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Morphomatrical Analysis of Aortic Valves of Bovine Heart for Bioprosthetic Purpose

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Abstract: Morphomatrical analysis of aortic valves of bovine heart was done for the purpose of manufacturing of bioprosthetic materials in Bangladesh. The study analyzed 32 healthy fixed bovine hearts; 50% of them obtained from males, 50% of them from female animals ranged from 2 to 4 years old. The characteristics assessed related to age and sexes were the following: number and height of the cusps and size of the lunulae. This study included the assessment of 32 aortic valves of the hearts, 8 valves from each of 2, 2.5, 3 and 4 years of indigenous cattle. All the bovine hearts assessed in the present study possessed tricuspid aortic valve. The values of the heights of left, right and noncoronary cusps were 14.91±2.47, 14.25±2.60 and 15.19±1.75 mm, respectively and NC cusp had the largest dimensions, followed by the RC and the LC cusps, whose dimensions were nearly similar. The highest values of lunula (width and length) were 8.31±1.35 mm for LC in case of width and 32.22±3.10 mm for RC in case of length. Data about height of the cusps, the size of the lunula (width and length) of the cusps and their anatomical relations facilitate the manufacturing of bovine tissue valves as well as those can be used in valve replacements as like as stentless porcine and bovine pericardial bioprostheses are being used clinically

Key words: Bovine heart, aortic valve, morphometry, analysis, height, lunula

INTRODUCTION

The aortic valve has three cusp architecture. The leaflet tissue ordinarily coapts to achieve the competent valve mechanism but there may be trivial incompetence at the central coaptation point. The leaflet tissue is attached to the aortic wall by dense fibrous connective tissue. This is called the annulus, which is a misnomer because the hinge point is actually semilunar in shape. Two bones, the ossa cordis, develop in the aortic fibrous ring of the heart of cattle and sheep and having three cusps of semilunar in shape and thicker and stronger than pulmonary valves in other ruminants, horse, dog and pig[1]. The aortic valve resembles the pulmonary in possessing three semilunar leaflets, the cusps, supported within the three aortic sinuses and thicker and stronger than pulmonary valve in human heart. The anatomy of the aortic valve of human heart is dominated by the fibrous semilunar attachment of the cusps[2]. Islam *et al.*[3] studied on the investigation of bovine aortic valve in cardiac research for bioprosthetic purpose. They investigated the morphology of the bovine aortic heart valve. This valve has three cusps or leaflets, viz, right, left and non-coronary cusp. The fibrocartilaginous, the ossa cordis is also found in the aortic fibrous ring. The study on anatomy of the pig heart: comparisons with normal human cardiac structure transgenic technology have potentially solved many of the immunological difficulties of using pig organs to support life in the human recipient[4]. The research was carried out on comparison of human and porcine aortic valves and compared the anatomy of human and porcine aortic valves. Various features of the aortic valve were measured: circumference, length between the commissural end point and central point of coaptation, surface diameter and surface area[5]. When a porcine tissue valve is processed using pressure fixation, leaflets stiffen and fibrosal corrugations are flattened, resulting in valve degeneration over time. When they are processed to retain the properties of a native valve, leaflets perform much like normal valve tissue and maintain the anatomical shape and function of natural valves[6], thus improving hemodynamic performance[7].

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Various tissues were used to construct bioprosthetic valves for aortic and other valve replacement. It was studied on technical aspects of implanting the St. Jude Toronto stentless porcine valve. Stentless xenograft aortic valves were designed to provide superior hemodynamic characteristics and durability, in comparison with stented tissue valves[8]. It was reviewed that the substitute heart valves composed of human or animal tissues have been used since the early 1960s, when aortic valves obtained fresh from human cadavers were transplanted to other individuals as allografts. Today, tissue valves are used in 40% or more of valve replacements worldwide, predominantly as stented Porcine Aortic Valves (PAV) and Bovine Pericardial Valves (BPV) preserved by Glutaraldehyde (GLUT) (collectively termed bioprostheses)[9]. Thus, the interest in the morphology of cardiac valves, which during the 60's and 70's was limited to the pathological features due to the large number of valvar replacements, was extended. The more accurate knowledge of normal anatomy began to play an important role in the success of valvoplasties, as many decisions during surgery are based on the visual assessment of the changes. Detailed knowledge of the anatomical characteristics of the aortic valve should improve the understanding of its anatomy and help much to obtain the better results in conservative procedures and in this way promoting return to anatomical and functional normality.

This precise knowledge also defines some details of the architecture of the aortic valve that are necessary for the development and manufacture of the prostheses. In addition, the knowledge and understanding of the structure and function of the normal and pathological cardiac valves are crucial for the selection of the patients for surgery and for planning the best treatment to be adopted. It was studied on aortic valve assessment of healthy human hearts and found that the aortic valve annulus did not show a perfect circumference, with some variations in the measurements of the annulus, in the cusps and in the relation with the ventricular septum[10].

Now, open-heart surgery becomes an acceptable means of treatment of congenital, rheumatic and ischaemic heart diseases. At present, impaired/defective valves are replaced with mechanical or tissue valves of pig and bovine (pericardium) origin. There is a suitable and relatively small sized breed of indigenous cattle (*Bos indicus*) of which aortic heart valve has a good prospect for bioprostheses. Some initial studies revealed that the aortic valve size of indigenous cattle of Bangladesh has focused a very prospective similarity with human heart aortic valve, which has created the present thirst of research in this area[11]. The analysis of morphometry on the cusps/leaflets of aortic valve of the heart of indigenous cattle (*Bos indicus*) are not found in literature, hence this research have aimed to elucidate the findings for the said study.

MATERIALS AND METHODS

This research was undertaken in the month of February of the year, 2004. A total of 32 bovine heart specimens were collected from the slaughter house of Mymensingh district of Bangladesh adopting aseptic measures. All the cattles of native breed (*Bos indicus*) of both sexes (50% male and 50% female of 2-4 years of old) were healthy and the hearts (500 to 800 g) were free from pathological lesions. After rinsing away the blood, the hearts were kept in the balanced isotonic saline solution until dissection in the laboratory. After dissection, 32 aortic valves, 8 valves from each of 2, 2.5, 3 and 4 years of age were fixed with cotton just after harvesting and embedded in 10% formalin. Using a standard mathematical measuring scale and a cotton thread, the Valsalva's sinuses were assessed as well as the Left Coronary Cusp (LCC), Right Coronary Cusp (RCC) and Non Coronary Cusp (NCC) were measured[10] using following parameters:

The Height of the cusps: The Height (H) obtained by stretching the cotton thread from the bottom of the Valsalva's sinus until the free margins of the cusps in the middle point between the commissures, respecting its curve. The sinus of Valsalva is defined as the area between the aorta and the valve leaflet edge when the valve opens. The aortic valve is inserted on the wall of the left ventricular outflow tract mostly above the anatomic ventriculoaortic junction, but the lowest point of the semilunar point of attachment is actually on the ventricular side of the junction. The highest point of attachment is called the commissure. This measure was then transferred to the standard mathematical measuring scale (Fig. 1).

The size of the lunula: The size of lunula is assessed by taking both Length (L) of the free margin of the cusps and Width (W) at the level of the commissure of the cusps, separately. The width is measured at the commissural level and the length is measured by stretching the cotton thread at the free margin of each cusp (Fig. 1).

RESULTS AND DISCUSSION

All the hearts of indigenous cattle examined possesses tricuspid aortic valves. The mean heights of the left, right and noncoronary cusps were 14.91, 14.25 and 15.19 mm, respectively and NC cusp had the largest

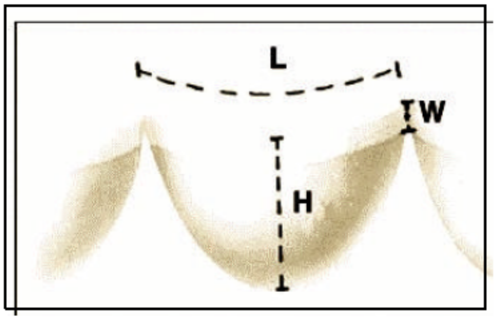

Fig. 1: A Sketch demonstrating the site of measurement in one of the 3 cusps, H: Height of the cusp, W: Width of the lunula and L: Length of the lunula

dimensions, followed by the RC and the LC cusps, whose dimensions were nearly similar (Table 1). The highest values of lunula (width and length) were observed; whose mean values were 8.31mm for LC in case of width and 32.22mm in case of length for RC, respectively (Table 1).

Height, width and length of Left Coronary Cusp (LCC): The height of the left coronary cusp of aortic valve of the heart was measured 15.25±3.20, 15.25±3.40, 14.50±1.31 and 14.75±1.75 mm and the width was measured 8.25 ±1.39, 8.38±2.13, 8.13±.83 and 8.50±.93 mm and the length of the LCC was measured 30.25±4.23, 32.00±4.38, 32.25±2.71 and 32.50±2.93 mm at Y2, Y2.5, Y3 and Y4 age groups, respectively (Table 2).

Height, width and length of Right Coronary Cusp (RCC): The height of the right coronary cusp of aortic valve of the heart was measured. It was found that the height of RCC of aortic valve of the heart was measured 15.38±3.70, 13.63±2.45, 13.25±1.75 and 14.75±1.98 mm and the width was measured 7.75±1.39, 8.00±2.14, 8.13±1.46 and 8.63±1.77 mm and the length was 32.13±4.39, 33.00±3.07, 32.13±2.80 and 31.63±2.20 mm at Y2, Y2.5, Y3 and Y4 age groups, respectively (Table 3).

Height, width and length of Non Coronary Cusp (NCC): The height of NCC of aortic valve of the heart was measured 15.25±2.19, 15.75±2.19, 14.75±1.28 and 15.00±1.31 mm and the width was measured 8.50±2.00, 7.50±1.93, 7.63±.92 and 8.38±.92 mm and the length was measured 31.38±5.18, 32.75±2.97, 30.00±5.78 and 31.88±2.95 mm at Y2, Y2.5, Y3 and Y4 age groups, respectively (Table 4).

According to Gardner *et al.*[12], the mean heart weight in males is around 328 g, varying from 256 to 390 g and in females; it is around 244 g, ranging from 198 to 270 g. It was stated that the weight of the human heart without

Table 1: Height (Mean) of the cusps and size of the lunulae (width at the level of commissure and length of the free margin of the cusps) of aortic valve of heart in mm of the total number of indigenous cattle (n = 32)

Measures	Cusps of aortic valve	Mean value	Sex: Male (n = 16)	Sex: Female (n = 16)	Age range: <3 (n = 8)	Age range: >3 (n = 8)
Height of the cusps	LCC	14.91	15.25	14.56	15.13	14.75
	RCC	14.25	14.13	14.38	13.63	14.75
	NCC	15.19	15.50	14.88	15.75	15.00
Width at the level of commissure	LCC	8.31	8.50	8.13	8.38	8.50
	RCC	8.13	8.44	7.81	8.00	7.63
	NCC	8.00	8.31	7.69	7.50	8.38
Length of the free margin cusps	LCC	31.75	30.88	32.63	32.00	32.50
	RCC	32.22	32.00	32.44	33.00	31.63
	NCC	31.50	31.25	31.75	32.75	31.88

Table 2: Height (Mean±SD) of the cusps of the aortic heart valve of indigenous cattle at different age groups irrespective of the sexes

Age Year (Y)	Height of different cusps of aortic valve of heart (n= 8): LCC (mm)	RCC (mm)	NCC (mm)
2.0	15.25±3.20	15.38±3.70	15.25±2.19
2.5	15.25±3.40	13.63±2.45	15.75±2.19
3.0	14.50±1.31	13.25±1.75	14.75±1.28
4.0	14.75±1.75	14.75±1.98	15.00±1.31

Table 3: Width (Mean± SD) of different cusps of the aortic heart valve of indigenous cattle at different age groups (n= 8)

Age Year (Y)	Width of different cusps of aortic valve of heart (n= 8): LCC (mm)	RCC (mm)	NCC (mm)
2.0	8.25 ±1.39	7.75±1.39	8.50±2.00
2.5	8.38±2.13	8.00±2.14	7.50±1.93
3.0	8.13±0.83	8.13±1.46	7.63±0.92
4.0	8.50±0.93	8.63±1.77	8.38±0.92

Table 4: Length (Mean ±SD) of different cusps of the aortic heart valve of indigenous cattle at different age groups (n= 8)

Age Year (Y)	Length of different cusps of aortic valve of heart (n= 8): LCC (mm)	RCC (mm)	NCC (mm)
2.0	30.25±4.23	32.13±4.39	31.38±5.18
2.5	32.00±4.38	33.00±3.07	32.75±2.97
3.0	32.25±2.71	32.13±2.80	30.00±5.78
4.0	32.50±2.93	31.63±2.20	31.88±2.95

LCC: Left Coronary Cusp, RCC: Right Coronary Cusp, NCC: Non Coronary Cusp

pathological alterations can reach 500 g. In situations where the work of the heart is chronically increased, as in athletes or workers who exercise intensely, the increase in heart weight is not caused by an increase in the number of muscle fibers but by an increase in the thickness and length of these fibers[13]. In addition, as already demonstrated by several authors, the heart weight is directly related to the individual body surface[14,15]. In the present study, it was revealed that the mean heart weight in males was 609.38 g, varying from 500 to 700 g and, in females; it was 603.13 g, ranging from 500 to 800 g. Among the data obtained in our study, statistically there was no significant in weight of cardiac masses of indigenous cattle in relation to their sex. The heart weight is increased in bovine in the present study in comparison to other genus including human. This is due to species variation.

In the present analysis, in regard to the height of the cusps, the NCC was larger, followed by the RCC and the LCC. In comparison of the size of the lunula (width and length) of the cusps, the width of the left coronary cusp was larger and the length of the noncoronary cusp was larger. The present data about height of the cusps, the size of the lunula (width and length) of the cusps and anatomical relations facilitate the manufacturing the tissue valves and this variation was non-significant. It was observed that in a clinical study relating age and the size of the aortic valve of human heart , there is an increase in the volume of the aorta with the increase in age and also that, after the age of 40 years, the aortic valve and its annulus become progressively dilated[16]. The study on aortic valve of human heart was carried out and showed that in regard to the height of the cusps and size of the lunula, the left coronary cusp was larger, followed by the right coronary cusp and the noncoronary cusp[10]. Present study revealed that the mean heights of the cusps were 14.91±2.47, 14.25±2.60 and 15.19±1.75 mm, respectively and NC cusp had the largest dimensions, followed by the RC and the LC cusps, whose dimensions were nearly similar. The highest values (width and length) were observed in case of lunula, whose mean values were 8.31±1.35 mm for LC and 32.22±3.10 mm for RC, respectively.

It is concluded that the study of the described parameters, the height, length and width of cusps of the aortic valve of bovine hearts were measured and revealed that the length of the left coronary cusp of aortic valve was always more followed by height and width at the all groups of age. The increase rate in height, width and length of LCC was not significant at all the different age groups of animals.

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