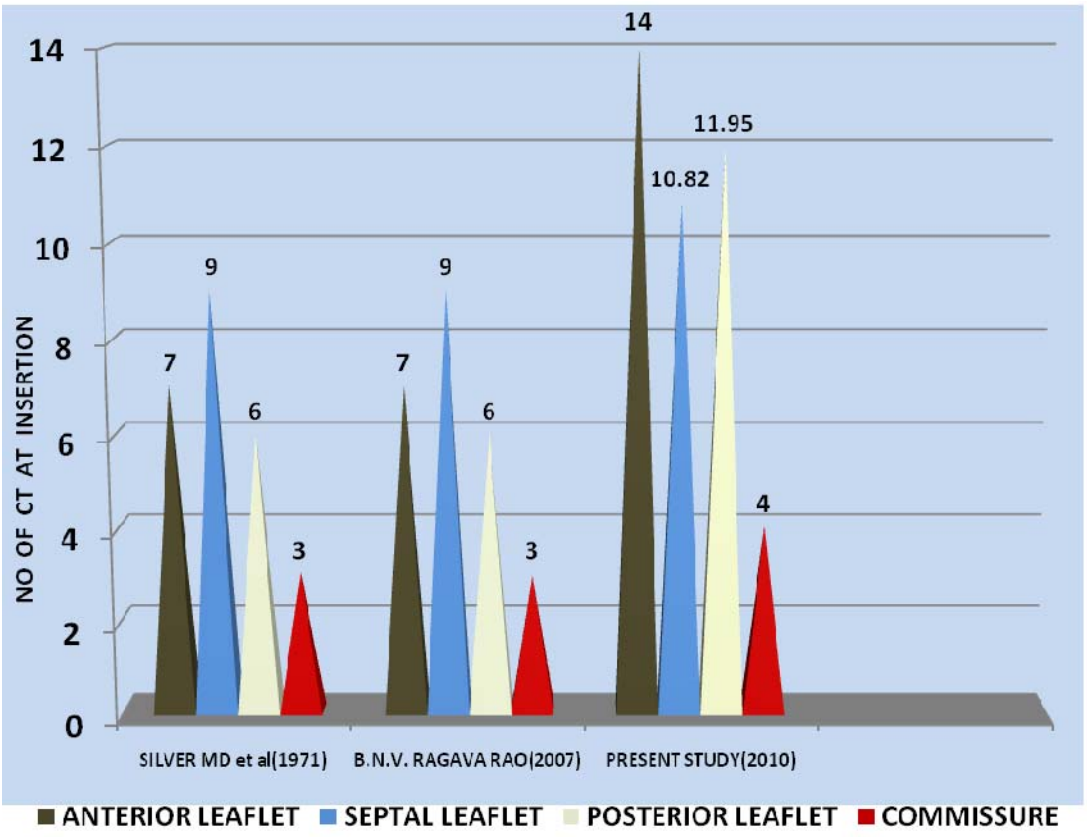


Chart No: 9(a)

Number of Bellies present in each Papillary Muscle

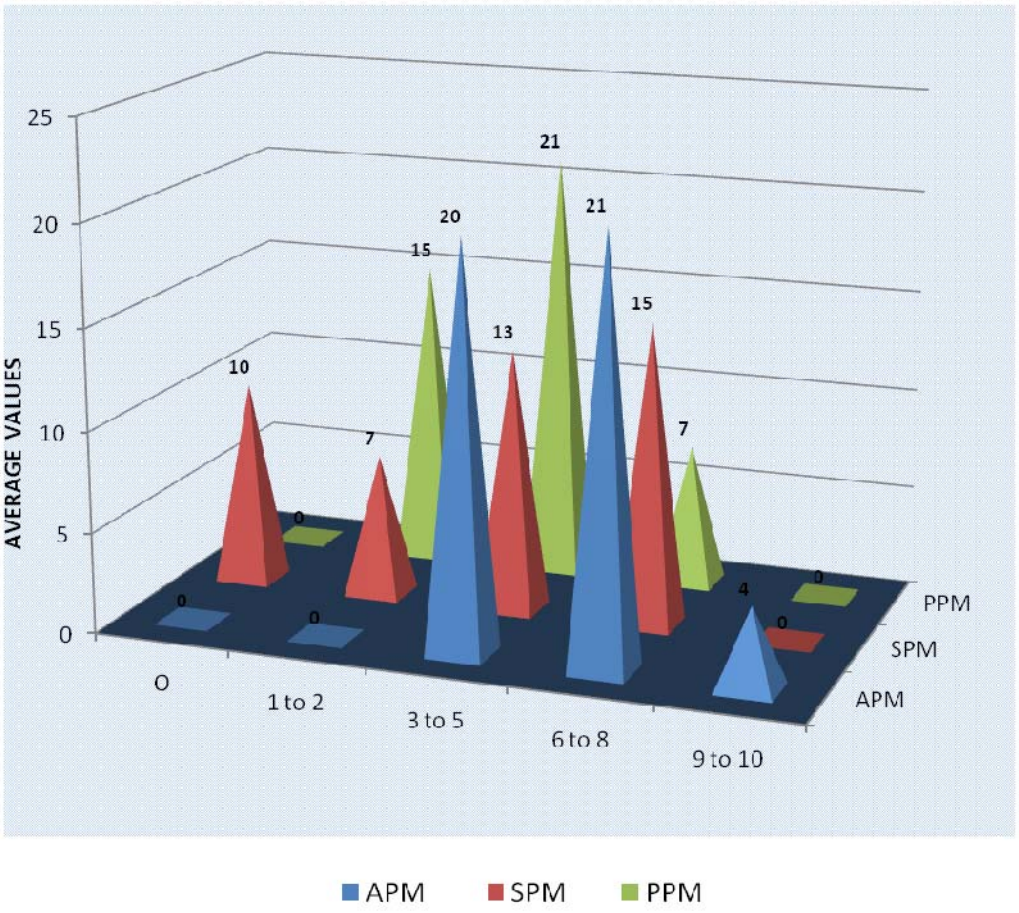


Chart No: 9(b)

Number of Bellies present in each Papillary Muscle

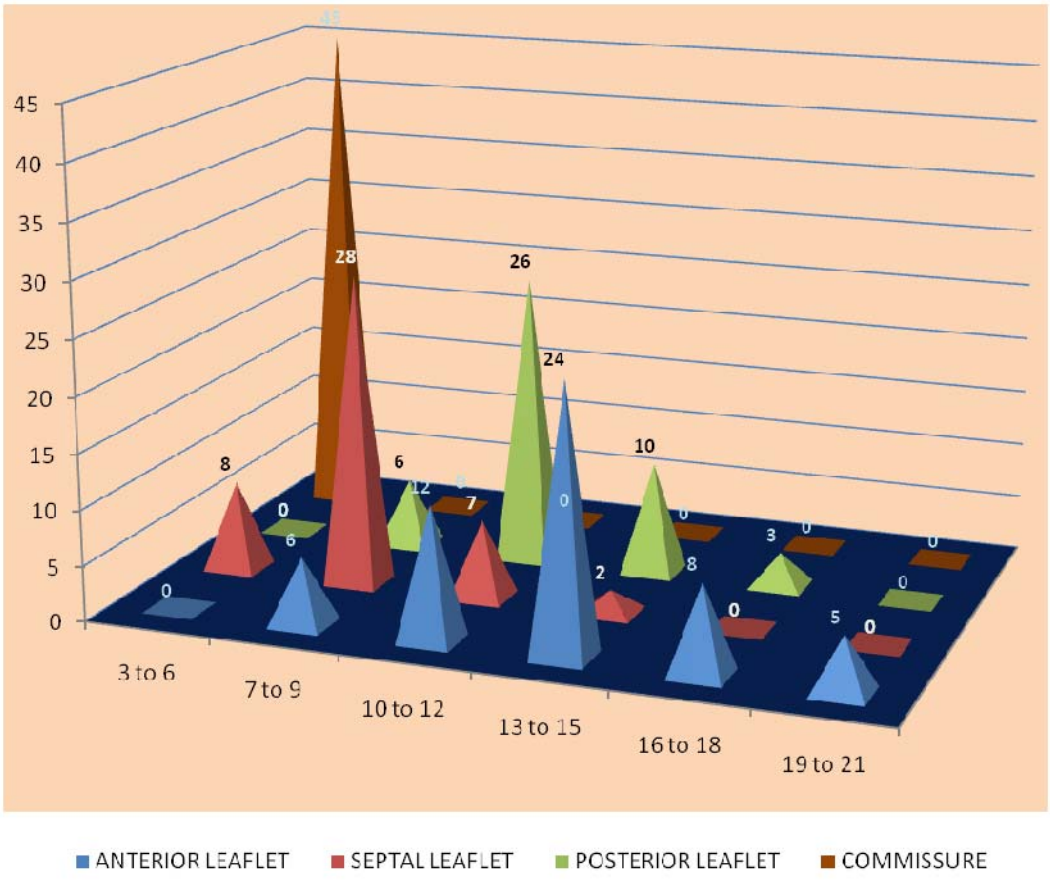
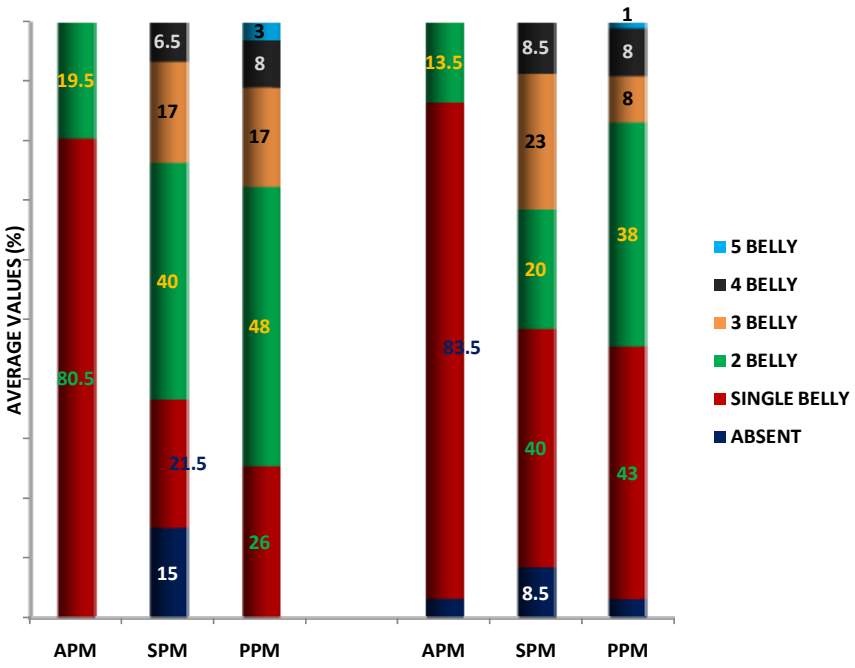


Chart No: 10

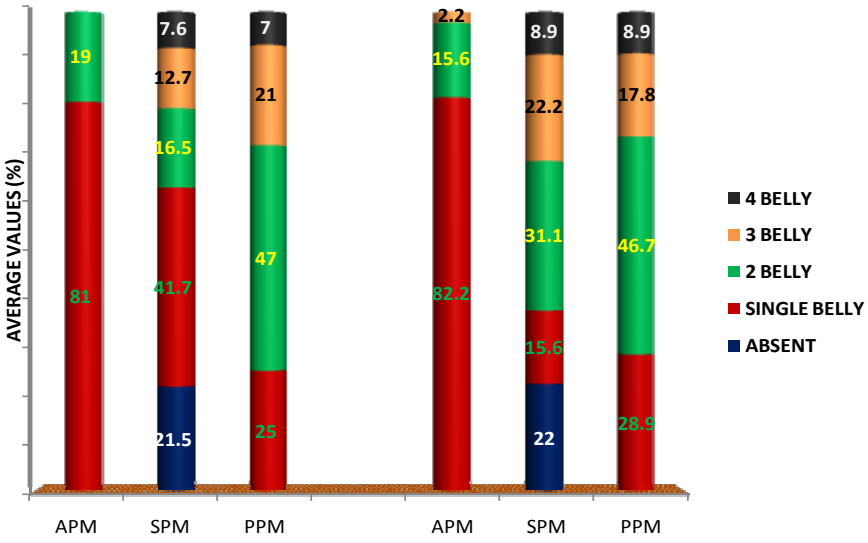
Number of Bellies present in each Papillary Muscle(%)



KOCAK et al STUDY(Non-Cardiac deaths) **KOCAK et al STUDY(Cardiac deaths)**

Chart No: 11

Number of Bellies present in each Papillary Muscle(%)



G.R.NIGRI STUDY(2001) **PRESENT STUDY(2010)**