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Morphometric and Histological Study of the Papillary Muscles and Tendinous Chords of the Heart of Local Breed Bulls (*Bos Taurus*)

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Abstract

This study was aimed to identify the anatomical and histological structures of papillary muscles of the right and left sides of bulls' hearts, in relation to the chordae tendineae which are normally extended from papillary muscles. Six hearts of fresh adult bulls were studied grossly and histologically for this research.

Anatomical study was conducted by dissecting bulls' hearts, and length, breadth of papillary muscles and number of chordae tendineae were described and measured. For histology study, special and routine stains were used to distinguish the general pattern contents of muscles, types of fibers and connective tissue. This study found that there were three papillary muscles in the right ventricle and two papillary muscles in the left ventricles, so the angular papillary muscle was absent in the left side. However, septal and parietal papillary muscles of left side were the largest papillary muscles. Also, the numbers of chordae tendineae were observed more numbers in the right papillary muscles.

Histologically, myocytes were similar into cardiac cell muscles. Although, there are increasing the scattered more connective tissues and fibers. The chorea tendineae was no myocytes and completely transited into connective tissue.

Briefly, this study was indicated that angular papillary muscle are the largest muscle and absent in left side. However, more chordae tendineae were detected in right side, in addition, the myocytes were shorter than cardiac cells, but gradually, myocytes were disappeared at the chordae tendineae. This results in relation to pathological heart diseases could be explained more reasons for heart failure diseases.

Keywords: *Heart, Papillary muscles, Chordae tendineae, Myocytes*

Introduction

The Papillary muscles are positioned in the ventricular wall of the right and left ventricles of the heart, and functionally are regulated the flow of the blood from in and out of the heart under controlled autonomic nervous system (Hosapatna et al., 2021). These muscles are extended from the wall of ventricles and connected to cusps of the atrioventricular valves of the mitral and tricuspid valves of the heart by fibrous cords which are called chordae tendineae. So chordae tendineae are prevented the inversion or prolapse of these valves during contraction and relaxation of the ventricles (Fedonjuk et al., 2015).

Papillary muscles are received blood from the segmental branches of the large vessels of the epicardial coronary arteries (Estes Jr et al., 1966). These muscles are extended from the endocardium and deeply myocardium layers of the heart, commonly, there are three muscles on the right side and two muscles on the left side of the ventricles of humans (Greenbaum et al., 1981; Nigri et al., 2001). Also, the length and thickness of them are various among the

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same muscles according to the location in the left or right ventricle of the heart, consequently, the length averages from 2 to 3.5 cm, while the thickness is between 0.5-1 cm in the human heart (Roberts and COHEN, 1972; Spreeuwers et al., 2005).

Structurally, there are many researchers have identified three of papillary muscles and classified according to the location in the right and left ventricles of the heart which are included posterior, anterior and septal papillary muscles, as a result, these muscles are normally attached and inserted to chordae tendineae of the cusps of the tricuspid valve in the right ventricle of heart, while the left ventricle is displayed only two papillary muscles that are attached to the cusps of the mitral valve via chordae tendineae (Aktas et al., 2004; Hutchison and Rea, 2015; Xanthos et al., 2011). Investigation studies of the human papillary muscles are showed that the average lengths of left papillary muscles are longer than the right papillary muscles (Hosapatna et al., 2014; Spreeuwers et al., 2005).

Moreover, in the left papillary muscles of the dog and rabbit are noticed that the Purkinje-ventricular junction is positioned adjacent to the base of the muscles, but the junctional regions for propagation are extended from the ventricular layer up into the papillary layer of muscles (Overholt et al., 1984; Veenstra et al., 1984).

The chordae tendineae (tendinous cords) are demonstrated as fibrous cords that connected the papillary muscles to the tricuspid valve and the mitral valve in the ventricles of the heart, which is functionally regulated the inward and outward flow of the blood (Ritchie et al., 2005). Histologically, the chordae tendineae are strings band and inelastic cords of fibrous connective tissue, and it has different lengths and thicknesses according to their position in the heart (Nigri et al., 2001). This study was aimed to identify the papillary muscles and chordae tendineae of the heart of the bovine and give more details that could be helped the researchers to do more studies because of no database for this part of the bovine, as well as, distinguish the transitional regions of papillary muscles into chordae tendineae and type of fibres in these muscles and chordae tendineae.

Materials and Methods

In this study, 12 hearts of healthy adult bulls were used, so fresh hearts were collected directly from the slaughterhouse and dissected for anatomy and histology study. The length and locations of the left and right papillary muscles were distinguished and measured. Specimens of papillary muscles were collected from the base of different muscles until the chordae tendineae became aware of the transitional region of muscles and fibres of muscles.
The specimens were fixed in formalin 10% and sections of tissue were prepared. The sections were stained with H and E for routine stain, and Masson's trichrome for distinguishing the pattern of connective tissue surrounding the muscles fibres or chordae tendineae. All sections were studied and snapped images using by light microscope model 6300 (Japan) and examined under magnificent 4x10x, 20x, 40x and. 100x.

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Statistical Analysis

The measurements were applied for 12 fresh hearts of bulls and analyse using Excel 2019. Successively, databases were analysed to compare between the left and right papillary muscles and chordae tendineae of both sides. The average and standard errors of the data were calculated for numbers of chord tendineae, breadth and length of papillary muscles of the left and right side of the heart.

Results

The anatomy study was exhibited that there are three papillary muscles in the right ventricle and two papillary muscles in the left ventricle and those should be regulated the blood flow in and outside of the heart, thus the right papillary muscles were classified according to location and relationship with valves and ventricular wall of the heart into septal, angular and parietal muscles, so muscles were controlled the tricuspid valves of right atrioventricular valve, while left side was had only two muscles included septal, and parietal muscles, and it is controlled the mitral valve of left atrioventricular valve of the heart, however, the left papillary muscles were larger than right papillary muscles Figure (1, and 2).

The measurements of the length, breadth and numbers of chordae tendineae of the right and left papillary muscles were different according to the type of papillary muscles, on other hand, the septal and parietal papillary muscles of the left side were displayed longer and wider than the septal and parietal papillary muscles of the right side, also the left septal papillary muscle was the longest and widest muscle for the right and left ventricles Figure (8,9, and 10) and Table (2). However, the right parietal papillary muscle was longer than the septal and angular papillary muscles but, it is shorter than the septal papillary muscle Figure (10) and Table (3).

Moreover, the numbers of chordae tendineae were noticed in more numbers in the right parietal papillary muscle in comparison with other papillary muscles on the left and right side of the heart, Figure (8). But, the left septal papillary muscle had more chordae tendineae on the left side of the heart, Figure (8), and Table (3).

The papillary muscles were extended from the right and left ventricles, which confirmed that the left papillary muscle was regulated by the mitral valves, while the right papillary muscles were regulated by tricuspids valves to control blood flow on both sides of the heart. The chorea tendineae revealed strings like chords and whitish in colour. Also, the chordae tendineae was thicker and longer on the left side in comparison with the right side Figure (10).

Also, results showed that the septal papillary muscle in the left ventricle was conical in shape and the breadth and length were measured at 3.3±0.09 (Centimetres) Cm, and 2.5±0.04 Cm in respectively, and averaged 16 in number of the primary chordae tendineae, table (3). This muscle has given origin to 9±0.6 primary chordae tendineae which were continued from the broad apex of this papillary muscle and extended into the mitral valves. Each one was branched into 2-4 small secondary chordae tendineae, which were branched to more sub-branches thinnest tertiary chordae tendineae before connecting with the edges of the valvular cusps of the heart.

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Consequently, 2-3 primary chordae tendineae were located nearly to the septal valvular cusp and connected radially along the edge of the parietal and septal valvular cusps by tertiary chordae. In same way, 3-4 other primary chordae tendineae were located very close to the parietal valvular connected by tertiary chordae radially along the edge of the parietal valvular cusp only, figure (1).

Besides, the primary moderate band arose from the middle part of the lateral side of the septal papillary muscle, and superio-caudally direction return insertion just below the septal valvular cusp at the upper third of the inner wall of the left ventricle. Also, it was given two small secondary bands in the opposite directions at the middle third of the inner wall of the left ventricle, figure (1).

The second muscle of the left side was the parietal papillary muscle which was conical in shape and the breadth was measured at about 2.5±0.06 Cm, while, the length was 1.2±0.04 Cm, table (3). Also, this muscle was given 7±0.6 primary chordae tendineae from the upper and caudal aspects of the apex of the parietal papillary muscle.

Subsequently, these primary chordae tendineae close to the septal valvular cusp were branched into 2-3 secondary chordae tendineae. Also, these secondary branches were turned and given more branches 3-4 tertiary chordae tendineae before attaching to the edges of the septal and parietal valvular cusps. The rest of the primary chordae tendineae were connected as tertiary branches directly into the parietal valvular cusp.

Likewise, the moderate bands in relation to the parietal papillary muscle were arisen from the lateral surface of its upper third and fused into the inner wall of the ventricle just below the septal cusp above the level of the apex of the parietal papillary muscle. So these bands appeared less thick than the bands which were originated from the septal papillary muscle.

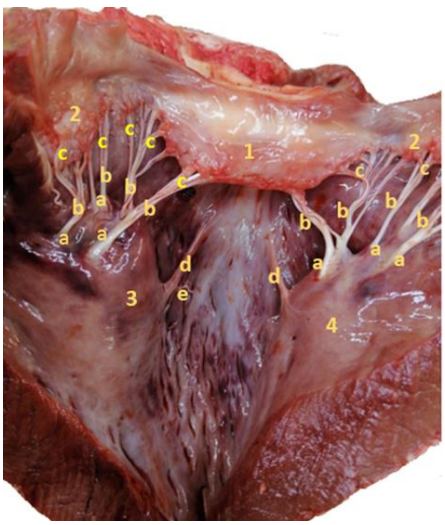

Figure (1): This figure showed internal view of the left ventricle of the heart shows the septal (1) and parietal (2) cusps of the mitral valve, which are connected to the papillary septal (3) and parietal muscles (4) by the primary (a), secondary (b), and tertiary (c) chordae tendineae, and illustrates the primary (d), and secondary (e) moderate bands.

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Our finding has been detected that there were three papillary muscles on the right side of the heart and averaged 22 number of the primary chordae tendineae, it is shown in table (3). Accordingly, the septal papillary muscle of the right ventricle was conical in shape and the breadth of muscle was 1.8±0.09Cm, while the length was 0.6±0.06 Cm, also it had given 3-4 primary chordae tendineae from the upper surface of the apex and 2-3 from the lateral side of the septal papillary muscle. The main branches of chordae tendineae were sub-branched into 2-3 secondary chordae tendineae Figure (2). The branches of chordae tendineae at the lateral side of the septal papillary muscle, and close to the septal valvular cusps were attached to the edges of the septal and parietal valvular cusps Figure (2). While another chordae tendineae close to the inner cardiac parietal wall of the heart was directly connected to the parietal valvular cusp, Figure (2).

Furthermore, there are 8-10 short moderate bands in relation with septal papillary muscle and arose along with the middle and lower third of papillary muscle, then it would be attached the opposite part of the inner surface of the cardiac parietal wall.

Also, the parietal papillary muscle was conical in shape, and had breath 1.6±0.06 Cm and 1.2±0.06 Cm in length. There were 4-5 of the primary chordae tendineae originated from this muscle, which were branched more into 2-3 secondary chordae tendineae. Subsequently, 3-4 primary chordae tendineae were arise from the lateral surface of the parietal papillary muscle and attached to the septal, parietal, and angular valvular cusps, additionally, 2-3 of them were arisen from the upper surface of the apex of the parietal papillary muscle and inserted in the parietal valvular cusp.

Besides, moderate bands were related to the parietal papillary muscle appeared as thick bands and originated from the base of the papillary muscles, so these bands were branched before being inserted into the inner wall of the right ventricle. Figure (2).

The angular papillary muscle was dome in shape, and the measurement of the breadth was 1.5±0.06 Cm, and it was offered 3-4 primary chordae tendineae that arose along with the convex surface of the muscle. Each of them was branched into 2-3 secondary chordae tendineae, and inserted into the septal and angular valvular cusps.

Figure (2): This figure showed internal view of the right ventricle of the heart shows the septal (1) and parietal (2) cusps of the tricuspid valve, which are connected to the papillary septal (3), parietal (4), and angular (5) muscles by the primary (a) and secondary (b) chordae tendineae, and illustrates the moderate bands (c).

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The histology study of right and left papillary muscles displayed that the myocytes are short and bands in shape, and the cytoplasm was similar to cardiac cell muscles. Also, the histology patterns of papillary muscles were presented that there are increasing the interspersed connective tissues and fibres among myocytes in comparison with main cardiac muscles, Figure (7).

Furthermore, the typical cardiomyocytes were observed as branched bands in shape and contained centrally one elongated nucleus which was surrounded by myofibrils, and haematoxylin, eosin and Masson's trichrome stains were stained the nucleus dark brown in colour, Figures (3 and 4).

Moreover, the myocytes of papillary muscles were gradually reduced toward the apex of papillary muscles and chordae tendineae, also more spaces and connective tissue are shown. Subsequently, the capillaries were very distributed between cardiac cells. However, the myocytes were completely disappeared at meeting papillary muscles with chordae tendineae, then it was completely transited into connective tissue. The chordae tendineae were covered by layer of endothelium which was mainly consisted of elastic fibers, and the core of it was dominantly collagen fibers, also there are capillaries and adipocytes were seen in the histological sections of muscles and chordae tendineae, Figure (4,5, and 6).

The special stain of connective tissue was revealed that chordae tendineae accomplished with different fibers of connective which was included collagen, elastic and reticular fibers. However, the collagen fibers were very dominant fibers and constituted the most abundant of fibers, but there is fewer amount of elastic fibers. Figures (4,5, and 6).

The collagen fibers were blue in colour, while elastic and reticular fibers were pale in colour under the special stain, but then again, the elastic fibers were more abundant and large in size in comparison with reticular fibers. Also, the fibroblast and fibrocytes were very clear, dark in colour and spindle in shape and were located between the connective tissues, Figure (4, 5, and 6).

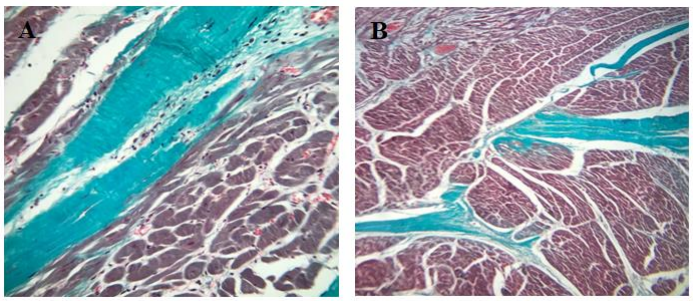

Figure (3): This section is illustrated the middle part of the papillary muscles of ventricle of the heart. A & B: Papillary muscles were stained with Masson's trichrome stain. Magnificent is 40x & and 20x.

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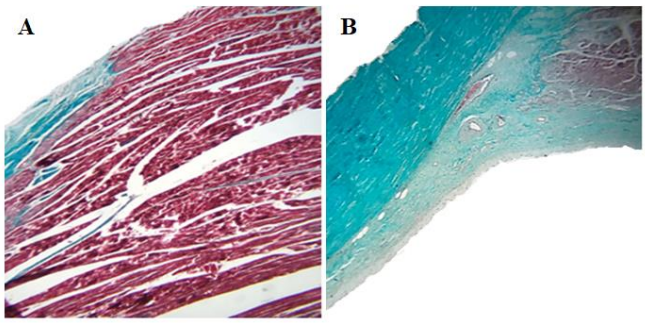

Figure (4): This section is illustrated the apex part of the papillary muscles of ventricle of the heart and the start of the transitional to chordae tendineae. A & B: Papillary muscles were stained with Masson's trichrome stain. Magnificent is 40x.

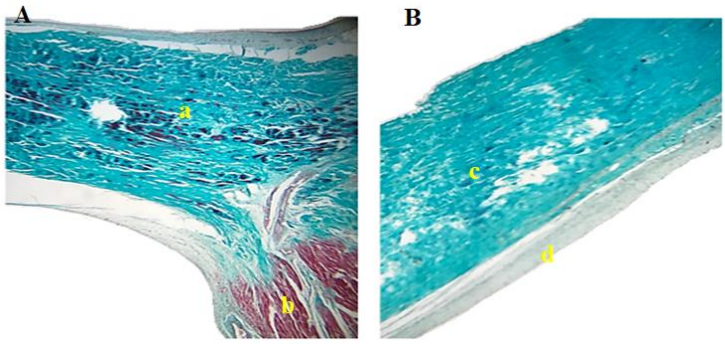

Figure (5): This section is illustrated the apex part of the papillary muscles of ventricle of the heart and the start of the transitional to chordae tendineae after replacing myocyte in to collage fibers and elastic fibers. A & B: Papillary muscles were stained with Masson's trichrome stain. So (a) is showed the collage fibers with elastic and reticular fibers, (b) is showed the apex of the papillary muscle, (c) is showed the collage fibers, (d) is showed the elastic fiber. Magnificent is 40x.

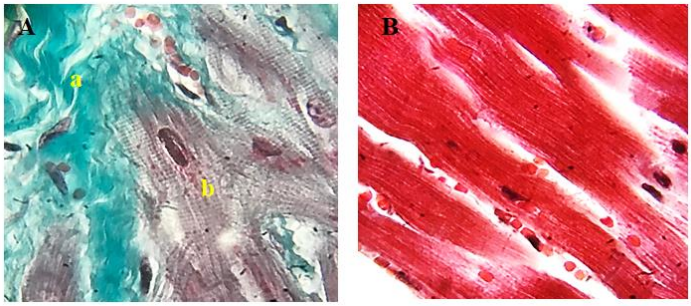

Figure (6): This section is illustrated the apex part of the papillary muscles of ventricle of the heart and the start of the transitional to chordae tendineae after replacing myocyte into collage fibers and elastic fibers. A: Apex of the papillary muscles were stained with Masson's trichrome stain, B: Papillary muscles and the start chordae tendineae were stained with Masson's trichrome stain. So (a) is showed the collage fibers with elastic and reticular fibers, and (b) is showed the apex of the papillary muscle. Magnificent is 100x.

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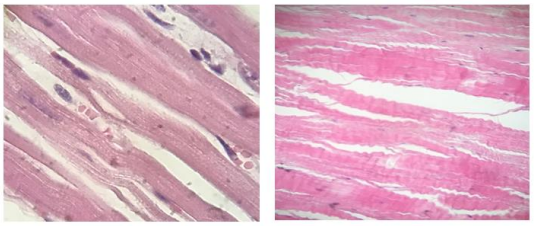

Figure (7): This section is illustrated the papillary muscles and chordae tendineae of ventricle of the heart. A: Papillary muscles were stained with H & E stain, B: Chordae tendineae was stained with H & E stain. Magnificent is 40x.

Table (1): This table is displayed the shape and origin of the right papillary muscles.

Papillary muscles	**Shape of Apex**	**Location of origin**
Parietal	Conical	Middle third of ventricle
Septal	Conical	Upper third of ventricle
Angular	Dom-shaped	Upper third of ventricle

Table (2): This table is displayed the shape and origin of the left papillary muscles.

Papillary muscles of Left ventricle	**Shape of Apex**	**Location of origin**
Parietal	Bifurcate	Upper third of ventricle
Septal	Trifurcate	Upper third of ventricle

Table (3): This table is displayed the average measurements of numbers, length and breadth of the right papillary muscles. So the abbreviations letters in this table are indicator as the following: No. R: number right, No. L: number left, B.R: breadth right, B.L: breadth left, L.R: length right L.L: length left.

1	**Average Numbers of Chordae tendineae**	**No. R. Parietal**	**No. R. Septal**	**No. R. Angular**	**No. L. Parietal**	No. L. Septal
	Measurements	11±0.7	7±0.3	4±0.3	7±0.6	9±0.6
2	**Breadth(CM)**	**B. R. Parietal**	**B.R. Septal**	**B.R. Angular**	**B. L. Parietal**	B. L. Septal
	Measurements	1.6±0.06	1.8±0.09	1.5±0.06	2.5±0.06	3.3±0.09
3	**Length(CM)**	**L. R. Parietal**	**L.R. Septal**	**L. R. Angular**	**L. L. Parietal**	L. L. Septal
	Measurements	1.2±0.06	0.6±0.06	**No Measurement**	1.2±0.04	2.5±0.04

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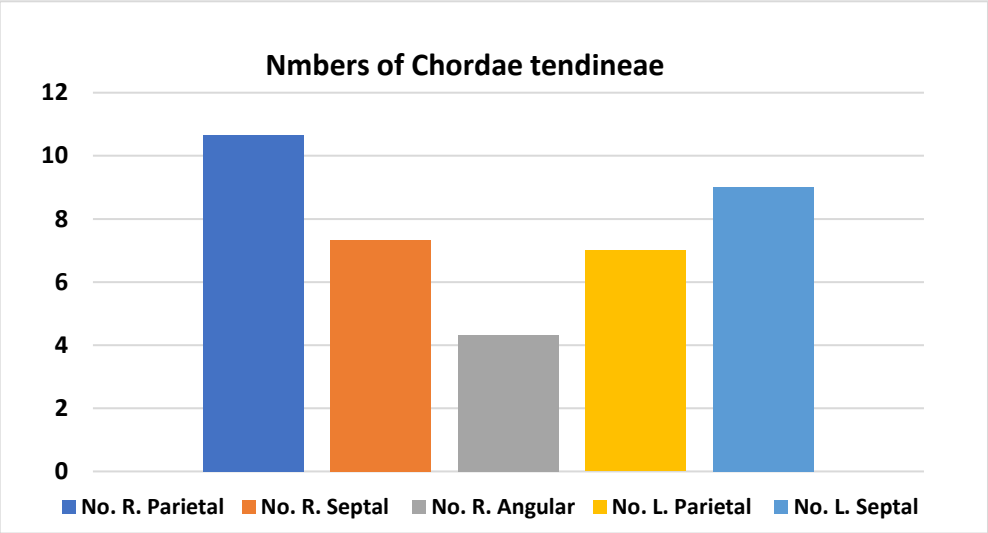

Figure (8): This chart is showed the numbers of chordae tendineae for the right and left side. So the abbreviations letters in this table are indicator as the following: No. R: number right, No. L: number left.

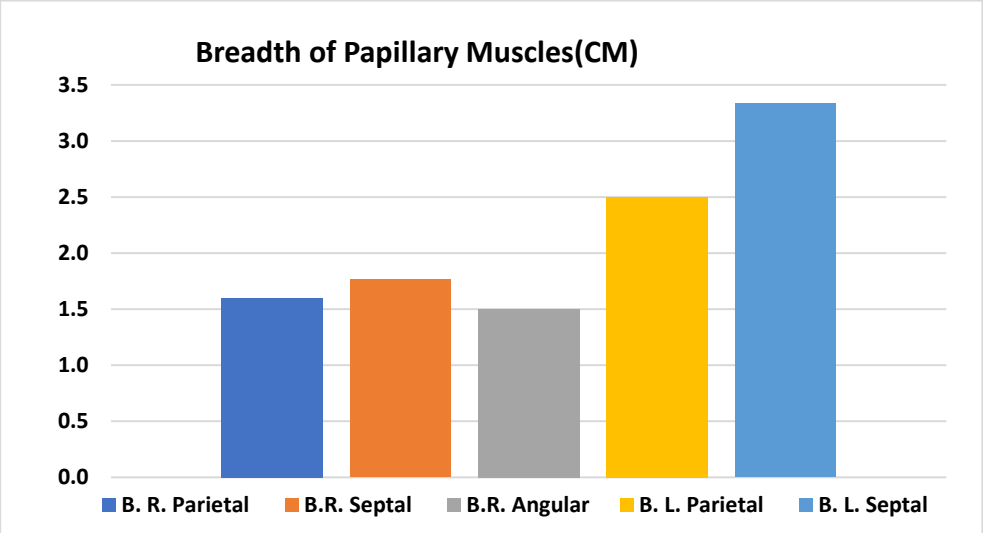

Figure (9): This chart is showed the breadth of the right and left side. The B.R: is indicator for breadth right, B.L and is indicator for breadth left.

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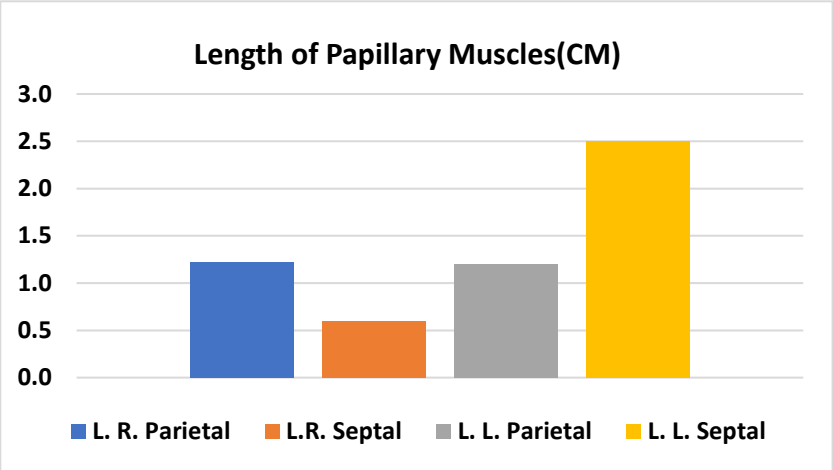

Figure (10): This chart is showed the length of the right and left side. The L.R is indicator for left right, L.L is indicator for left length.

Discussion

This study was showed that the heart of bovine has been three papillary muscles in the right ventricle to organise the blood flow of the right atrioventricular valve, and two papillary muscles in the left ventricles to control blood flow for the mitral valve of the left atrioventricular valve of the heart, so this result has corresponded with anatomy the structure of hearts of the human and some animals (Abd-Elbasset et al., 2021; Ateş et al., 2017; Hosapatna et al., 2014; Nigri et al., 2001). So the right papillary muscles were displayed that there are three muscles which included septal, angular and parietal muscles, while, the left papillary muscles were showed two muscles septal, and parietal muscles, these findings were confirmed by other studies (Alves et al., 2008; Nam et al., 2014).

However, the researchers on the human heart have different nomenclatures of papillary muscles, so the papillary muscles of the right were anterior, posterior and septal papillary muscles, and anterior and posterior papillary muscles were recorded on the left side (Hosapatna et al., 2014; Nigri et al., 2001), but then again, these studies confirmed that there is a high similarity between the heart of humans and the heart of bovines which can be used as animal models for human's heart studies..

A recent study showed that papillary muscles of the right and left side of the human heart are conical in shape which is confirmed our result in the bovine heart, but the angular papillary muscle was dome in shape, as, the septal papillary muscle was absent in some specimens of human heart, but, our investigation was recorded that there were three papillary muscles in the right side of the bovine's heart (Hosapatna et al., 2022). Accordingly, absent septal papillary muscle in some human hearts could be due to deformity or congenital malformation reasons.

Significantly, the left septal papillary muscle was wider than all other papillary muscles about 3.3±0.09 Cm, while the right septal papillary muscle was shorter than papillary muscles for

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both sides of the heart about 0.6±0.06 cm, this result has been agreed with other researchers (Ozbag et al., 2005; Roberts and COHEN, 1972), so this size of left papillary muscles is needed and might be explained that the left atrioventricular valve is under high pressure of blood because the majority of organs of the body are received oxygenated blood from the left side of the heart, in comparison with the right atrioventricular valve which is had less pressure.

The average number of chordae tendineae on the right side of the human heart in male and female were 25 totally and divided into the anterior, posterior and commissural chord tendineae of the papillary muscles (Lam et al., 1970), while our results of the right side were averaged 22 number of chordae tendineae of bovine heart.

New research on the human heart was distinguished that the length of myocytes fibers of papillary muscles are short and small in size in comparison with cardiac muscle (Kavitha and Manjunath, 2017), which was related to this study which also demonstrated that the myocytes are short in size and band in shape. As well as, the myocytes were gradually reduced toward the apex of muscles and chordae tendineae.

Our result displayed that chordae tendineae were structured from collagen, elastic and reticular fibers. However, the collagen fibers were constituted the main core of fibers of chordae tendineae, and the collagen fibers were externally surrounded by a layer of elastic fibers, this result was shown in chordae tendineae of the heart of the human (Chen et al., 2020; Gross and Kugel, 1931; Millington-Sanders et al., 1998), so the majority amount of collagen fibers was covered by a layer of elastic fibers which might be supported the flexibility movement of these cords during blood flow.

In conclusion, the gross study recognised that there are three papillary muscles involved with the angular, septal, and parietal muscles of the heart, so three muscles were identified in the right ventricle and two papillary muscles in the left ventricles because the angular papillary muscle was absent.

However, the septal and parietal papillary muscles of the left side were wider than the right papillary muscles of the right side, and the right septal papillary muscle was the muscle among papillary muscles. Also, the numbers of chordae tendineae were distinguished more numbers in the right papillary muscle in comparison with other papillary muscles on the left side.

Furthermore, histologically, myocytes of the right and left papillary muscles were revealed that were short, branched and band in shape, but the cytoplasm was similar to cardiocyte. The myocytes were absent in chordae tendineae and completely transited into fibers connective tissue.

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Conflict of Interest

This study has no conflict of interest.

References

[1]. Abd-Elbasset, A.E.-D., El-sayed, A., Mohamed, H., El-Bherey, E., Nouh, D., 2021. Computed Tomographic, Echocardiographic, Radiographic, and Morphological Anatomy of the Heart in Goats (Capra Hircus). Zagazig Veterinary Journal 49, 414-431.

[2]. Aktas, E.O., Govsa, F., Kocak, A., Boydak, B., Yavuz, I.C., 2004. Variations in the papillary muscles of normal tricuspid valve and their clinical relevance in medicolegal autopsies. Saudi Med J 25, 1176-1185.

[3]. Deepak Mathur, N. K. V. . (2022). Analysis & Prediction of Road Accident Data for NH-19/44. International Journal on Recent Technologies in Mechanical and Electrical Engineering, 9(2), 13–33. https://doi.org/10.17762/ijrmee.v9i2.366

[4]. Alves, J., Wafae, N., Beu, C., Tuzuki, L., Ruiz, C., Wafae, G., 2008. Morphometric study of the tricuspid valve in dogs. Anatomia, histologia, embryologia 37, 427-429.

[5]. Ateş, S., Karakurum, E., Takcı, L., Başak, F., Kürtül, İ., 2017. Morphology of the atrioventricular valves and related intraventricular structures in the wild pig (Sus scrofa). Folia morphologica 76, 650-659.

[6]. Chen, S., Sari, C.R., Gao, H., Lei, Y., Segers, P., De Beule, M., Wang, G., Ma, X., 2020. Mechanical and morphometric study of mitral valve chordae tendineae and related papillary muscle. journal of the mechanical behavior of biomedical materials 111, 104011.

[7]. Gupta, D. J. . (2022). A Study on Various Cloud Computing Technologies, Implementation Process, Categories and Application Use in Organisation. International Journal on Future Revolution in Computer Science &Amp; Communication Engineering, 8(1), 09–12. https://doi.org/10.17762/ijfrcsce.v8i1.2064

[8]. Estes Jr, E.H., Dalton, F.M., Entman, M.L., Dixon II, H.B., Hackel, D.B., 1966. The anatomy and blood supply of the papillary muscles of the left ventricle. American Heart Journal 71, 356-362.

[9]. Fedonjuk, L.Y., Penteleychuk, N., Tumanova, O., 2015. MORPHOLOGICAL CHARACTERISTICS OF THE TENDINOUS CORDS OF ATRIOVENTRICULAR HEART VALVES OF FETUSES, NEWBORNS AND INFANTS IN THE NORM, In: Актуальные научные исследования. Теория, практика, pp. 86-88.

[10]. Greenbaum, R., Ho, S.Y., Gibson, D., Becker, A., Anderson, R., 1981. Left ventricular fibre architecture in man. Heart 45, 248-263.

[11]. Gross, L., Kugel, M., 1931. Topographic anatomy and histology of the valves in the human heart. The American journal of pathology 7, 445.

[12]. Gill, R. . (2022). Hulls for a Partially Right-Prime, Orthogonal Random Variable. International Journal on Recent Trends in Life Science and Mathematics, 9(2), 47–57. https://doi.org/10.17762/ijlsm.v9i2.135

[13]. Hosapatna, M., DSouza, A., Ankolekar, V.H., 2021. Morphology of the Papillary Muscles and the Chordae Tendinae of the Ventricles of Adult Human Hearts. Cardiovascular Pathology, 107383.

[14]. Hosapatna, M., DSouza, A., Ankolekar, V.H., 2022. Morphology of the papillary muscles and the chordae tendineae of the ventricles of adult human hearts. Cardiovascular Pathology 56, 107383.

[15]. Hosapatna, M., Souza, A.D., Das, M.A., Ankolekar, V.H., Souza, A.S.D., 2014. Morphology of Papillary Muscles in Human Adults: A Cadaveric Study. Ibnosina Journal of Medicine & Biomedical Sciences 6.

[16]. Hutchison, J., Rea, P., 2015. A comparative study of the morphology of mammalian chordae tendineae of the mitral and tricuspid valves. Veterinary record open 2, e000150.

[17]. Kavitha, S., Manjunath, K., 2017. Micrometric And Microanatomical Study of Papillary Muscles In Adult Human Hearts. IOSR J Dent Med Sci 16, 31-37.

[18]. Lam, J., Ranganathan, N., Wigle, E., Silver, M., 1970. Morphology of the human mitral valve: I. Chordae tendineae: A new classification. Circulation 41, 449-458.

[19]. Millington-Sanders, C., Meir, A., Lawrence, L., Stolinski, C., 1998. Structure of chordae tendineae in the left ventricle of the human heart. The Journal of Anatomy 192, 573-581.

[20]. Palagan Senopati Sewoyo, Anak Agung Ayu Mirah Adi, Ni Luh Eka Setiasih, I Gusti Ayu Mirah Afsari Dewi. (2022). Haematological Profile of Rat Fibrosarcoma Models After Virulent Newcastle Disease Virus Virotherapy: A Pilot Study. Revista Electronica De Veterinaria, 47 - 55. Retrieved from https://www.veterinaria.org/index.php/REDVET/article/view/138

[21]. Nam, C.-H., Kim, H.Y., Lin, C., Yon, J.-M., 2014. Comparative anatomical characteristics of cardiac valves in animals. Journal of Biomedical Research 15, 19-23.

[22]. Nigri, G., Di Dio, L., Baptista, C., 2001. Papillary muscles and tendinous cords of the right ventricle of the human heart morphological characteristics. Surgical and Radiologic Anatomy 23, 45-49.

[23]. Overholt, E.D., Joyner, R.W., Veenstra, R.D., Rawling, D., Wiedmann, R., 1984. Unidirectional block between Purkinje and ventricular layers of papillary muscles. American Journal of Physiology-Heart and Circulatory Physiology 247, H584-H595.

[24]. Ozbag, D., Gumusalan, Y., Demirant, A., 2005. The comparative investigation of morphology of papillary muscles of left ventricle in different species. International journal of clinical practice 59, 529-536.

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[25]. Ritchie, J., Warnock, J.N., Yoganathan, A.P., 2005. Structural characterization of the chordae tendineae in native porcine mitral valves. The Annals of thoracic surgery 80, 189-197.

[26]. Roberts, W.C., COHEN, L.S., 1972. Left ventricular papillary muscles: description of the normal and a survey of conditions causing them to be abnormal. Circulation 46, 138-154.

[27]. Spreeuwers, L., Bangma, S., Meerwaldt, R., Vonken, E., Breeuwer, M., 2005. Detection of trabeculae and papillary muscles in cardiac MR images, In: Computers in Cardiology, 2005, pp. 415-418.

[28]. Veenstra, R., Joyner, R., Rawling, D., 1984. Purkinje and ventricular activation sequences of canine papillary muscle. Effects of quinidine and calcium on the Purkinje-ventricular conduction delay. Circulation research 54, 500-515.

[29]. Xanthos, T., Dalivigkas, I., Ekmektzoglou, K.A., 2011. Anatomic variations of the cardiac valves and papillary muscles of the right heart. Anatomic Variations of the Cardiac Valves and Papillary Muscles of the Right Heart, 111-126.