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RESEARCH ARTICLE

COMPARATIVE ANATOMICAL STUDY OF THE TRICUSPID VALVE-COMPLEX IN HUMAN, SHEEP, GOAT, COW AND PIG

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ABSTRACT

Aims and objectives: Accurate functioning of the papillary muscles and their chordae is very essential to maintain good competence of the valves. Their dysfunction can lead to valvular incompetences. A comparative study of papillary muscles of ventricles of human, sheep, goat, cow and pig is done. Through this comparative anatomic approach, the morphology of the human tricuspid valve complex, its similarities and differences to those of the animal hearts studied becomes more apparent.

Methods: The hearts were opened to view the interior of the ventricles. Diameter of the tricuspid valve was measured in all the hearts. The number of papillary muscles, their positions, length and thickness in man and other mammals were noted. The number of chordae tendineae attached to each papillary muscle and the cusps along with their attachment to different zones of the cusps were observed and counted.

Results: The number and position of the papillary muscle was similar in all the specimens but the number of bellies of each papillary muscle varied. Length and thickness of the papillary muscles were more in cow and least in pig. Chordae tendineae number attached to the papillary muscle and to the cusp was more in pig and man. It was least in sheep and goat.

Interpretation and Conclusion: The internal structure of the heart differs from species to species. Although some differences exist, the heart of pig appears very similar to man.

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INTRODUCTION

William Harvey has compared the heart's interior to a ship's rigging. This forms an accurate description of cardiac morphology. Atrioventricular valve is defined as a complex consisting of a fibrous ring or annulus, cusps, chordae tendineae and papillary muscles. Right atrium communicates with the right ventricle through the right atrioventricular orifice guarded on the ventricular side by a tricuspid valve and so is known as tricuspid orifice. Papillary muscles are conspicuous protrutions (Standring Gray's *et al*., 2005). Anterior papillary muscle (APM), posterior papillary muscle (PPM) and septal papillary muscle (SPM) are located in the right ventricle. Veterinary textbooks describe that in animals, right atrium communicates with the right ventricle through the ostium atrioventriculare dext (tricuspid orifice). The right atrioventricular valve has three flaps attached to a fibrous ring that encircles the opening (Keith M Dyce *et al*., 2015). Generally three papillary muscles project into the right ventricle (Motabagani, 2006). All the papillary muscles supply chordae to adjacent components of the cusps they support. The clear knowledge of the morphology of the valves is mandatory for diagnosis of valvular diseases (Sakai *et al*., 1999). The understanding of the comparative anatomy is essential for the use of animal tissue as biological prosthesis and for xenotransplantation. The present study is done to note the similarities and differences between the anatomical structure of human and other mammalian tricuspid valve components.

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Objectives

In the hearts of man, sheep, goat, cow and pig,

a. To measure the diameters of tricuspid valvular complexes
b. To study the papillary muscles in the right ventricle with respect to their number, positions, length and thickness
c. To study the number of chordae attached to each papillary muscle, cusp, and commissures of the tricuspid valves

MATERIALS AND METHODS

The study was done at Kempegowda Institute of Medical Sciences (KIMS), Bangalore. 10 hearts each of cow, pig, sheep, goat, and human were dissected. The human hearts were obtained from formalin fixed cadavers of department of Anatomy, Kempegowda Institute of Medical Sciences (KIMS), Bangalore. Hearts of cow, pig, sheep and goat were collected from local slaughterhouses and were brought in jars containing 10% formalin solution. Hearts with gross evidence of congenital heart disease were excluded from the study. 10% formalin solution was injected into the chambers of the hearts and the specimens were kept immersed in the preservative. The right chambers of the heart were opened. Blood clots if present were washed out from the chambers. Diameter of the valve from anterolateral to posterolateral commissure, was measured by using a pair of dividers with fine points and ordinary ruler with subdivisions of 0.1cm. The number of papillary muscles, and their positions were noted. The length of the papillary muscles was also measured using a pair of dividers with fine points and ordinary ruler. Thickness of the papillary muscles was measured at their origin using slide calipers. The number of chordae tendineae attached to each papillary muscle and the cusps were observed and counted using a hand lens. After observations, the moisture over the papillary muscles, valve leaflets, and chordae tendineae was removed using a filter paper, and the structures were painted. The specimens were allowed to dry. The papillary muscles were painted in brown and Chordae tendineae in white. The photographs of the painted specimens were taken.

RESULTS

Diameters of tricuspid valvular complexes along with number of cusps (Table 1)

The tricuspid valve of human and also of the other mammals studied showed three leaflets- anterior, posterior and septal. The anterior leaflet was the biggest in all the hearts. The second big one was the posterior leaflet. Accessory cusps were not seen in any of the hearts examined. When the diameters of tricuspid valves among different mammals are compared, it is observed that it is highest in cow, followed by man, sheep, goat and pig. It seems that the diameter of the valve is in direct proportion with the weight and size of the heart.

Papillary muscles in the right ventricle of man and other mammals, their number, positions, length and thickness (Table 1)

The papillary muscles, the anterior, posterior and septal of right ventricle were found in 100 % cases of both human and animal hearts. (Fig 1, 2, 3, 4, 5)

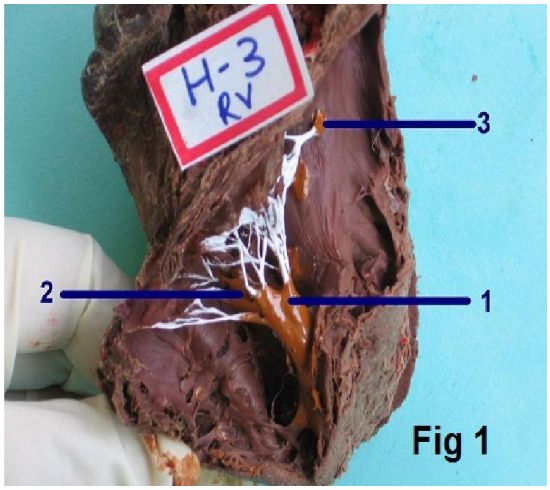

Fig. 1. Interior of right ventricle of human, 1- Anterior papillary muscle, 2-Posterior papillary muscle, 3- Septal papillary muscle

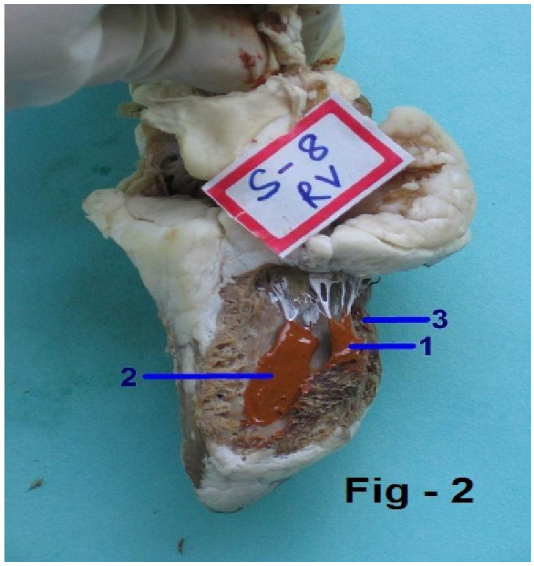

Fig. 2. Interior of right ventricle of Sheep, 1- Anterior papillary muscle, 2-Posterior papillary muscle, 3- Septal papillary muscle

Table 1. Diameter of tricuspid valve, length and thickness of papillary muscles of right ventricle in man and other mammals, The average values of 10 specimens of human, sheep, goat, cow and pig are tabulated

Specimen	Tricuspid Valve diameter, *(All figures in cms.)*	Papillary muscles *(All figures in cms.)*					
		Length			Thickness		
		APM	PPM	SPM	APM	PPM	SPM
Human	2.85	2.72	2.57	0.34	0.58	0.48	0.17
Sheep	2.02	2.72	2.56	0.40	0.53	0.41	0.13
Goat	1.76	2.68	2.66	0.39	0.38	0.35	0.14
Cow	4.42	6.08	5.75	2.05	1.35	1.27	1.06
Pig	1.55	2.60	2.22	0.45	0.27	0.26	0.73

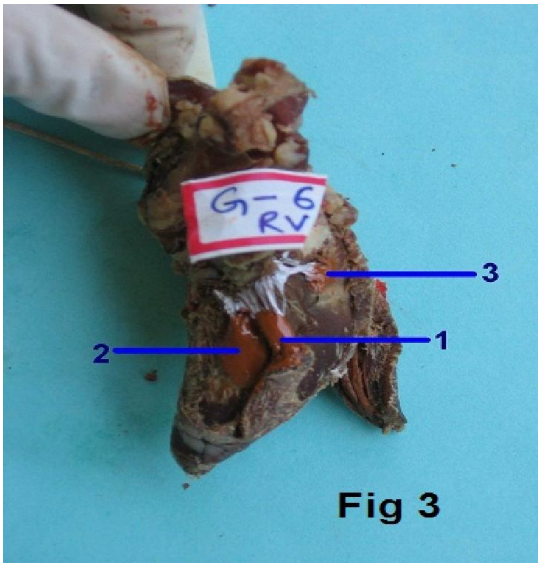

Fig. 3. Interior of right ventricle of Goat, 1- Anterior papillary muscle, 2-Posterior papillary muscle, 3- Septal papillary muscle

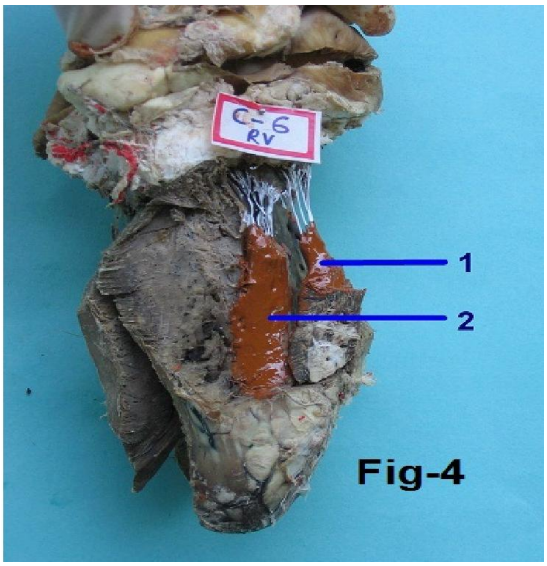

Fig. 4. Interior of right ventricle of cow, 1- Anterior papillary muscle, 2-Posterior papillary muscle

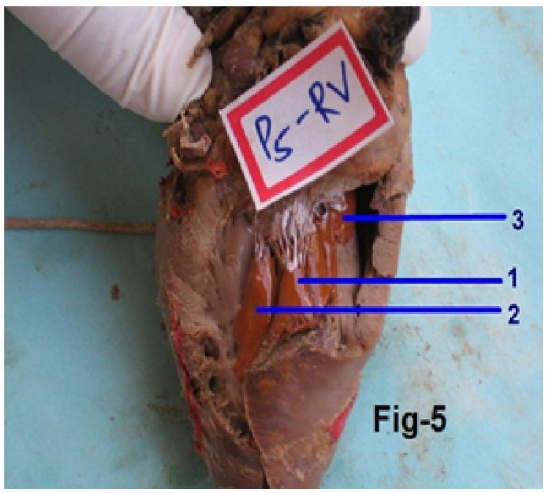

Fig. 5. Interior of right ventricle of pig, 1- Anterior papillary muscle, 2-Posterior papillary muscle, 3- Septal papillary muscle

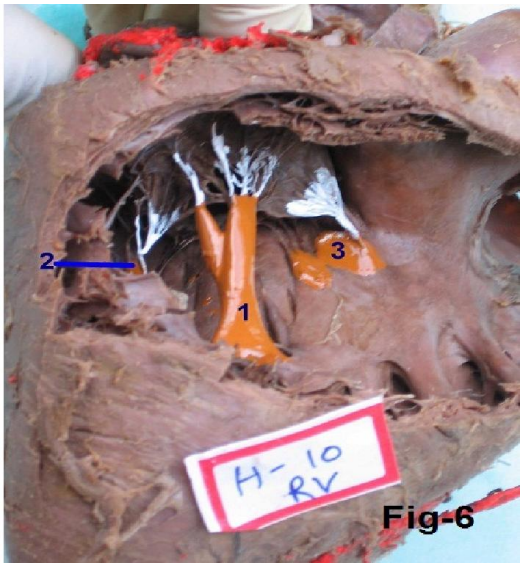

Fig. 6. Human right ventricle showing, 1- two bellies of anterior papillary muscle, 2- groups of bellies of posterior papillary muscle, 3-septal papillary muscle

In human right ventricle anterior papillary muscle was noted to be the largest of the three. It was single in most of the hearts. In one heart it had two bellies (Fig 6). Its base was present on the right anterolateral ventricular wall. Posterior papillary muscle was found to have a number bellies in most of the hearts. Septal muscle was small and arose from the septal wall. In right ventricle of animals the anterior papillary muscle had single belly in all animal hearts. It was located on the outer wall. The posterior papillary muscle in sheep, goat and cow had single belly but in pig it had multiple bellies. Septal papillary muscles were located on the septum. It was noted that the number of chordae tendineae attached to papillary muscle were significantly less in ventricles of sheep and goat when compared with those of human and pig.

Number of chordae attached to each papillary muscle, cusp, and commissures of the tricuspid valves of man and other mammals

The chordae tendineae of the tricuspid valve in human and other mammalian hearts originated from the apex and sides of the papillary muscles. The number of chorda tendineae attached to the cusps were highest in human, followed by pig, and cow. It was observed that the number of chorda tendineae were less in sheep and goat.

DISCUSSION

Human heart weight ranged from 150-490grams (Sakai *et al*., 1999). The mean heart weight \ body weight ratio of cow was 0.37-0.65 and that of pig was 0.23-0.27 (Nickel *et al*., 1976). The porcine heart is small in proportion to the body weight, 0.23-0.28% (Getty *et al*., 1975). The mean heart weight \ body weight ratio of a goat was 0.46, the range being 0.26-0.66, that of a cow was 0.48, the range being 0.3-0.87 and of a pig was 0.40, the range being 0.23-0.48 (Nickel *et al*.,1976). The right valve had three cusps which were named posterior, septal and anterior based on their position. The chordae tendineae are

attached to the margins and ventricular surfaces of the cusps (Romanes, 2000). In animals, the three leaflets of the tricuspid valve were located septally, anterosuperiorly and inferiorly. Their attachments were as found in human right ventricle (Crick *et al*., 1998) The diameter of the human tricuspid valve as mentioned is 3.43-3.63 cms (Standring *et al*. Gray's, 2005). The tricuspid valve circumference is reported to be 108- 114 mm (Silver *et al*., 2007). In another study conducted on 96 human hearts the circumference of the tricuspid valve ranged from 104.04 to 120.9mm (Skwarek *et al*., 2007). In a study of 40 human tricuspid valves it is stated that circumference ranged from 113-139 mm (Motabagani, 2006). In the present study the diameter of human tricuspid valve ranged between 2.4 -3.5cms. In order to compare diameter values with the circumference values obtained from literature, the values obtained as diameter can be multiplied by 3.142. (75.5mm-110mm). In human there are two papillary muscles in the right ventricle which are located in anterior and posterior positions. A third muscle is attached to the ventricular septum (Standring S *et al*. Gray's, 2005). In animals two of the three papillary muscles of right ventricle termed m.papillaris subarteriosus, and mm. papillares parvi, were situated on septum.

The third and largest papillary muscle is the m. papillaris magnus was generally located on the outer wall. This may also contain accessory papillary muscles (Nickel *et al*., 1976). Fifty six human hearts were studied to note the presence or absence of each papillary muscle in the right ventricle. Anterior and posterior papillary muscles were present in all the hearts. 30 percent of the studied hearts showed absence of septal papillary muscle. Single anterior papillary muscle were found in 85% of cases and double anterior papillary muscle was found in 10% of cases (Parvatha Priya *et al*., 2000). In our study all the three papillary muscles, the anterior, posterior and septal of right ventricle were found in 100 % cases of both human and animal hearts. On an average 25 chordae were inserted into the tricuspid valve. Of them 7 were inserted to the anterior leaflet, 6 to the posterior leaflet, and 9 to the septal and 3 to the commissural areas (Silver *et al*., 2007). The number of human chordae tendineae are 1-11 from the anterior muscle, 1-8 from the posterior muscle, and 1-5 from the septal muscle (Nigri *et al*, 2000). In the present study the average number of chordae in human were 7- 10 from the anterior papillary muscle, 6-9 from the posterior papillary muscle, 3-4 from the septal papillary muscle. Human and animal hearts have similar morphological findings. Hence the animal hearts can be used as a model instead of human hearts in experiments involving papillary muscles.

Conclusion

The present study reveals the similarities and differences that exist in the anatomical structure of the components of tricuspid valve apparatus in human and the mammalian hearts. Among different mammals studied, the diameter of the valvular complexes is highest in cow, followed by man, sheep, goat and pig. The number of bellies of papillary muscles differed in different mammals. The length and thickness of the papillary muscles are more in cow, which is proportional to its body size. The number of chordae tendineae attached to each papillary muscle varied. Although differences exist, the heart of pig has many features resembling to those of human heart.

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