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Tricuspid valve complex- a study on its variations in North Indian population and clinical implications

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SUMMARY

Since cardiovascular diseases are emerging as major causes of morbidity and mortality in the modern era, emphasis is laid on understanding normal as well as variant cardiac anatomy. Moreover, the advancement in diagnostic and therapeutic cardio-invasive techniques have prompted the revision of our existing knowledge and understanding about fine details of atrio-ventricular, valvular and chordo-papillary complexes. This study is an endeavour to establish the morphology of the tricuspid valve and chordo-papillary complex of the right ventricle in north Indian population and to compare it with previously provided data by different researchers. The study was conducted using 52 formalin-fixed adult human hearts. The presence, number, shapes, length, number of additional heads of the papillary muscles were observed. The morphology of the tricuspid valve was also noted. The morphology and morphometry of the tricuspid valve and papillary muscles were defined. Awareness of such information, whether normal or variant, is considered a prerequisite for successful, uncomplicated cardiac surgeries and interventional radiology.

Key words: Tricuspid valve – Papillary muscle – Morphology – Chordae tendineae – Right ventricle

INTRODUCTION

Since cardiovascular diseases are emerging as major causes of morbidity and mortality in the modern era, emphasis is laid on understanding normal as well as variant cardiac anatomy. The harmonious interplay of atrio-ventricular valvular complex and cardiac skeleton components together with atrial and ventricular myocardial masses is critical to achieve an efficient cardiac cycle. Moreover, the advancement in diagnostic and therapeutic cardio-invasive techniques have prompted the revision of our existing knowledge and understanding about fine details of atrio-ventricular valvular and chordo-papillary complexes.

The tricuspid valve is having 3 leaflets made up of reduplication of endocardium enclosing a collagenous core, continuous marginally and on its ventricular aspect with diverging fascicles of chordae tendineae and basally confluent with the annular connective tissue. According to Silver et al. (1971), the tricuspid valve annulus is best seen from its atrial aspect. It is roughly triangular and its margins are described as antero-superior, inferior and septal corresponding to the lines of attachment of the valvular leaflets. Trabeculae carneae, which are irregular muscular ridges and projections in the ventricular cavity, lined by the endocardium, are of varying type like free, fixed and papillary muscles. Classically, three groups of papillary muscles – the anterior papillary muscle, the posterior papillary muscle and the septal papillary muscle – are present in the right ventricle, bearing fibrous chordae tendineae, which support the adjacent cusps of the tricuspid valve and prevent their reversion and regurgitation during systole. The anterior papillary muscle is the largest and arises from the anterior wall, while the posterior papillary muscle is frequently bifid or trifid and arises from the inferior wall of right ventricle. Third smaller and most variable septal papillary muscle has a medial position, attached to the ventricular septum (Skwarek et al.,

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2004; Standring, 2008).

The tricuspid valve is often called the "forgotten valve" or "lost valve", because it is relatively understudied in comparison to the other cardiac valves; however, a few variations have been noted. Among the first who paid attention to the presence of accessory cusps was Tandler (1913), and later on Testut and Latarjet (1923) and Jastrzębski (1926); but the limitation of these studies was due to smaller sample size (Silver et al., 1971).

Morphological variations of papillary muscles and chordae tendineae are also frequently encountered, which may alter the fine synchronization between various components of the heart and so the cardiac activity. Such type of variations may lead into hazardous outcome during cardio-invasive procedures. Several studies also suggested disparities in epidemiology of various cardiovascular diseases McGruder et al. (2004).

This study is an endeavour to establish the morphology of the tricuspid valve and chordo-papillary complex of the right ventricle in North Indian population and to compare it with previously provided data by different researchers.

MATERIALS AND METHODS

The present work was carried out in the department of Anatomy, M.L.N. Medical College, Allahabad, India. 52 formalin fixed cadaveric hearts were dissected and the architecture of the tricuspid valve and the chordo-papillary complexes was studied. Papillary muscles were measured in length with the help of a digital vernier calliper. All hearts were within the age range between 45 and 80 years and sex was not considered in our study.

Method of dissection

We opened the right ventricle in 16 hearts by making an incision through the right atrium toward the right ventricle; the second incision was made from the pulmonary valve to the apex of the right ventricle. The drawback with this method was that the moderator band and the right coronary artery were often cut, so we opened the rest of the 36 hearts by making a small circular incision a few centimetres below the subpulmonary infundibulum and the right ventricular anterior wall was removed in pieces to visualise the interior of the right ventricle till the moderator band and the papillary muscles were identified (Loukas et al., 2005).

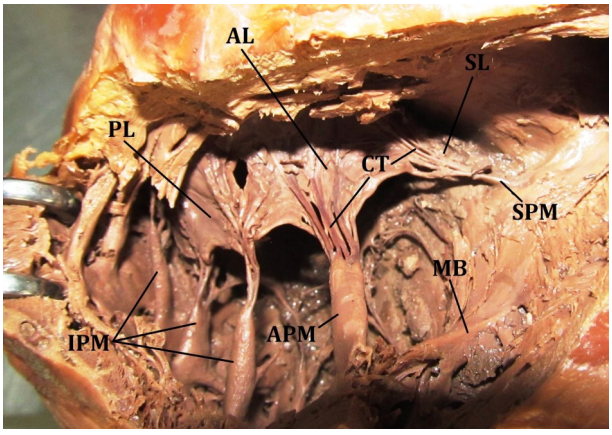

Fig 1. Showing 3 papillary muscles (APM- anterior papillary muscle, IPM- inferior papillary muscle, SPM-septal papillary muscle) along with tricuspid valve leaflets (AL-anterior leaflet, PL- posterior/Inferior leaflet, SL-septal leaflet), chordae tendineae (CT) and moderator band (MB).

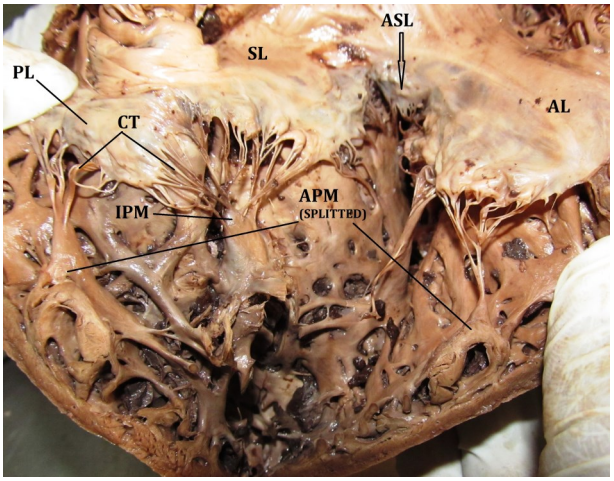

Fig 2. Right ventricle is splitted through anterior papillary muscle (APM) to expose 3 leaflets of tricuspid valve complex (AL- anterior leaflet, PL- posterior/Inferior leaflet, SL- septal leaflet) and black arrow showing accessory septal leaflet (ASL).

Observation

Leaflets of right atrio-ventricular (A-V) valve

The right A-V valves in all the specimens of this study were having three roughly triangular leaflets projecting into the right ventricle. Although indentations between adjacent leaflets were variable but appreciable enough to demarcate antero-superior (anterior), inferior (posterior) and medial (septal) leaflet of the tricuspid valve (Fig. 1). Commissures are deep indentations along the annulus which divide valve leaflets from each other. The commissure between anterior and septal leaflet is located in the membranous part of the interventricular septum dividing it into interventricuar and atrioventricular components. The rest of the two commissures are posterolateral and posteromedial, separating anterior, inferior and septal leaflets from each other respectively. The largest among them was the antero-superior leaflet, interposed between the conus arteriosus and the A-V orifice while the attachment of the inferior leaflet was mural, guarding the diaphragmatic margin of the A-V orifice. The septal leaflet was attached from the infero-septal to the antero-septal commissure on the posterior ventricular wall across the interventricular septum. We encountered accessory septal leaflets in 2 cases (3.85%) (Fig. 2).

Papillary muscles

Inspection of the interior of right ventricle revealed trabeculae carnae as endocardium lined muscular ridges and projections. The projections

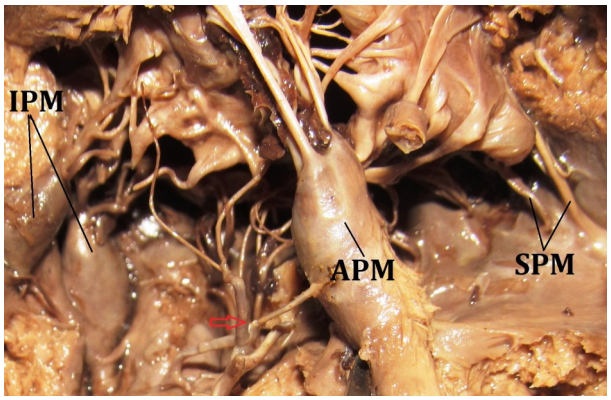

Fig 3. Two inferior papillary muscles (IPM) and one anterior papillary muscle (APM) and two septal papillary muscles (SPM). Arrow indicates false tendons in Rt ventricle.

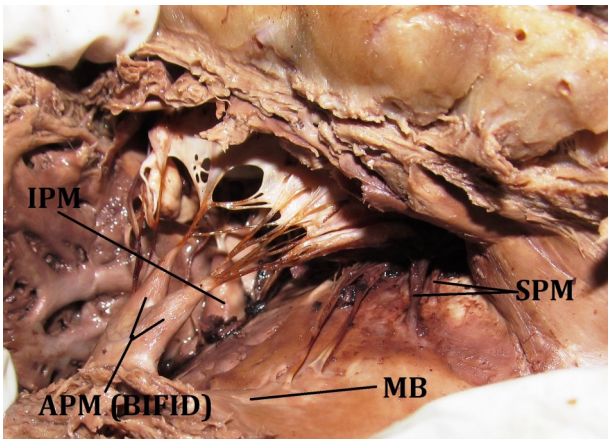

Fig 4. Bifid anterior papillary muscle (APM) and two septal papillary muscles (SPM).

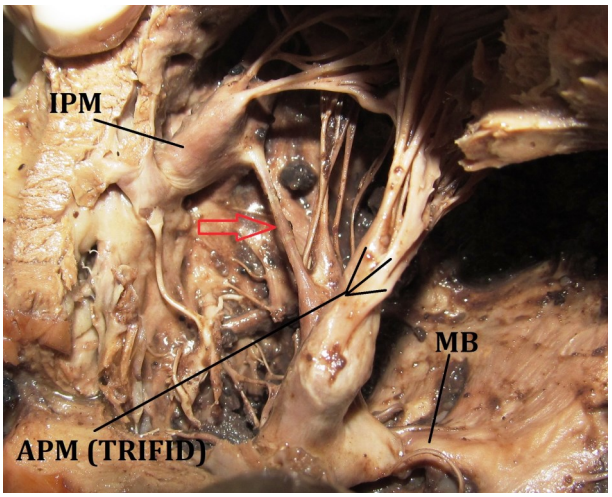

Fig 5. Trifid anterior papillary muscle (APM). Arrow indicates a thick muscular band of false tendon connecting the base of inferior papillary muscles (IPM) with anterior papillary muscle (APM).

attached with ventricular surface of free margins of the tricuspid valve leaflets through fibrous cord like chordae tendineae were recognised as papillary muscles and grouped into anterior, posterior/ inferior and septal papillary muscles.

It was noted that the anterior and inferior papillary muscles were present in 100% of cases while in 5 cases (9.6%) a definite septal papillary muscle was absent (Fig. 2). We also encountered two and three posterior papillary muscles in 4 cases (7.69%) and 2 cases (3.85%) respectively (Fig. 3).

The anterior papillary muscle was observed to be the largest among the three, arising from the antero-lateral wall of the right ventricle. It was single in its whole extent in 43 cases (82.69%) while bifid in 13 cases (25%) and trifid in 6 cases (11.54%) (Figs. 4, 5). In 10 cases (19.23%) we encountered accessory anterior papillary muscles (Fig. 6), and in 1 case (1.92%) the anterior papillary muscle was having two heads of origin from antero-lateral wall of right ventricle (Fig. 7). We also noticed an interesting case in which a thin muscular band was running between the base of the inferior papillary muscle to the tip of the anterior papillary muscle (Fig. 5).

In this study we measured the length of the papillary muscles and calculated the mean +/- 2SD for anterior, inferior and septal papillary muscles as 15.5 +/- 3.6, 14.3 +/- 3.1 and 8.0 +/- 1.4 mm respectively. These ranges are slightly different from those suggested by Hosapatna et al. (2014) for anterior, inferior and septal papillary muscles as 1.3 +/- 0.4, 0.98 +/- 0.4 and 0.55 +/- 0.2 cm respectively.

False tendons were observed in only 2 heart specimens (Figs. 3 and 5): the incidence of its occurrence in North Indian population is 3.84%.

DISCUSSION

The dynamic advancements of therapeutic and diagnostic cardio-invasive procedures have prompted researchers to revisit the anatomy of the tricuspid valve-complex (Wafae et al., 1990; Kocak et al., 2004; Chauhan et al., 2014; Aktas et al., 2004; Skwarek et al., 2005; Hosapatna et al., 2014; Xanthos et al., 2011). Comparing our results with those found in the literature, we found similarities but also differences, sometimes quite conclusive. Wafae et al. (1990) carried out an anatomical study in 50 human hearts and reported the commissural leaflets in 64% cases, and suggested that the tricuspid valves are not consistently tricuspid. But in our study, we have found only 2 cases (3.85%) having accessory septal leaflet; rest of 96.15% cases were having three leaflets in right atrio-ventricular valves.

Kocak et al. (2004) studied the structure of the human tricuspid valve and associated the chordae tendineae in an autopsy series of 400 cases of unexpected death. They reported two, three and four leaflets in right atrio-ventricular valves of 40 cases (20%), 140 cases (70%) and 20 cases (10%) respectively in a group of 200 deaths of non -cardiac origin. Another group of 200 cases under the death due to cardiac causes showed two, three and four leaflets in the right atrio-ventricular valves in 36 (18%), 130 (65%) and 34 (17%) cases respectively. Later on, Chauhan et al. (2014) also reported the presence of two, four and three leaflets in the right atrio-ventricular valves in 1%, 10%

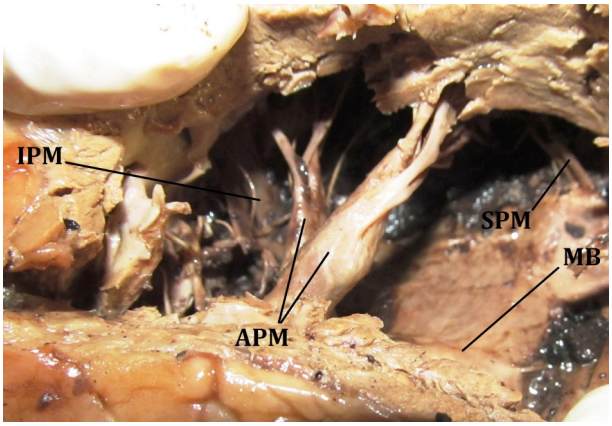

Fig 6. Showing two anterior papillary muscles (APM).

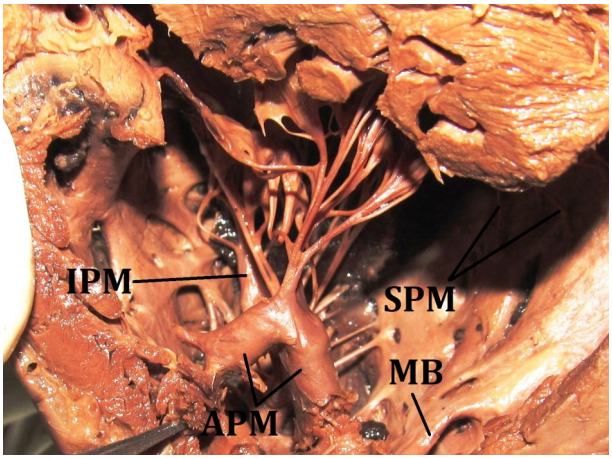

Fig 7. Anterior papillary muscle (APM) with two heads of origin.

and 89% of cases respectively in their study. Table 1 shows the comparison of leaflets observed in tricuspid valve in different studies.

The number of papillary muscles in the right ventricle ranges from 2 to 9, but usually 2 or 3 can be seen. The anterior papillary muscle is most prominent and inferior papillary muscle is frequently bifid or trifid (Standring, 2008). The septal/medial papillary muscle is least prominent and sometimes can even be absent Xanthos et al., 2011).

Nigri et al. (2001) studied a series of 79 human hearts focusing on the morphological characteristics of papillary muscles and associated chordae tendineae of the right ventricle. They observed that the anterior and inferior papillary muscles were present in 100% cases, whereas the septal papillary muscle was absent in 21.5% of cases. The average length of the anterior papillary muscles in this study was 19.16 mm and they were single headed in 81% and biheaded in 19% of cases. Septal papillary muscles were found to be on average 5.59 mm long and presented one, two and three heads in 41.7%, 16.5% and 12.7% of cases respectively. The average length of the inferior papillary muscle was 11.53 mm and one, two, three and four heads were observed in 25.4%, 46.8%, 21.5% and 6.3% of cases respectively.

In the present study, the anterior and inferior papillary muscles were found in 100% cases, while the septal papillary muscle was absent in 5 cases (9.61%). We also appreciated the anterior papillary muscle as the largest one, arising from the anterolateral wall of the right ventricle. It was single in its whole extent in 44 cases (84.62%), bifid in 5 (9.61%) and trifid in 3 cases (5.77%). In 10 cases (19.23) we noticed an accessory anterior papillary muscle, while in 12 cases (23.08%) the accessory inferior papillary muscle was present. The inferior papillary muscles arose from the inferior wall of the right ventricle and was single in 46 cases (88.46%) while bifid and trifid in 4 (7.69%) and 2 (3.84%) cases respectively.

In 2004, Aktas et al. studied variations in the papillary muscles of the normal tricuspid valve and their clinical relevance in medico legal autopsies. They found a single anterior papillary muscle in 80.5% of the cases (161 cases) and a double anterior papillary muscle in 19.5% (39 cases). Skwarek et al. (2005) worked on the morphology of papillary muscles of the right ventricle and subdivided the papillary muscles of the right ventricle into 16 subtypes. Ozgur et al. (2004) investigated the relationship of structure as well as number of papillary muscles in the tricuspid valve in cases of sudden deaths, especially those resulting from cardiac disease.

Table 2 shows the comparison of number of papillary muscles observed in various studies.

Saremi et al. (2015) have given an insight into various imaging modalities such as CT and MRI describing both quantitative and qualitative parameters related to the tricuspid valve and reviewed the role of these imaging modalities in the assessment of cardiac valve malfunction, and compared the role of well-established imaging modality echocardiography with CT and MRI in different pathological conditions of cardiac valves.

Addetia et al. (2017) described the geometry of the tricuspid annulus in different healthy volunteers using transthoracic 3D echocardiography. They inferred that gender and body size should be considered for making reference values for tricuspid valve annulus dimensions. They also stated that 3D echo underestimates tricuspid valve annulus parameters.[15]

Loukas et al. (2008) identified 35 out of 100 heart specimens with false tendons and classified them into five subtypes; type 1, 2, 4 were composed more of muscular fibres and type 2 and 5 were mainly fibrous in nature[16], while in our study false tendons were noted in only 2 heart specimens (Figs. 3 and 5); in one specimen it was mainly fibrous in nature and muscular in another one.

CONCLUSION

This study gives an overview about the normal anatomy and variations related to tricuspid valves and associated chordo-papillary complexes in the North Indian region, and can be used as a database. Accurate knowledge of the morphology and all possible variations is of utmost important in a

Table 1. Comparison of percentage of cases having different number of leaflets of right AV valve with other studies.

S. No.	Studies	% of cases having following no. of leaflets		
		3 leaflets	4 leaflets	2 leaflets
1.	Sutton et al. (1995)	62	8	30
2.	Kocak et al. (2004) (death: non-cardiac)	70	10	20
	Kocak et al. (2004) (death: cardiac)	65	17	18
3.	Krunal et al. (2014)	89	10	1
4.	Skwarek et al. (2007)	63.85	36.15	0
5.	Kujur et al. (2016)	100	0	0
6.	Present study	96.15	3.85	0

Table 2. Comparison of percentage of cases having single, double and multiple number of anterior and inferior papillary muscles in the right ventricle with other studies.

S. No.	Studies	Anterior Papillary Muscle			Inferior Papillary Muscles			Septal Papillary Muscle	
		single	double	multiple	single	double	multiple	present	absent
1.	Aktas et al (2004)	80.5	19.5	0	100	0	0	100	0
2.	Hosapatna et al. (2014)	80	20	0	46.7	53.3	0	100	0
3.	Nigri et al. (2001)	100	0	0	100	0	0	78.5	21.5
4.	Kujur et al. (2016)	97.6	0	2.4	97.6	0	2.4	100	0
5.	Present study	80.8	19.2	0	88.5	7.7	3.8	90.4	9.6

successful and uncomplicated cardiothoracic surgery and other invasive procedures.

REFERENCES

ADDETIA K, MURARU D, VERONESI F, JENEI C, CAVALLI G, BESSER SA, MOR-AVI V, LANG RM, BADANO LP (2017) 3-Dimensional echocardiographic analysis of the tricuspid annulus provides new insights into tricuspid valve geometry and dynamics. *JACC Cardiovasc Imaging*, pii: S1936-878X(17)30902-6.

AKTAS EO, GOVSA F, KOCAK A, BOYDAK B, YAVUZ K (2004) Variations in papillary muscles of normal tricuspid valve and their clinical relevance in medicolegal autopsies. *Saudi Med J*, 25(9): 1176-1185.

CHAUHAN KR, UDAINIA A, MEHTA CD, CHAVDA K (2014) Study of incidence of an abnormal tricuspid valve in the human cadaveric heart. *Nat J Med Res*, 4 (3): 238-240.

HOSAPATNA M, SOUZA AD, DAS A, SUPRIYA M, ANKOLEKAR VH, SOUZA AS (2014) Morphology of papillary muscles in human adults: A cadaveric study. *Ibnosina J Med BS*, 6(4): 168-172.

KOCAK A, GOVSA F, AKTAS EO, BOYDAK B, YAVUZ IC (2004) Structure of the human tricuspid valve leaflets and its chordae tendineae in unexpected death: A forensic autopsy study of 400 cases. *Saudi Med J*, 25 (8): 1051-1059.

LOUKAS M, BENNINGER B, TUBBS RS (2013) *Gray's Clinical Photographic Dissector of the Human Body*. 1st ed. Saunders, Philadelphia, pp 90-94.

LOUKAS M, WARTMANN CT, TUBBS RS, APAYDIN N, LOUIS RG JR, BLACK B, JORDAN R (2008) Right ventricular false tendons, a cadaveric approach. *Surg Radiol Anat*, 30(4): 317-322.

MCGRUDER HF, MALARCHER AM, ANTOINE TL, GREENLUND KJ, CROFT JB (2004) Racial and ethnic disparities in cardiovascular risk factor among stroke survivors: United States 1999 to 2001. *Stroke*, 35(7): 1557-1561.

NIGRI GR, DI DIO LJ, BAPTISTA CA (2001) Papillary muscles and tendinous cords of the right ventricle of the human heart: Morphological characteristics. *Surg Radiol Anat*, 23(1): 45-49.

SAREMI F, HASSANI C, MILLÁN-NUÑEZ V, SÁNCHEZ -QUINTANA D (2015) Imaging evaluation of tricuspid valve: analysis of morphology and function with CT and MRI. *Am J Roentgenol*, 204: 531-542.

SILVER MD, LAM JHC, RANGANATHAN N, WIGLE ED (1971) Morphology of the human tricuspid valve. *Circulation*, 43: 333-348.

SKWAREK M, GRZYBIAK M, KOSINSKI A, HRECZECHA J (2004) Notes on the morphology of the tricuspid valve in the adult human heart. *Folia Morphol*, 63(3): 319-324.

SKWAREK M, HRECZECHA J, GRZYBIAK M, KOSINSKI A (2005) Remarks on the morphology of papillary muscles of the right ventricle. *Folia Morphol*, 64(3): 176-182.

STANDRING S (2008) Gray's Anatomy: The Anatomical Basis of Clinical Practice. 40th ed. Elsevier Churchill Livingstone, pp 966-967.

WAFAE N, HAYASHI H, GEROLA LR, VIEIRA MC (1990) Silver anatomical study of the human tricuspid valve. *Surg Radical Anat*, 12(1): 37-41.

XANTHOS T, DALIVIGKAS I, EKMEKTZOGLOU KA (2011) Anatomic variations of the cardiac valves and papillary muscles of the right heart. *Ital J Anat Embryol*, 116(2): 111-126.