Short Communication

A gross comparative anatomical study of hearts in human cadavers and pigs

Garg S [1], Singh P[2], Sharma A[3], Gupta G [4]

*[1]**Dr Shavi Garg***
MBBS, MS
Demonstrator, Anatomy
Pt. Bhagwat Dayal Sharma Post Graduate Institute of Medical Sciences
Rohtak, Haryana, India

*[2]**Dr Poonam Singh***
Professor & Head, Anatomy
DMCH, Ludhiana, India
*[3]**Dr Anu Sharma***
Associate Professor
DMCH, Ludhiana, India
*[4]**Dr Gaurav Gupta***
Senior Registrar, Medicine
LPS Institute of Cardiology
GSVM Medical College, Kanpur

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Correspondence to:

Dr Shavi Garg
9992112772,720651272
vishalksingla@yahoo.com

ABSTRACT

The inadequate availability of human donor hearts and other organs has inspired interest in field of xenotransplantation. The prospect of transgenic pig providing compatible organs for human xenotransplantation is becoming more likely. We aim to compare cardiac anatomy of pig hearts with human cadaveric hearts. A comparative analysis of pig and human cardiac anatomy was made by gross examination and dissection of hearts. The mean value of various parameters along with standard deviation was calculated.and T-test was applied and p-value was calculated. The average weight of human heart was 266.5g whereas the average weight of pig heart was 302.8g. An average adult human heart was about 9.8cm (9.2cm-12cm) from base to apex, 8.6 cm (7.4cm-10.8cm) in its broadest transverse diameter and 7.1 cm (5cm-8.4cm) anteroposteriorly. An average pig heart was about 10.2 cm (8.5cm-11cm) from base to apex, 8.9 cm (6.5cm-11cm) in its broadest transverse diameter and 6.6 cm (5cm-8cm) anteroposteriorly. The human heart was trapezoidal in shape. The pig heart, in contrast, was a broad cone shaped organ. In humans, the left atrium received the four pulmonary veins whereas in pig it received two pulmonary veins. In right atrium of man, orifices of superior and inferior caval veins were in a direct line whereas in pig veins opened at right angles to each other.

The present study suggests that the morphology of human and porcine heart is almost similar with significant anatomical differences between porcine and human hearts that might effect the success of the cardiac xenograft within the human recipient.

***Keywords**: Cardiac anatomy, xenotransplantation, xenograft*

Introduction

The field of xenotransplantation is the transplantation of organs between species. It provides the best solution to the shortage of transplantable organs. Over the last decades, the pig has been chosen as a feasible animal organ donor for human species, mainly regarding heart transplantation. The pigs are omnivorous and a number of aspects of their anatomy are sufficiently close to the human pattern with reference to the cardiovascular system. [1] There is little factual knowledge about xenografting of human hearts with pig hearts. Our study is an effort to describe the anatomy of human heart and its characteristics that are significant when using pig hearts as a biomedical model for humans.

Material and methods

This study was conducted in the Department of Anatomy, DMCH, Ludhiana after approval from the Hospital Ethics Committee. For the study, thirty hearts were taken, out of which fifteen were human cadaveric hearts and fifteen were pig hearts (from slaughter house). The ascending components were cut above the arterial valves and the atriums were opened posteriorly. Blood clots were washed from atrium and ventricles. The hearts were fixed in 10%formal saline. The following external features of each heart were studied.

1. Weight of the heart (in gms.): was measured on electronic weighing scale.
2. Size of the heart

- Measurement from centre of base to apex (also called as heart height /heart length)
- The biggest longitudinal heart dimension, from centre of horizontal plain adjacent to base of heart to apex of heart.
- Broadest transverse diameter.
- Broadest antero posterior diameter.

All the measurements (in cms) were taken with the help of vernier caliper, non stretchable nylon thread and a metric rule.

The pericardial fat and epicardium were removed from the surface of the heart. In this dissection, the right atrium was opened from inferior caval vein opening to the tip of right atrial appendage. An incision was made along the anterior atrioventricular groove of the heart and was extended to the right ventricular apex. The left ventricle was opened by an incision across its roof between the anterior and posterior papillary muscles along the obtuse margin to the apex. The left atrium opened by an incision across its roof between the right and left pulmonary veins.

T-test was applied and p-value was calculated. The p-value <.05 was considered to be significant* and >.05 was considered to be non significant.

Results

Gross external features of the heart

The human heart was trapezoid in shape when seen from front whereas pig heart had a conical shape. The human heart had three borders-right, left & inferior; three surfaces-anterior (sternocostal), an inferior (diaphragmatic) and posterior (base). [Fig. 1]

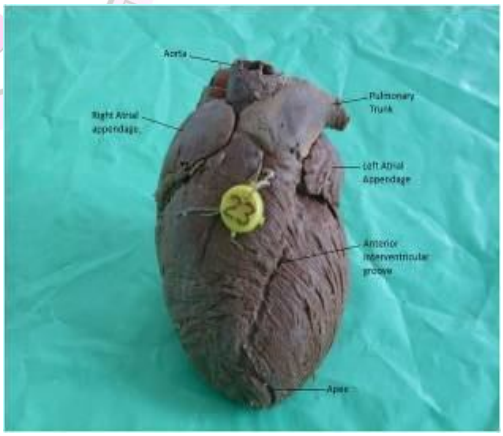

Fig. 1 Anterior aspect of human heart

In contrast, the pig heart had two borders- upper and lower border, two surfaces- ventral or sternocostal and dorsal or diaphragmatic surface with an apex and a base. [Fig. 2]

Fig. 2 Anterior aspect of porcine heart

Atriums

In the human heart, the right atrium was larger than the left whereas in the pig, both the atriums were of similar size. The cavity of right atrium of man received the openings of superior vena cava and inferior vena cava which were directly in line in man whereas in pig, the orifices of the two caval veins opened at right angles to one another. The human right atrial appendage was larger than the left whereas in pig, the right and left porcine atrial appendages were of comparable size. The right atrial appendage in the pig had a tubular appearance whereas in man it was triangular in shape. Both in human and pig hearts, the interior of the auricle was irregular and is formed by a series of ridges, musculi pectinate that arose from crista terminalis and formed a highly developed network in the auricle. The terminal crest, the most obvious muscle was arranged longitudinally with its pectinate muscles connecting to the musculature of the A-V vestibule.

The human left atrium had four openings for the pulmonary veins whereas the porcine left atrium was posteriorly placed and received two pulmonary veins. The human left atrial appendage had a tubular appendage whereas in pig it was long, wavy, hooked with a narrow junction and crenelated lumen.

Ventricles

In both the human and pig hearts, the tricuspid valve guards the right atrioventricular orifice and consists of three cusps. The leaflets were located anteriorly, posteriorly and septally in man whereas in pig, the leaflets were located anterosuperiorly, inferiorly and septally. In both human and pig heart, the cusps were fused at their attatchment but free towards the center of the opening where their margins were thick and irregular. Each cusp was joined by fibrous strands (chordae tendineae) which descend from ventricular cavity to insert on projections from walls (papillary muscles). Many irregular ridges (trabeculae carneae) in the lower part of the right ventricular wall gave it a spongy appearance. These were much broader and coarse as compared to that of humans. Both in human and pigs, the outlet of the right ventricle supported three leaflets of the pulmonary valve in semilunar manner.

As in humans, mitral valve had two leaflets, anterior and posterior. The leaflets are attatched to the paired papillary muscles which are located anterolaterally and posteromedially within the ventricle. The criss–cross apical trabeculations of the left ventricle were coarser than that of human ventricle. Both in human and pig hearts, the aortic and pulmonary valves were similar but showed different orientations of their cusps. It is clear from the Table 1, that differences in

weight and external dimensions of human and pig hearts are non significant.

Table 1 Showing weight and external dimensions of human and pig hearts

	Number of cases		*Range*	*Mean ± S.D.*	*p-value*
Weight (gms)	**15**	**Human**	160-442	266.5 ± 78.13	0.121
	15	**Pig**	148-435	302.8 ± 72.22	
Broadest Transverse	**15**	**Human**	7.4-10.8	8.6 ± 0.89	0.206
diameter(cm)	**15**	**Pig**	6.5-11	8.9 ± 1.08	
Broadest	**15**	**Human**	5-8.4	7.1 ± 0.91	0.120
Anteroposterior	**15**	**Pig**	5-8	6.6 ± 0.91	
diameter(cm)					
	15	**Human**	9.2-12	9.8 ± 1.45	0.150
Heart Height(cm)	**15**	**Pig**	8.5-11	10.2 ± 0.57	

*** Significant ** Highly Significant**

Discussion

The average weight calculated by Jatene MB, [2] Arora V, [3] Johnson D [4] in females, Garg M [5] in females, Dhruva GA [6] in males is comparable with our findings. [Table 2] Our study was done on the preserved collection of cadaveric human hearts in our department, where knowing the sex was not possible. The average value of weight in our findings is in between those found in males and females. Ghoshal [7] worked only on adult pig hearts. Our study was done on pig hearts taken from the slaughter house, where the age of the pig could not be known. This may explain the disparity in the findings. Arora V [3] measured the anteroposterior diameter in postmortem hearts. He found the diameter to be in the range of 3-7 cm. It was found to be 6 cm by Johnson D [4] et al. This difference in the anteroposterior diameter of heart with our study could be due to racial differences. The transverse diameter and length of heart is

comparable with previous studies. To the best of our knowledge we could not find any literature on the size of the porcine heart to compare the same in pig hearts used in our study, though these values are comparable with human hearts.

Table 2: Table showing the comparison of external features of human and pig hearts with previous studies

Author	*Average weight of heart (gms)*		*Weight (gms)*	*Size(cm)*		
	Males	**Females**		**Transverse diameter**	**Antero-posterior diameter**	**Length/ height**
Jatene MB et al [2] (H)	247.92	164.29	259.4±59.3	-	-	-
Arora V. [3] (H)	293	260.5	-	5-12	3-7	10-19
Johnson D et al[4] (H)	300	250	-	8-9	6	12
Garg M et al [5] (H)	289±71	269 ±77	-	-	-	-
Dhruva GA et al [6](H)	270±75	248±85	-	-	-	-
Present Study (H)	-	-	266.5±78.13	8.6 ± 0.89	7.1 ±0.91	9.8±1.45
Ghoshal et al [7] (P)			240-550			
Present Study (P)			302.8±72.22	8.9 ± 1.08	6.6 ±0.91	10.2 ±.57

H – Human, P – Pig

Many gross morphological differences between human and pig hearts may be attributed to the posture adopted by the two species, quadripedal (unguligrade) in pigs versus bipedal (orthigrade) in humans, with gravity playing playing an important role in the

development of cardiovascular system. [8] These facts may have implications for the placement of the cardiac xenograft within the thoracic cavity during transplantation. [9] The shape of the pig heart, and its position within the thoracic cavity along with the quadripedal posture adopted by pig might account for the right angle between the openings of superior and inferior caval veins in the right atrium. [10] The orifices of caval veins in the human heart are in direct line, suggesting the upright posture of the human body.

The porcine left ventricular wall is thicker than that of human. The thickness of the papillary muscles and the trabeculations influence ventricular contractility. [11] The thick trabeculation also have an effect on blood flow within the ventricular chamber, thus affecting the efficiency of ventricular activation in the pig heart.

Today, the majority of people in our society do agree with the idea of the humane and responsible use of animals in research. In addition, the use of an animal such as the pig which is bred easily in captivity with high parity ensures a ready supply of organs with less chances of hyperacute rejection.

The very encouraging results yielded by various therapeutic strategies are critically dependent on a clear understanding of the relation of structure and function of both pig and human heart that our study attempted to promote. One of the most important scientific missions in this century is integration of basic research with clinical medicine, this study is not merely of academic importance, but will also be helpful in the clinical evaluation and treatment of various heart diseases.

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