Anatomy of the Human Tricuspid Valve*

KHAN, A.A.
ALI, I.I. and
KARIM, M.A.

SUMMARY

A study of the gross morphology of the tricuspid valve and its components was undertaken in 43 human hearts uncomplicated by cardiopulmonary disease. Some variations in the anatomic features of the cusps, papillary muscles and chordae tendineae were found in this valve. These variations suggest a spectrum of normality in the tricuspid valve of human heart, at least in the Pakistani population. In the light of these findings, some of the terminology has been reviewed and re-defined.

Key words :

Commissure - Papillary muscles - Chordae tendineae - Cusps.

INTRODUCTION

Despite considerable clinical interest in the diseases of the tricuspid valve (Perloff & Harvey, 1960; Carpentier et al., 1974 and Mahapmra et at., 1978), studies on the structure of this valve complex are limited (Silver et al., 1971). This is in contrast to the large repertory of work on the mitral valve (Ranganathan et at., 1970; Lam et al., 1970; Becker & De Wit, 1979 and Wenink & Giltenberger - de Groot, 1986). Since surgical management of the valvular heart disease is one of the recommended methods of treatment in selected cases (Grondin et al., 1967 and Colin, 1978), gross morphology of the normal human tricuspid valve needs further elucidation.

The present study was undertaken to examine the anatomic features of the cusps, papillary muscles and chordae tendineae of the tricuspid valve and to identify their variations within normal limits in order to establish a spectrum of normality in human hearts. Hopefully, the findings may be useful in future surgical procedures on this valve.

Besides, some ambiguity seems to have crept up in the terminology used by various workers for commissure, notch, and cleft of the valves. We found it necessary to review previous literature and re-define (see DISCUSSION) some of the terms to clarify the concept of these structures.

MATERIALS AND METHODS

A total of 43 hearts obtained from embalmed cadavers, 37 males and 6 females were examined. However, a detailed study of the number, size and attachments of the papillae, chordae tendineae and leaflets of the tricuspid valve was carried out in 25 hearts; the remaining 18 hearts were discarded because of poor perfusion and preservation. The hearts belonged to individuals aged 15 to 50 years who died of accidental or natural causes and had not suffered from any major cardiopulmonary disease.

Right ventricles were opened through an incision starting from the pulmonary trunk and ending at the ventricular apex running parallel to the interventricular septum on the anterior aspect. A cut was made in the anterior

* Request for reprints to Professor M. A. Karim,
Chairman, Department of Anatomy,
The Aga Khan University,
Faculty of Health Sciences.
Stadium Road, P.O. Box 3500
KARACHI - 5, PAKISTAN.

cusp through its mid-region upto its basal attachment. A second incision was made through the supraventricular crest joining the previous incision in the basal part of the anterior cusp and this incision was extended to the right atrium.

In view of the fact that the hearts were preserved in formalin and some shrinkage had occurred, all measurements which were made to the nearest millimeter by a metric scale, were considered of only relative significance and are being not reported here. Observations were made on the configuration of cleft, notch and margin of the cusps from the atrial and ventricular aspects of the valve. In order to examine in detail the ventricular aspect of the cusps which received chordal 'insertions', papillary muscles were severed at their bases and all other muscular attachments of chordae made free. The location, length, attachment and abnormalities of the papillary muscles and chordae tendineae were noted.

RESULTS CUSPS/LEAFLETS:

The ditrmensions of the posterior and septal cusps were significantly variable as compared to those of the anterior cusp. On average, the anterior cusps were relatively larger than the posterior and septal cusps; the latter two were approximately equal in size. The septal and posterior cusps were semicircular in contrast to the quadrangular shape of the anterior cusp. However, the posterior cusp because of subdivision into scallops gave the appearance of pelmets. Clefts were seen in a majority of posterior cusps and in only 5 hearts the posterior cusp showed no cleft. The posterior cusp was tri-scalloped in 9 hearts, bi-scalloped in 11 hearts and scallopless in 5 hearts. As regards the anterior cusp, a single cleft located immediately adjacent to the anteroseptal commissure was identified in only 9 hearts. Chordal insertions at the margin produced marginal undulations in all cusps, otherwise no inherent serrations were evident at the margin.

PAPILLARY MUSCLES :

With the exception of the papillary muscle of the conus, which either took origin from the posterior limb or from the point of union of the anterior and posterior limbs of the trabecula septomarginalis, all other papillary muscles showed considerable variation, both in number and in location.

Separate anterior and posterior papillary muscles were present in 21 hearts and in the remaining 4 hearts they were fused. The fused anteroposterior papillary muscle was seen attached to the ventricular wall close to the distal end of the septomarginal trabecula (Fig. 1). Septal papillary (SP) muscles were found in only 16 hearts: in 11 hearts there was one SP muscle each, in 4 there were two SP muscles and in one heart there were as many as three SP muscles. A single mural papillary muscle was seen in 4 hearts and in 2 hearts, two mural papillary muscles were observed projecting from the anteroinferior wall of the ventricle. In 3 hearts, a septomural papillary muscle could be delineated with its septal and mural limbs of origin. A septomural papillary muscle was typically situated in the angle between the septal and inferior ventricular walls.

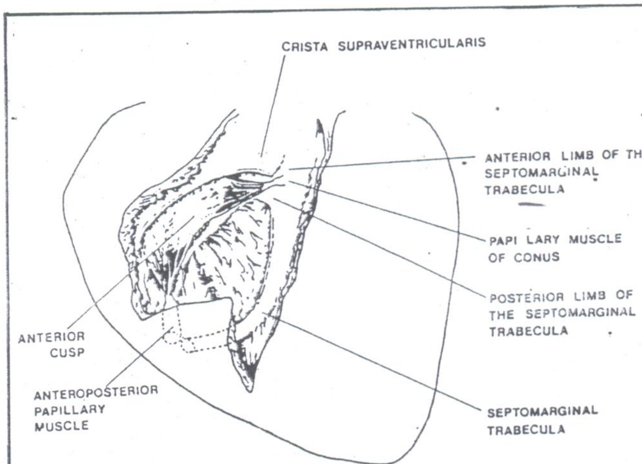

Fig. 1 Topographical reconstruction of the right ventricle showing attachment of the anteroposterior papillary muscle.

CHORDAE TENDINEAE :

There was no correlation between the size of a papillary muscle and the number of chordae tendineae originating from it. See Table I for the number of chordae tendineae originating from various papillary muscles and their pattern of attachment to cusps of the tricuspid valve.

TABLE I

Average number of chordae tendineae originating from various papillary muscles and their attachment to cusps of the Tricuspid valve.

Papillary muscles	Anterior cusps	Posterior cusps	Septal cusps
Anterior	5	2	0
Posterior	1	3	1
Anteroposterior	3	5	1
Papillary muscle of the conus	3	0	0
Mural	0	2	0
Septal	0	1	1
Septomural	2	3	0
Ventricular wall or Interventricular septum	2	3	9

Out of the total number (826) chordae counted in 25 tricuspid valves, 463 (56%) came directly from the papillary muscles, the remaining 363 (44%) were attached to either the ventricular wall or to the interventricular septum. Of all the chordae originating from the papillae, 37 (8%) chordae were found attached to the papillary muscles subapically. The papillary muscles mostly gave rise to rough-zone (33%), basal (24%), fanshaped (21%), deep (13%) and free-edge (9%) chordae. The stem of a rough-zone chorda in 97% of cases divided into three branches, each sub-dividing into groups of small branches before getting attached to the leaflets (Fig - 2). Most of the basal chordae (78%) were either attached to the ventricualr wall or to the interventricular septum. Rough-zone and fanshaped chordae originated from almost all papillary muscles. A single 'webbed', fanshaped chorda attached to a commissure in one of the valves was also identified. Interchordal bridges were observed in most of the branching chordae tendineae (fanshaped and rough-zone) and sometimes even existed between two different chordae. A clear pattern in the arrangement of false chordae tendineae could not be discerned.

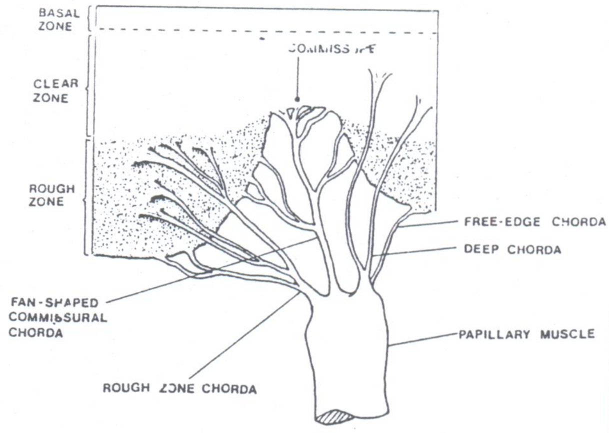

Fig. 2 Diagrammatic representation of the chordae attached to the tricuspid valve leaflets.

COMMISSURES AND COMMISURAL CHORDAE TENDINEAE:

Of the three commissures, the anteroseptal and posteroseptal commissures were, in general, not as deeply indented as was the anteroposterior commissure, In 4 hearts, the anteroseptal commissure was fused with the pars membranacea septi; consequently, a commissural chorda was lacking.

The site of origin of the anteroposterior, posteroseptal and anteroseptal commissural chordae varied considerably. See Table II for distribution of these chordae in 25 hearts examined in this study.

DISCUSSION

In this study, we have focused attention mainly on the investigation of the anatomic features and variations within normal range seen in the human tricuspid valve. As stated in the introduction, with the exception of the classical work of Silver et al. (1971), studies on the gross morphological components of this valve are limited.

We recognize the involvement of epigenetic forces as one of the factors contributing variability in cardiac development (Krediet & Klein, 1981). This has led us to introduce certain criteria in the definitions of some of the terms used by

TABLE II

DISTRIBUTION OF COMMISSURAL CHORDAE

TYPES OF COMMISSURAL CHORDAE			
Site of Origin	Antero-posterior	Postero-septal	Antero-septal*
Ventricular wall or Interventricular septum	0	5	16
Anterior papilary muscle	16	0	0
Posterior papillary muscle	5	5	0
Anteroposterior papillary muscle	4	2	0
Papillary muscle of conus	0	0	5
Septal papillary muscle(s)	0	5	0
Septomural papillary muscle(s)	0	8	0
Mural papillary muscle	0	0	0

(Numbers indicate the number of hearts)

* In four hearts the anteroseptal commissural chordae were lacking because of fusion of the commissure with the pars membranacea septi.

earlier workers. According to these criteria, a commissure in the leaflets was identified by: (a) presence of a prominent (primary) indentation; (b) attachment of a fan-shaped chorda; (c) absence of rough-zone; and (d) the evidence of clear-zone extending to the margin in the indented area. We considered it necessary to clearly differentiate commissure from cleft and notch. While clefts and notches were both secondary and smaller indentations in a cusp's margin, a cleft had a rough-zone or a fan-shaped chorda in contrast to the notch where the rough-zone was reduced and a corresponding chorda was missing.

With regards to the definition of a cusp, we are in agreement with Lam et al. (1970) who have described a cusp as the valvular tissue between two commissures and have considered the concept of accessary cusps (Chiechi & Lees, 1956) as redundant. In our experience, the posterior and septal cusps appeared variable in size. Conte & Grieco (1984) have explained this variation on the basis of varying degrees of development of the cusp primordium. Any fusion of the cusps with the wall of the tricuspid orifice should be considered as an incomplete liberation of the cusps. The anteroseptal half of the septal leaflet, which corresponds to the membranous interventricular septum, is perhaps the last to be liberated (Odgeres, 1938). It is, as has been pointed out by Carpentier et al. (1974), not uncommon for this part to be partially fused with the membranous septum. In the present study, partial or complete fusion of the anteroseptal commissural part with the pars membranacea septi has been observed.

The papillary muscles showed numerous variations, both in morphology and in location. We have proposed the concept of septomural, mural and anteroposterior papillary muscles based on their topography in addition to the conventional types described by earlier workers. We continue to view papillary muscles as free standing trabeculae carneae because such an explanation could provide a developmental basis for a wide range of variability in these muscles. The atrioventricular valve leaflets develop by myocardial undermining and junctional invagination (Van Gils, 1977). As growth proceeds and the flaps enlarge, these muscular trabeculae become free and constitute the papillary muscles, and their juxtavalvular ends get converted into fibrous chordae tendineae (Williams & Warwick, 1980).

A clear pattern in the distribution of chordae tendineae was not discernible. A variety of chordae in the form of free-edge, basal, deep, rough-zone and webbed fan-shaped chordae was identified. Contrary to the classical description of rough-zone chordal stem dividing into three branches and getting attached directly to the cusps (Williams & Warwick, 1980), we found each of these branches further dividing into groups of smaller branches before their attachment to the cusps. It was of interest to note that most of the interchordal bridges were attached at right angles to the chordal stems.

The concept of 'chordal deficiency' in the mitral valve briefly alluded to by Lam et al., (1970) has been discussed at length by Becker and De Wit (1979) who have defined 'deficient chordae' as the chordae with an irregular (atypical) branching pattern, not compensated by neighbouring chordae and resulting in parts of the valve leaflets bulging upward termed 'hooding'. Becker & De Wit have suggested 'hooding' in mitral cusps as an acquired phenomenon which increases with age and in conditions accompanied by a prolonged rise in intraventricular pressure. We, on the other hand noted hooding in tricuspid leaflets of the hearts at all ages between 15 and 50 years and in the absence of any major heart disease. Chordal deficiency appears to be one of the major differences between the tricuspid and mitral valves. As far as the tricuspid valve was concerned, parts of the leaflets insufficiently supplied by chordae were characterized by three features. (a) irregular undulating margin, (b) hooding as an upward bulging of interchordal leaflet, and (c) thickening of the adjacent rough-zone. In our study, hearts with deficient chordae predominated, that is, 17 of the 25 hearts had deficient chordae.

The occurrence of false chordae was lacking in repetitive patterns. It appears that false chordae are remnants of trabecular connections in the ventricle which have become fibrous to varying extents as a result of ventricular expansion during cardiac development.

The most common aetiology of the tricuspid valve disease appears to be congenital (Becker and Anderson, 1981). This is commensurate with the observed preponderance of variability in the components of the tricuspid valve as compared to the mitral valve. Hence, what is normal in the tricuspid valve may not be so in the mitral valve. The danger in readily applying concepts of anomaly established from mitral valve studies to the tricuspid valve based on purely embryological studies should be obvious (Anderson, 1986).

References:

Anderson RH (1986) Normal and abnormal development of the mitral valve. Int J Cardiol 11: 99-101

Becker AE, & Anderson RH (1981) In: Pathology of Congenital Heart Disease, Postgraduate Pathology Series: Butterworths & Co. Ltd-London

Becker AE, & De Wit APM (1979) Mitral valve apparatus. A spectrum of normality relevant to mitral valve prolapse. Br Heart J 42: 680-689

Carpentier A, Deloche A, Hanania G, Furman J, Sellier P, Piwnica A, & Dubost C (1974) Surgical management of acquired tricuspid valve disease. J Thorac Cardiovasc Surg 67: 53-64

Cheichi MA, Less WM, & Thompson R (1956) Functional anatomy of the normal mitral valve. J Thorac Surg 32: 378-381

Colin LH (1978) Surgical treatment of valvular heart disease. Am J Surg 135: 444-447

Conte G, & Grieco M (1984) Closure of the Interventricular Foramen & Morphogenesis of the Membranous Septum and Ventricular Septal Defects in the Human Heart. Anat Anaz Jena 155: 39-55

Grondin P, Lepage G, Castongnay Y and Meere C (1967) The tricuspid valve: A surgical challenge. J Thorac Cardiovasc Surg 53: 7-11

Krediet P & Klein HW (1981) Synopsis of Normal Cardiac Development. IN: Perspective in Cardiovascular Research (ed) Thomas Pexieder, Vol 5 Mechanisms of Cardiac Morphogenesis & Teratogenesis Ravan Press New York

Lam JHC, Ranganathan N, Wigle ED and Silver MD (1970) Morphology of the human mitral valve. I chordae Tendineae: A new classification. Circulation 41: 449-458

Mahapmra RK, Agarwal JB, and Wasir AS (1978) Rheumatic tricuspid stenosis: Indian Heart J 30: 138-142

Odgeres PNB (1938) The development of the pars membranancea septi in the human heart, J Anat 72: 247-259

Perloff JK, and Harvey WP (1960) Clinical recognition of tricuspid stenosis; Circulation 22: 364-368

Ranganathan N, Lam JHC, Wigle ED, and Silver MD (1970) Morphology of the Human Mitral Valve: II The Valve Leaflets; Circulation 41: 459-467

Silver MD, Lam JHC, Ranganathan N, and Wigle ED (1971) Morphology of the human tricuspid valve; Circulation 43: 333-348

Van Gils FAW (1977) The prenatal development of the atrioventricular valves in man. Acta Morphol Neerl-Scand 15: 90-91

Wenink, ACG and Giltenberger-de Groot AC (1986) Embryology of the mitral valve. In J Cardiol 11: 75-84

Williams PL and Warwick R (1980) In: Gray's Anatomy (36 edition) Churchill Livingstone - London 645-647