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Gross Morphometrical and Histological Studies on the Heart of Postnatal Goat (*Capra hircus*)

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ABSTRACT

A study was conducted to elucidate normal gross morphometrical and histological features in heart of 21 goats at different stages of postnatal development ranging from birth to three years. The specimens were divided into three age groups *viz.,* group-I (less than 6 months), group-II (6 to 12 months) and group-III (above 12 months to 3 years). The goat heart was somewhat flattened cone shaped and consisted of four chambers. The mean values of length, maximum width and circumference at base of the heart increased significantly from birth to 3 years. The length of cranial and caudal borders of heart as well as length and maximum width of right and left ventricles showed significant increase with age. The mean heart weight and mean volume were 160.17 ±15.02 g and 162.13 ±14.53 cc, respectively in between above 12 months to 3 years. The wall of all four chambers of the heart was consisted of three layers *viz.,* epicardium, myocardium and endocardium. The epicardium was composed of mesothelium and thin sheet of loose connective tissue. Myocardium was formed by cardiac muscle bundles embedded in loose connective tissue and oriented in various directions. Purkinje fibres were observed between myocardial bundles and endocardium. Group of adipose cells was also noticed in the endocardium layer of adult goats. Gross morphometrical data of goat heart at various stages of development would help diagnosis and treatment of cardiac diseases in goats.

HIGHLIGHTS

- Recorded gross external and internal mean biometric values of heart in different age groups of postnatal goats.
- Histomorphology of atrial and ventricular walls of goat heart.

Keywords: Goats, heart, histomorphology, morphometry, ventricle

The heart is the central hollow muscular organ of the cardio vascular system that pumps the blood continuously through the blood vessels by rhythmic contraction (Dyce *et al.,* 2010 and Konig and Liebich, 2014). It is mainly composed of cardiac muscles which forms a sac, divided into four chambers; right atrium, left atrium, right ventricle and left ventricle. The heart of large mammals share many similarities and yet the sizes, shapes and positions of the hearts in the thoracic cavities can vary considerably between species (Getty, 1975). In recent decades, goats have emerged as excellent animal models and considered as a suitable for the study of human cardiovascular diseases and its management (Smith and Sherman, 2009 and Alvites *et al.,* 2021). The dissected heart generates anatomical knowledge and description (Abd-Elbasset *et al.,* 2021). Detailed anatomical knowledge of goat heart is important for diagnosis of cardiac diseases. Therefore, the present study is aims to explore normal gross morphometrical and histological features of goat heart at various stages of postnatal development that can be used to understand cardio-physiology, diagnostic purpose, veterinary education and pathological studies.

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MATERIALS AND METHODS

A total of 21 heart specimens were collected from apparently healthy goats irrespective of sex slaughtered at the local abattoirs of Navsari. The approximate age of the postnatal goats was estimated on the basis of dentition pattern (Noden and de Lahunta, 1985). The goats were divided into three age groups based on their approximate age *viz.,* group I (less than 6 months (n=7)), group II (6 to 12 months (n=6)) and group III (above 12 months to 3 years (n=8)). Immediately after collection of specimens blood clots in the chambers of the heart were removed out by flushing the water, then gross and morphometrical parameters were recorded by Vernier caliper (Mitutoyo Caliper) and non stretchable thread. After recording gross observations, the tissue pieces of heart were fixed in 10 % neutral buffered formalin and processed for paraffin embedding technique. Tissue sections (5µ thick) were obtained and stained with Harri's haematoxylin and eosin method for general histoarchitecture and Masson's trichrome method for collagen fibres (Luna, 1968). The data of gross parameters were statistically analysed by using one way ANOVA and means were compared using Duncan's multiple range test (DMRT) (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

Gross morphology and topography

The heart of goat was present in the ventral part of thoracic cavity and occupies greater part of middle mediastinum (Fig. 1). The heart was somewhat flattened cone shaped with its broad base directed dorsally and the apex ventrally (Fig. 1). The base of the heart was extended between 3rd to 6th rib and the apex was lies centrally above the last segment of the sternum. Similar observations were reported by other authors (Gayatri, 2010; Abd-Elbasset *et al.,* 2021 in goats and Sandhu *et al.,* 2021 in sheep). The heart was consisted of two borders, two surfaces, base and apex. The anterior border was strongly convex and curves ventrally and backward (Fig. 2). The caudal border was nearly vertical and entirely formed by left ventricle. It was shorter than the cranial border. The right and left surfaces were convex and marked by transverse and longitudinal grooves which indicate division of the heart into four chambers (Fig. 2). The transverse groove was circumference at coronary groove. It indicates the division between the atrium and ventricles (Fig. 2). The longitudinal grooves right and left correspond to the septum between the ventricles. A shallow intermediate groove was extends down from the transverse groove at the left side of caudal border. These findings were in accordance with the observations of Gayatri (2010); Abd-Elbasset *et al.* (2021) in goats and Konig and Liebich (2014) in domestic animals.

The right atrium was located above the right ventricle and formed the right anterior part of the base of the heart. It was consisted of a main part sinus venarum and a blind ended part the right auricle. The veins drained the blood opens into the sinus venarum at right atrium (Fig. 2). A depressed area was lies on the interatrial septum, the fossa ovalis which was foetal remnant of the foramen ovale of foetal life. The right atrio-ventricular orifice was situated at in the ventral part and opened towards the right ventricle. The meshwork of pectinate muscle was observed on the internal wall of right auricle, formed irregular ridges on the inner surface. These findings were in agreement with Getty (1975) and Konig and Liebich (2014) in domestic animals.

The right ventricle formed the right anterior part of the ventricle. It was crescent shaped in cross section and does not reach the apex of heart which was entirely formed by the left ventricle (Fig. 3). The base was connected with right atrium and communicated through the right atrioventricular orifice. Its left part was projected higher and formed conus arteriosus from which the pulmonary artery arised. The right atrioventricular orifice was guarded by tricuspid valve (Fig. 4). The chordae tendineae were attached these valves with below to the three papillary muscles (Fig. 4). According to Komala and Jayanthi (2015), three papillary muscles namely anterior, posterior and septal were located in the right ventricle and the number of chordae tendineae attached to the cusps with papillary muscles were higher in human, followed by pig and cow and were less in sheep and goat. The wall of the right ventricle was marked by presence of numerous ridges trabeculae carneae. In the lumen of right ventricle a single, thick and unbranched moderator band was observed in all goat hearts (Fig. 4). Similarly, Abd-Elbasset *et al.* (2021) in goat and Sandhu *et al.* (2021) in sheep also observed single, unbranched moderator band in right ventricle.

Table 1: Gross external biometric values (Mean ± SE) of heart in different age groups of postnatal goats

Parameters	Group-I (n=7)	Group-II (n=6)	Group-III (n=8)	F-Value	P-Value
Heart weight with pericardium (g)	49.030^{a} ± 3.947	84.321^{b} ± 6.728	160.176^{c} ±15.021	29.84	0.00
Heart weight without pericardium (g)	44.551^{a} ± 3.701	78.816 ^{b} ± 6.126	149.348^{c} ± 14.855	28.54	0.00
Heart volume with pericardium (cc)	47.71^{a} ±5.003	84.33^{b}±5.643	162.130^{c} ±14.531	33.45	0.00
Length of heart (mm)	58.994^{a} ± 2.042	71.036^{b} ± 2.213	88.417^{c} ± 2.588	42.44	0.00
Maximum width of heart (mm)	38.305^{a} ± 1.447	47.898^{b} ± 1.022	60.512^{c} ± 1.803	55.59	0.00
Circumference at base of heart (cm)	11.814^{a} ± 0.455	14.000^{b} ± 0.567	17.788^{c} ± 0.446	41.89	0.00
Length of cranial border (cm)	5.84^{a} ± 0.203	7.70^{b} ± 0.278	9.53^{c} ± 0.374	38.34	0.00
Length of caudal border (cm)	4.729^{a} ± 0.264	6.133^{b} ± 0.209	7.325^{c} ± 0.297	24.61	0.00
Maximum length of right atrium (mm)	24.358 ^{a} ± 1.596	24.840 ^{a} ± 1.762	28.795 ^{a} ± 1.675	2.74	0.09
Maximum width of right atrium (mm) (at widest part)	14.417 ^{a} ± 1.078	17.683 ^{a} ± 0.750	17.907 ^{a} ± 1.491	2.01	0.16
Maximum length of left atrium (mm)	22.562 ^{a} ± 0.999	24.166 ^{a} ± 1.015	26.342 ^{a} ± 1.482	2.48	0.11
Maximum width of left atrium (mm) (at widest part)	16.100 ^{a} ± 1.061	17.520^{ab} ± 1.331	20.197^{b} ± 1.345	2.90	0.08
Maximum length of right ventricle (mm)	35.871 ^{a} ± 1.195	45.356^{b} ± 2.235	54.020^{c} ± 2.427	20.49	0.00
Maximum width of right ventricle (mm)	30.665 ^{a} ± 1.710	38.006 ^{a} ± 2.694	50.042^{b} ± 2.996	15.36	0.00
Maximum length of left ventricle (mm)	46.320 ^{a} ± 1.746	56.040^{b} ± 1.656	65.307^{c} ± 3.617	12.85	0.00
Maximum width of left ventricle (mm)	27.937 ^{a} ± 1.411	33.947^{b} ± 1.501	43.985^{c} ± 2.252	20.44	0.00
Distance Between origin of pulmonary artery and apex (cm)	6.129 ^{a} ± 0.257	7.383^{ab} ± 0.101	8.325^{b} ± 1.001	2.74	0.09
Distance Between junction of right and left longitudinal groove and apex (cm)	1.514 ^{a}± 0.208	1.567 ^{a} ± 0.206	1.950 ^{a} ± 0.108	2.02	0.16

Means bearing different superscript (a, b, c) in a row vary significantly (P<0.05).

Table 2: Gross internal biometric values (Mean ± SE) of heart in different age groups of postnatal goats

Parameters	Group-I (n=7)	Group-II (n=6)	Group-III (n=8)	F-Value	P-Value
Thickness of right atria wall (mm)	1.660^{a} ± 0.192	2.126 ^{a} ± 0.130	2.317 ^{a} ± 0.171	1.94	0.17
Thickness of left atria wall (mm)	1.902 ^{a} ± 0.219	1.983 ^{a} ± 0.207	2.082 ^{a} ± 0.223	0.46	0.63
Thickness of right ventricle at middle (mm)	4.151 ^{a} ± 0.336	5.293^{ab} ± 0.555	6.347 ^{b} ± 0.636	4.42	0.03
Thickness of left ventricle at middle (mm)	7.825 ^{a} ± 0.919	9.233^{ab} ± 0.510	10.495 ^{b} ± 0.643	3.60	0.04
Diameter of cranial venacava (mm)	5.108 ^{a}± 0.381	5.510 ^{a}± 0.440	7.365 ^{b}± 0.448	8.44	0.00
Diameter of caudal venacava (mm)	5.560^{a} ± 0.424	6.037 ^{a}± 0.363	6.778 ^{a}± 0.502	1.98	0.16
Diameter of anterior aorta (mm)	3.805 ^{a}± 0.270	5.800 ^{b}± 0.557	5.625 ^{b}± 0.208	10.23	0.00
Diameter of caudal aorta (mm)	5.711 ^{a}± 0.529	6.500 ^{a}± 0.338	6.957 ^{a}± 0.346	2.40	0.11
Diameter of pulmonary aorta (mm)	5.914 ^{a}± 0.186	7.563^{ab}± 0.644	8.470 ^{b} ± 0.836	4.18	0.03

Means bearing different superscript (a, b, c) in a row vary significantly (P<0.05).

The left atrium was formed left posterior part of the base of the heart. The shape and structure of the left atrium was similar to that of right atrium. Several opening of pulmonary veins were noticed on the wall of left atrium. The left atrium was connected with left ventricle through left atrioventricular orifice (Fig. 4). These findings were similar with those reported by Dyce *et al.* (2010) and Konig and Liebich (2014) in domestic animals.

The left ventricle was formed the left caudal part of the ventricular mass. The wall of the left ventricle was thicker than the right ventricle. The interventricular septum faces towards the left ventricle was concave, so cavity usually appeared almost circular in cross section (Fig. 3). The left atrioventricular orifice was guarded by the bicuspid valve that connected to the papillary muscles by chordae tendineae (Fig. 4). The two papillary muscles were found

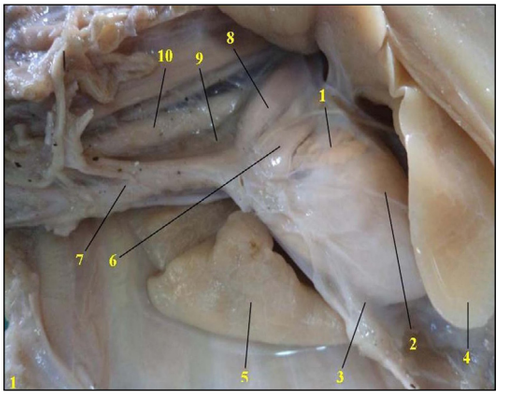

Fig. 1: *In-situ* position of the goat heart. **(1)** Left atrium; **(2)** left ventricle; **(3)** pericardium; **(4)** cardiac lobe of left lung; **(5)** apical lobe of right lung; **(6)** pulmonary aorta; **(7)** brachiocephalic trunk; **(8)** posterior aorta; **(9)** trachea; **(10)** oesophagus

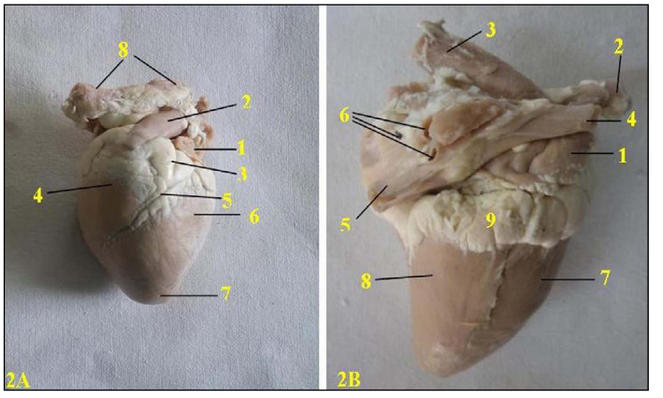

Fig. 2: Left **(A)** and right **(B)** views of the goat heart. **(A) (1)** Left atrium; **(2)** pulmonary aorta; **(3)** transverse groove; **(4)** right ventricle; **(5)** left longitudinal groove; **(6)** left ventricle; **(7)** apex of heart; **(8)** aorta. **(B) (1)** Right atrium; **(2)** anterior aorta; **(3)** posterior aorta; **(4)** cranial venacava; **(5)** caudal venacava; **(6)** opening of pulmonary veins; **(7)** right ventricle; **(8)** left ventricle; **(9)** transverse groove

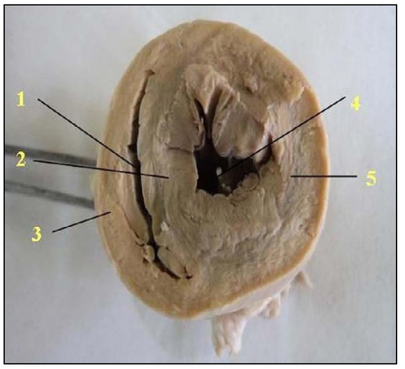

Fig. 3: Cross section of ventricular part of the heart of goat. **(1)** Right ventricle; **(2)** ventricular septum; **(3)** right ventricle wall; **(4)** left ventricle; **(5)** left ventricle wall

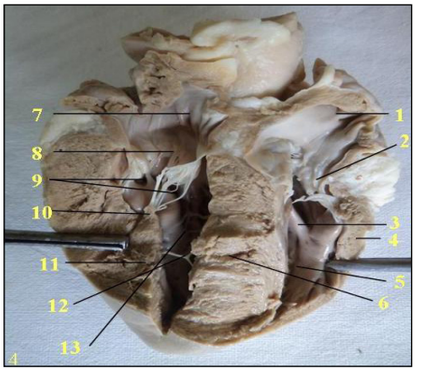

Fig. 4: Section of the goat heart exposing the four chambers. **(1)** Right atrium; **(2)** right atrioventricular valve; **(3)** right moderator band; **(4)** right ventricular wall; **(5)** right ventricular cavity; **(6)** interventricular septum; **(7)** left atrium; **(8)** left atrioventricular valve; **(9)** chordae tendineae; **(10)** papillary muscles; **(11)** left ventricular wall; **(12)** left moderator band; **(13)** left ventricular cavity

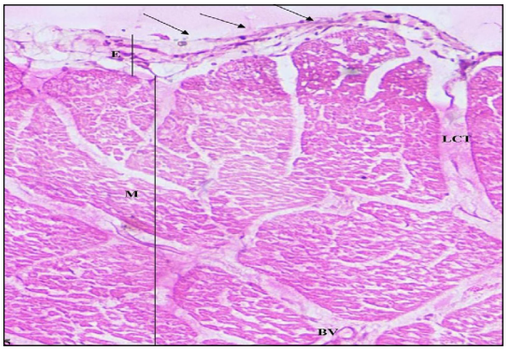

Fig. 5: Photomicrograph of right ventricle of goat (G-I) showing **(E)** epicardium, **(M)** Myocardium, LCT: loose connective tissue, BV: section of blood vessels and mesothelium (arrows). (H&E × 100)

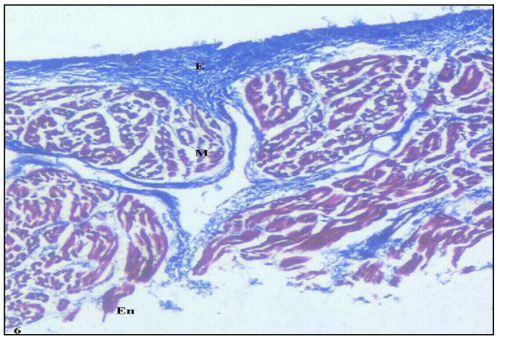

Fig. 6: Photomicrograph of right atrium of goat (G-III) showing blue collagen fibres in epicardium **(E)**, myocardium **(M)** and endocardium (En) layers. (Masson's Trichrome Method × 40)

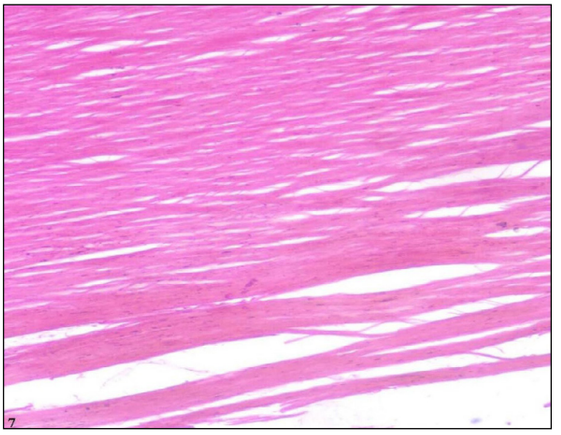

Fig. 7: Photomicrograph of left ventricle of goat (G-III) showing branching myofibres and striations. (H&E × 40)

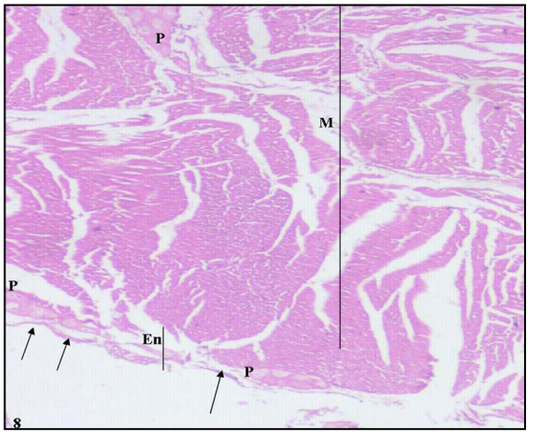

Fig. 8: Photomicrograph of right ventricle of goat (G-I) showing **(M)** Myocardium, En: endocardium, **(P)** purkinje fibres and endothelium (arrows). (H& E × 40)

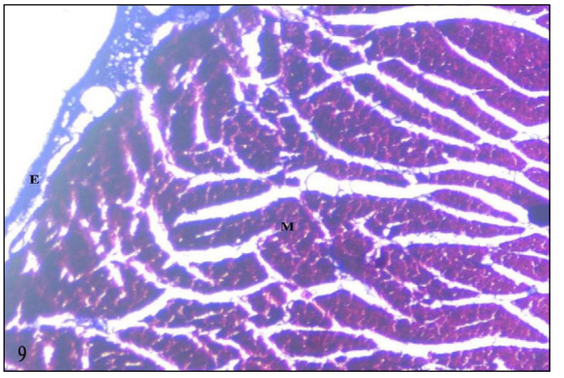

Fig. 9: Photomicrograph of right ventricle of goat (G-III) showing blue collagen fibres in epicardium **(E)** and myocardium **(M)** layers. (Masson's Trichrome Method × 100)

in the left ventricle. The trabeculae carneae were resembled like the right ventricle. The aortic orifice was the opening in the left ventricle directed upward and forward into the ascending aorta. In the left ventricle the moderator bands were varied in size and number. Some were larger and branched while few were small to medium size (Fig. 4). Deniz *et al.* (2004) reported that the left ventricular bands usually extended from the papillary muscles to the interventricular septum in animal hearts. Sandhu *et al.* (2021) reported that the small, medium and large sized moderator bands were present in left ventricle of sheep.

Biometrical study

The mean heart weight (with and without pericardium) and volume with pericardium increased significantly with advancement of age in postnatal goats. The maximum increase in heart weight and volume was noticed between groups II to III (Table 1). Gayatri (2010) recorded average heart weight 47.50 ± 4.95 g at prepubertal goats and 162.0 ± 14.19 g at adult goats. Sathapathy *et al*. (2013) reported average heart weight 138 ± 6.01 g in male goats and 145 ± 4.67 g in female goats of 2 to 3 years. The mean values of length, maximum width and circumference at base of the heart were increased significantly ($P<0.01$) from the age group I to group III (Table 1). Similar observations were reported by Gayatri (2010) in goats with age. The mean length of cranial border was larger as compared to caudal border in each group and both the lengths increased significantly from the age groups I to III (Table 1). These findings were in accordance with the observations of Panhwar *et al.* (2007) in buffaloes and

Gayatri (2010) in goats. The mean values of maximum length and width of right and left atrium were statistically not significant between groups (Table 1). The mean values of maximum length and width of right and left ventricle were increased significantly (P<0.01) from the age groups I to III. The mean distance between origin of pulmonary artery and apex was not significant between groups (Table 1). Similarly, distance between junction of right and left longitudinal groove and apex was not significant between groups (Table 1).

The mean thickness of right and left atrial wall was not significant between groups (Table 2). Maguigad and Balagan (2021) reported that the mean thickness of the left atrial wall showed no significant difference to that of right atrial wall in mature Philippine water buffalo. The mean thickness of right and left ventricle at its middle was increased significantly between groups I and III, however, the mean thickness of left ventricle wall was maximum in each group which was similar to that of observations reported by Gayatri (2010) in goats and Maguigad and Balagan (2021) in mature Philippine water buffalo. The mean diameter of cranial venacava and anterior aorta increased significantly (P<0.01) from the age groups I to III, however, the mean diameter of caudal venacava and posterior aorta was not significant between groups. The mean diameter of pulmonary aorta increased significantly (P<0.05) from the age group I to III (Table 2). Vaish *et al.* (2000) reported that diameter of larger vessels of goat heart shows greater increase in the early foetal life as compared to late prenatal and postnatal life.

Histomorphological study

The histological sections of atrial and ventricular walls of goat heart were consisted of three layers. The outermost layer was epicardium, a middle myocardium and an innermost endocardium. Similar to the present findings Eurell and Frappier (2006) described the three layers of the heart wall in domestic animals. The epicardium was composed of mesothelium resides upon the thin sheet of loose connective tissue, the subepicardial layer (Fig. 5). This layer was consisted of collagen fibres with blood vessels and nerves (Figs. 5 & 6). The epicardium of the atrium was appeared thicker as compared to the epicardium of ventricles (Fig. 6). These findings were in accordance with those reported by Nagpal (1977) in goats and Sandhu *et al.* (2021) in sheep. The middle and thickest layer of the ventricle was myocardium composed of cardiac muscles, connective tissue sheath, blood vessels and cardiac conduction fibres (Figs. 7 & 8). In myocardium, the cardiac muscles were oriented in various directions *viz*., longitudinal, circular and oblique. The bundles of cardiac muscle fibres were embedded in loose connective tissue (Figs. 7 & 8). The greater amount of connective tissue was noticed at adulthood (Fig. 9). Emam and Abugherin (2019) reported that the amount of connective tissue was increased in adult Egyptian bovine as compared to immature animals. The cardiac myocytes were irregular polygonal cells of different sizes with centrally placed large round nucleus and showed striations in longitudinal section (Fig. 7). Cardiac muscle bundles in the ventricular myocardium were comparatively larger as compared to the atrial wall. Similar observations were also reported by Sandhu *et al.* (2021) in sheep. The innermost layer was endocardium composed of an endothelium, a subendothelial layer and a subendocardial layer (Fig. 8). These findings were similar with the observations made by Emam and Abugherin (2019) in Egyptian bovine, Sandhu *et al.* (2021) in sheep and Eurell and Frappier (2006) in domestic animals. The endothelium was made by simple squamous epithelium resting on the basement membrane (Fig. 8). The subendothelial layer was thick than endothelium and composed of dense irregular connective tissue and purkinje fibres (Fig. 8). The subendocardial layer was continuous with myocardium and it was composed of connective tissue fibres. Group of adipose cells was also noticed in the endocardium of adult goat heart. Similar to present findings, Sandhu *et al.* (2021) observed isolated bundles of adipose tissue in the endocardium of adult sheep heart. Eurell and Frappier (2006) also described the presence of adipose cells in the subendocardial layer of endocardium in domestic animals.

From our investigation it is concluded that topography and detailed anatomy of the heart can be used to understand normal cardiac anatomy and cardiac-physiology. Moreover, values of various morphometrical parameters of the heart from birth to three years of age may help to surgeons, radiologist and pathologist for diagnosis of cardiac diseases in goats.

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