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UNIQUE DEVELOPMENT OF THE HEART OF THE DROMEDARY CAMEL: A COMPARATIVE REVIEW

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ABSTRACT

The cardiovascular system was one of the first body systems to appear within the embryo. The heart was active by the beginning of the fourth week. The aim of this review is to describe the prenatal developmental changes that occur in dromedary camel foetus and compared the structures of the foetal camel heart to that of other mammals.

Key words: Camel, development, foetus, heart

The heart is the first organ to develop during embryogenesis, and the researchers places a great deal of importance on the heart's early circulation function. Therefore, both classical and molecular embryologists have given a great deal of attention to the developmental mechanisms that coordinate the formation and morphogenesis of this organ. Several vertebrate and invertebrate embryos have been studied in depth because of the evolutionary conservation of many of these processes (Zaffran and Frasch, 2002; Tan and Lewandowski, 2020; McGeady *et al,* 2017). In humans, the heart beats spontaneously by the fourth week of development. Its development begins with the formation of two endocardial tubes, which merge to form the tubular heart (primitive heart tube). It loops and become separated into four chambers and paired arterial trunks, (Moorman *et al,* 2003). According to Moorman and Christoffels (2003) and van den Hoff *et al* (2004) the heart development started when the first mesodermal cells migrated anterolateral and formed the bilateral heart- forming primordia during gastrulation. The main walls of the heart were formed between day 27 and day 37 of the development of the embryo. Growth began with two tissue masses, which were actively growing towards each other until they finally merged and split into two separate tubes (Fernández, 2002). Only one research in the available literature was conducting during pregnancy in the dromedary camel, the beats of the heart was detected on day 26 - day 28 (Alhaider, 2019).

Histological development of the heart:

Balogh and Sótonyi (2003) studied the early cardiac development in rabbit. They have stated that on the 9th day of gestation the embryonic disc appeared, on the 10th day the single cardiac tube was formed, on the 11th day the bulboventricular loop was formed and the heart consisted of three chambers. On the 12th day the partitioning of atria and ventricles was close to its end. On the 13th day the heart consisted of four chambers and on the 14th day the developmental stage of the heart was very similar to that seen in the newborn. In rabbits the most intensive development of the heart took place in the period between the 10th and the 13th day.

The smooth zones of the interventricular septum and the pulmonary and aortic roots, compared to the trabeculated parts of the right and left ventricles, were recognisable. The transition zone between compact and trabeculated tissues was called the spongy layer and it was recognised as a network of fine trabeculations, the different layers of the ventricular myocardium (Savolainen *et al*, 2009). Important studies were conducted in the development of dromedary camel heart (Babiker, 2016). At the stage of 2cm CVRL (71 days of gestation), the pericardium of the camel heart was associated with the diaphragm, liver, and thoracic vertebrae. The atrial outlines were irregularly showing many undulations, whereas the ventricular outlines were relatively regular. The epicardium appeared as a thin layer. The ventricular endocardium showed many trabeculae (Fig 1). At

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the stage of 17cm CVRL (112 days of gestation), the atria were formed of a thin layer of mesenchymal connective tissue covering the atrial myocardium. The endocardium was formed of an endothelium supported by a subendothelial layer of mesenchymal connective tissue. The atrial myocardium presented scattered and thick cardiac muscle bundles (Fig 2) (Babiker, 2016).

Ventricular myocardium was in the form of compact layers of cardiac muscle fibres rich on mesenchymal connective tissue and blood vessels with decreased trabeculation and wide luminae. The right ventricle at this stage showed mainly cardiac muscle fibres and mesenchymal connective tissues. The left ventricle had a thick layer of myocardium and a considerable amount of mesenchymal connective tissue. Many cardiac muscle fibres were closely surrounding the endocardium and some others were transformed from myofibroblasts to myocytes (Fig 3) (Babiker, 2016).

As foetal age increased, a gradual increase was also observed in the myocardial thickness of the ventricular wall and atrial pectinate muscles by an increase of cell layers. Large amount of adipose tissue was observed in the dromedary camel foetus in the epicardium in which the interventricular branches of coronary arteries and their branches were embedded (Fig 4) (Babiker, 2016).

Cardiac Conduction System

The components and structure of the specific conduction system in humans are like those found in commonly used laboratory animals. The conduction system was composed of specialised myocytes. Its atrial components, sinus node and atrioventricular node, are in contact with atrial myocardium. The bundle of His penetrates the right fibrous trigone, then divides into two specialised ventricular branches (right and left). It is surrounded by a fibrous sheath that separates the specialised myocytes from the ordinary myocardium. The fibrous sheaths disappear at the distal ramifications of the bundle branches, allowing continuity with the ventricular myocardium (Sánchez-Quintana and Yen Ho, 2003).

Miquerol *et al* (2010) stated that the propagation of electrical activity through the heart is regulated by the ventricular conduction system to synchronise cardiac contraction.

Sinoatrial Node (SAN)

The sinus node of yak contained an extensive framework of collagen and two main type cells: pacemaker cells (P cells) and transitional cells (T cells). The P cells had a perinuclear clear zone, contained less myofibrils. The T cells were longer and slender than P cells. At the periphery of sinus node, there were many nerve fibres and ganglions (Duan *et al,* 2012). Ghazi *et al* (1998) also found that, the SAN in the domestic cat contained normally a dense collagenous framework.

The sinus node in adult camel was located 0.5 mm beneath the epicardium, near the junction between the cranial vena cava and the right atrium at the sulcus terminalis. It's shape was elongated, and oblong; 28.25 mm in length, 5.75 mm in width and 5.38 mm in thickness. The adult camel's SAN histology described by Ghazi and Tadjalli (1996) was comparable to that of the yak described by Duan *et al* (2012).

The histological structure of the SAN in the dromedary camel foetus was investigated using routine histological techniques and some special stains (Marwa-Babiker *et al,* 2016b). The SAN in the first trimester camel foetus was found in subendocardial region cranial to the opening of cranial vena cava at the junction between the cranial vena cava and right atrium. Two types of cells were observed; the first type had dark cytoplasm and large spherical lightly stained nucleus. The second type were small and spindle in shape with dark small nuclei. The SAN in camel foetuses in the second and third trimesters; it had the same location as in the adult camel also had two types of cells as in other mammalian species like yak (Marwa-Babiker *et al,* 2016b).

Atrioventricular Node (AVN) and Atrioventricular Bundle (AVB)

The anatomy and histology of AVN and AVB were studied in the heart of the dromedary camel (Ghazi and Tadjalli, 1993). They stated that the trunk of the atrioventricular bundle (Bundle of His) was a direct continuation AVN with no sharp line of demarcation between the node and the bundle. The AVB ran through the fibrous trigone and entered the lower part of the interventricular membranous septum beneath the right endocardium. They lay then over or slightly to the side of the centre of the muscular interventricular crest. The AVB of camels measured 4.12±1.00 mm in length, 3.66±1.13 mm in width and 1.13±1.85 mm in thickness, it's maximum sectional area being 12.68±6.13 mm^2 (Ghazi and Tadjalli, 1993 and 1996).

Histologically, the AVB in the heart of camels comprised multiple strands of Purkinje cells separated

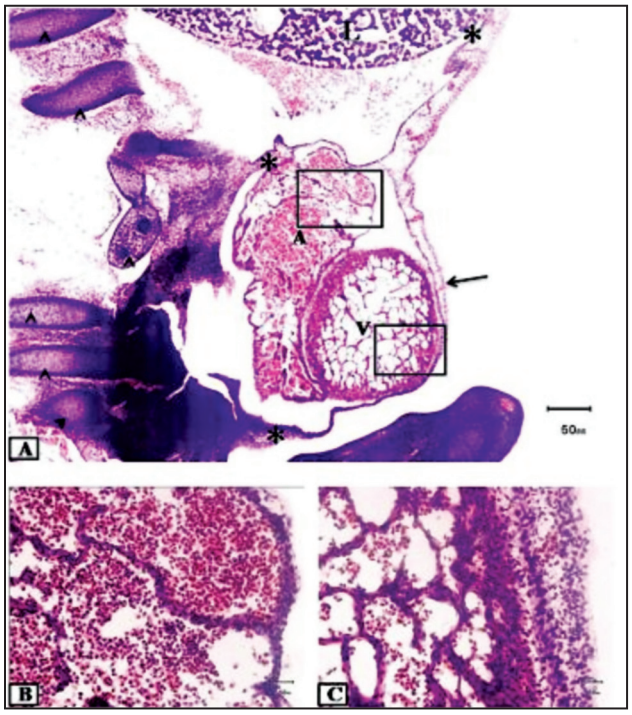

Fig 1. **A:** Photomicrograph showing the heart of 2 cm CVRL (71 days) camel foetus: right atrium A, pericardium (arrow), vertebrae (arrowheads), pericardial attachments (asterisk), right ventricle V, liver L, H and E (X4). **B:** Magnification of the upper rectangle in A: irregular outlines (X40). **C:** magnification of the lower rectangle in A: regular outlines (X40).

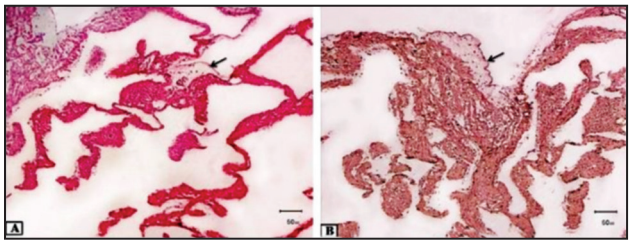

Fig 2. **A** and **B:** Photomicrographs showing the atrium of 17 cm CVRL camel foetus; epicardium (arrow) consisting of large amount of mesenchymal connective tissue and lined by simple squamous epithelium. A: H&E (X10). B: Verhoff's (X10).

by collagen fibres and surrounded by connective tissue. It resembled that in humans and dogs except that, in camels, intercalated discs were present at the intercellular connections in the AVB (Ghazi and Tadjalli, 1996). The development of the AVB and ventricular Purkinje system and their innervation has been studied in sheep foetuses from 27 to 140 days of gestation (term is 147 days) (Canale *et al,* 1987). The AVB initially consisted of a primordium, which lacked innervation and was composed of small, relatively undifferentiated myocytes. Differentiation of Purkinje-like cells within the AVB began near

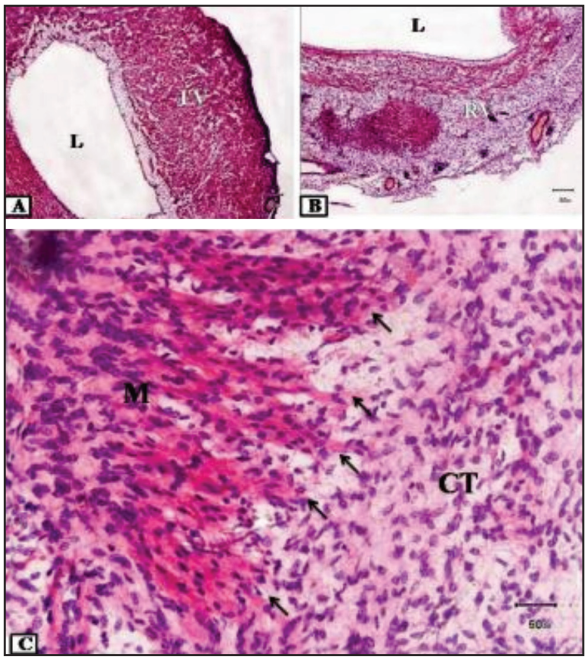

Fig 3. **A:** Photomicrograph showing histogenesis from connective tissue to muscular tissue of LV, left ventricle of 17.5 cm CVRL camel foetus. L, lumen of the left ventricle. H&E, (X4). **B:** Photomicrograph showing the right ventricle of the same heart the histogenesis was comparatively less than that in the left ventricle. L, lumen of the right ventricle. H&E, (X4). **C:** Photomicrograph showing higher magnification of the same section in B, histogenesis is very clear in the right ventricle (arrows). CT, connective tissue, M, myocardium. H&E, (X40).

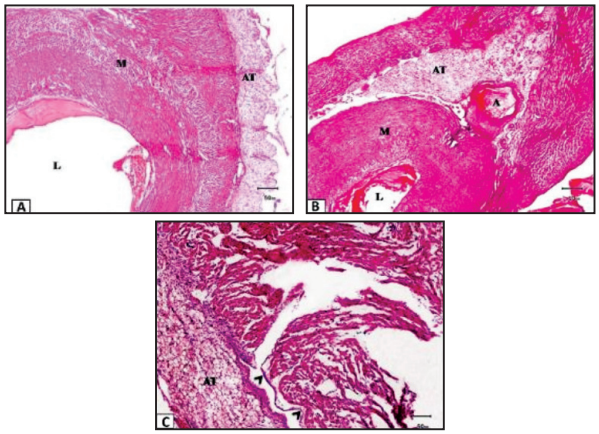

Fig 4. **A:** Photomicrograph showing the right ventricle of the heart of 30 cm CVRL camel foetus. Epicardium lined by simple squamous epithelium and has large amount of adipose tissue (AT) attached to the myocardium (M). L, lumen of the right ventricle. H&E (X4). **B:** Photomicrograph showing the left ventricle of the heart of 30 cm CVRL camel foetus. Epicardium lined by simple squamous epithelium. Large amount of adipose tissue (AT) in the myocardium (M) and around the aorta (A). L, lumen of the left ventricle. H&E (X4). **C:** Photomicrograph showing the atria of 68 cm CVRL of camel foetus containing large amount of adipose tissue (AT) covering epicardium (arrowheads). H&E (X4).

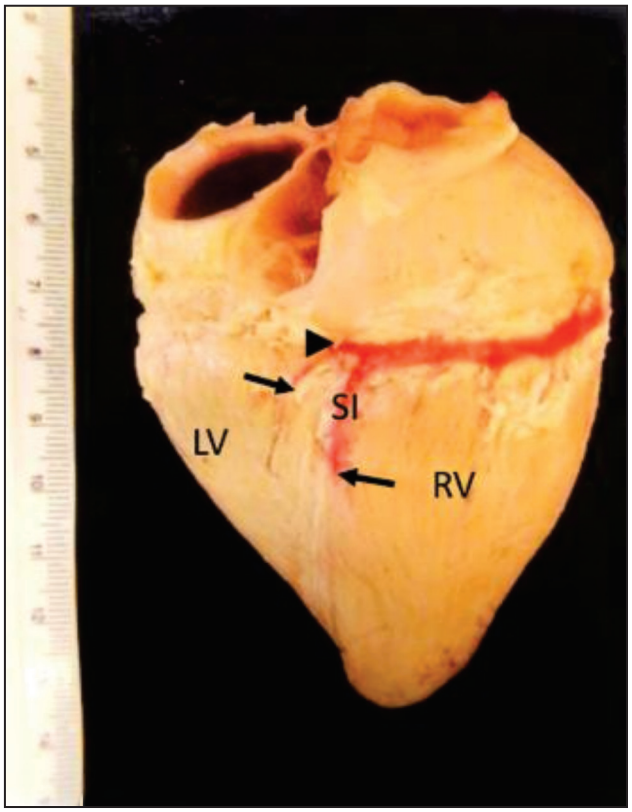

Fig 5. Photograph of a dissection of right aspect of the heart of a foetus of the dromedary camel showing that the subsinuosal interventricular branch (SI), is covered by type II myocardial bridge in the middle part of the subsinuosal groove. The arrow points to the site where the artery dips in the myocardium. Arrowhead the caudal branch of the right coronary artery, LV; left ventricle, RV; right ventricle.

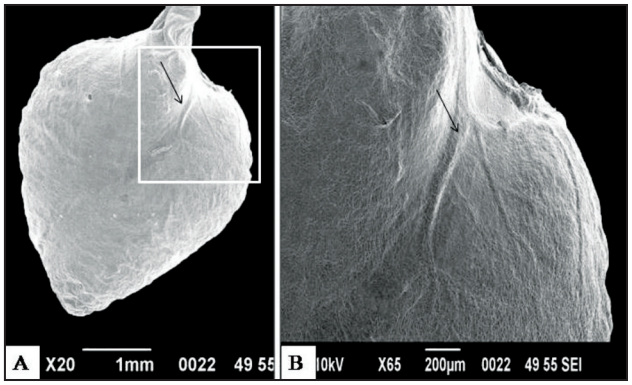

Fig 6. **A:** Scanning electron micrographs of the camel heart foetus of 6.8 cm CVRL showing two ventricles as semi-triangular in shape and a shallow left longitudinal groove (arrow). **B:** Magnification of A showing interventricular branches of coronary artery (arrow) in the upper part of the groove.

its distal end and extended towards the AVN. Differentiation of the ventricular Purkinje system extended distally from the region of bifurcation of the AVB from cells that were indistinguishable from

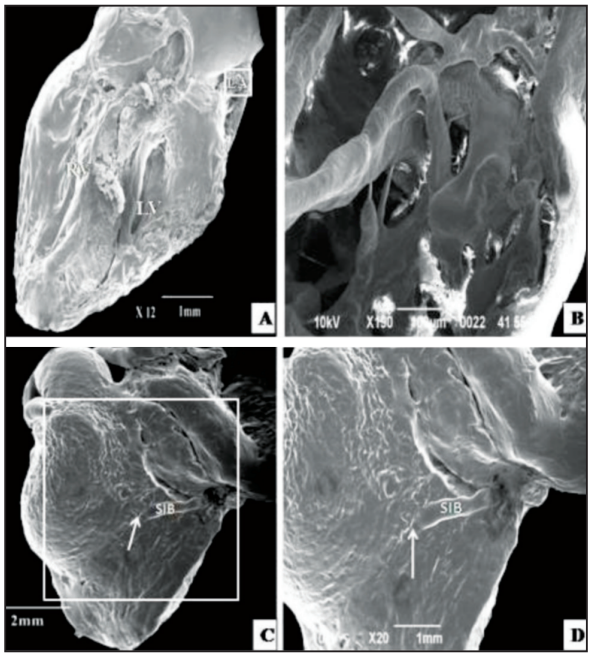

Fig 7. **A:** Scanning electron micrograph of the camel heart foetus of 23 cm CVRL. **B:** A higher magnification of the square in A showing atrial pectinate muscles in the form of cords; **C:** showing type II myocardial bridge over the subsinuosal interventricular branch of right coronary artery (SIB) dipping in the myocardium (arrow) without reappearing. **D:** Magnification of the square in C.

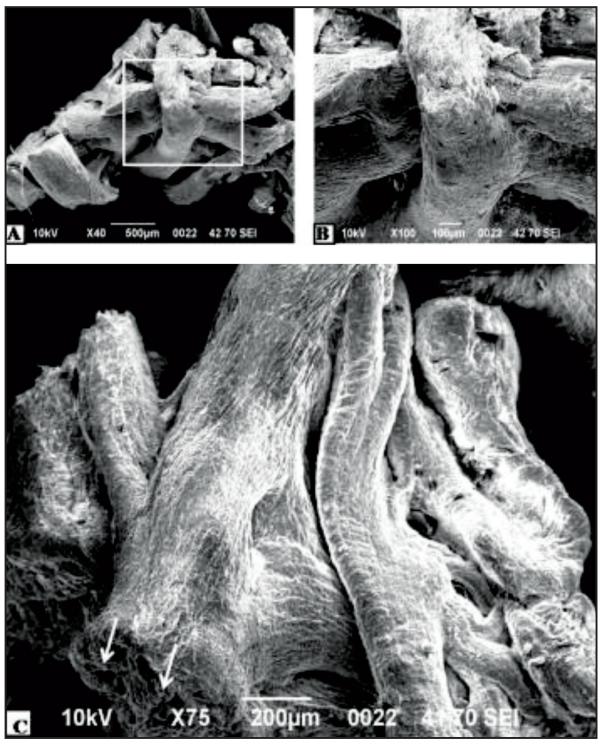

Fig 8. **A, B** and **C:** Scanning electron micrographs showing atrial pectinate muscles of 60 cm CVRL camel foetus as a plexus. B: Magnification of the square in A. C: Higher magnification of the same age showing some branches of pectinate muscles in cross section (arrows).

the working myocardium and continuous with the AVB primordium. Differentiation of Purkinje-like AVB cells was complete by 46 days gestation but Purkinje fibres were still differentiating within the ventricular wall at 60 days of gestation. The main morphological changes included a large increase in cell size and organisation into strands, development of characteristic glycogen-filled regions containing many intermediate filaments and early development of myofibrillar M lines compared to the working myocardium. The differentiation of AVB cells and the ventricular Purkinje system preceded their innervation (Canale *et al,* 1987).

Canale *et al* (1987) stated that in sheep the AVB became innervated earlier than ventricular Purkinje fibres. Intimate contacts between proximal AVB cells and nerve axons were present at 60 days of gestation. Nerve fibres were observed in the septomarginal band at this time. Although the AVB and ventricular Purkinje system of adult sheep composed morphologically of similar cells, they differed in origin and their mode of differentiation as well as timing and intimacy of innervation. Innervation was not part of the developmental mechanism leading to the differentiation of Purkinje fibres (Canale *et al*, 1987).

The AVN and AVB development in the camel heart were studied during the 1st, 2nd and 3rd trimesters of gestation using histological techniques (Marwa-Babiker *et al,* 2019b). AVN was found close to the atrioventricular opening in the first trimester and close to the opening of the coronary sinus in the second and third trimesters. It generally appeared as a group of large-sized and lightly stained cardiac muscle cells. AVB was embedded either in myocardium in the second trimester as a bundle of lightly stained fibres as strands located between the endocardium and myocardium or within the myocardium. At the early stages of the third trimester, they appeared as strands of fibres, which were covered by connective tissue between the endocardium and myocardium (Marwa-Babiker *et al,* 2019b).

Purkinje fibres (PF)

Canale *et al* (1987) in sheep and Miquerol *et al* (2010), in mammals, studied the development of Purkinje fibres. It is well known that Purkinje fibres are found in the subendocardium. They are larger than cardiac muscle cells, but have light glycogen content, fewer myofibrils and no T-tubules (Eliška, 2006). They are specialised conducting fibres, which extend from the interventricular septum, to the papillary muscles and up the lateral walls of the ventricles.

When compared to regular cardiac muscle, bovine Purkinje fibres were investigated by Forsgren and Thornell (1981). Gradually, it became clear that the two cell types differed in terms of the intercalated disc, myofibril content, mitochondrial organisation, glycogen content, and T-tubule development. The development of the PF was studied in dromedary camel foetuses during the three gestational periods (Marwa-Babiker *et al,* 2017). In the 1st trimester PF were embedded in cardiac muscle fibres close to the ventricular endocardium. Also, either between the endocardium or in the connective tissue. Some of Purkinje fibres were bi-nucleated. The striation was clear in peripheral parts of some fibres. At the 2nd trimester of gestation most of fibres were bi-nucleated and the cytoplasm around the nuclei was light. At the 3rd trimester PF appeared as bundles of fibres parallel to cardiomyocytes. Additionally, they were present as individual fibres or strands implanted in the endocardial mesenchymal connective tissue. Until the last stages of pregnancy, most Purkinje fibres in camel foetuses were not discovered in their typical place (Marwa-Babiker *et al,* 2017).

Myocardial Bridges (MBs)

MBs are defined as a congenital coronary abnormality in which a branch of a coronary artery passes intramurally through the myocardium (Kosinski and Grzybiak, 2001; Chen *et al,* 2004; Singh *et al,* 2005; Alegria *et al,* 2005; Demirsoy *et al,* 2006). They were also considered as structures consisting of heart muscle which passed above the coronary arteries or their branches (Chen and Lin, 2003; Kosinski *et al,* 2004; Aytan *et al,* 2006). The coronary arteries might dip into the myocardium for varying lengths and reappear on the heart's surface; this muscle overlying the segment of the epicardial coronary artery was termed a myocardial bridge (Loukas *et al,* 2006; Bharambe and Arole, 2008).

Iuchi *et al* (2013) stated that in human, the anatomical properties of MBs, especially of its length and thickness, played decisive roles as regulators of atherosclerosis in the left anterior descending coronary artery regardless of the amount of adipose tissue around it.

In bovines, the histological appearance of the pre-myocardial bridge segments differed from the other segments with or without a myocardial bridge

in that the intimal layer was well-developed (Shinjo *et al,* 2004).

Myocardial bridges in adult dromedary camel were studied previously by Taha and Abdel-Magied (1996). These were also found in 90% of dissected adult hearts of the dromedary camel (Marwa-Babiker and Taha, 2013). According to Marwa-Babiker and Taha (2013) and Marwa-Babiker *et al* (2015b) myocardial bridges in dromedary camel were classified into two types according to their relationship with the overbridged artery. In Type I, the descending interventricular subsinuosal or paraconal branches were bridged by one or two bands of cardiac muscle, in Type II, the descending interventricular subsinuosal or paraconal branches were noticed to dip in the myocardium without reappearing. Eight out of eleven hearts of foetuses had myocardial bridges (72.7%); seven hearts had myocardial bridges of Type II category in the subsinuosal interventricular branch (Fig 5), (87.5%); only one heart showed myocardial bridges on both sides (12.5%). In this heart, Type I category was observed over the subsinuosal interventricular branch whereas Type II category was confined to the paraconal interventricular branch. Type II myocardial bridges were observed in the intermediate stages of the first trimester (Marwa-Babiker *et al,* 2015b; Marwa-Babiker *et al,* 2016a).

Ultrastructure of the heart:

Chacko (1976) studied the ultrastructural differentiation of myocardium of Sprague-Dawley rat's embryos. Both thick (myosin) and thin (actin) filaments became identifiable for the first time in the tenth-day myocardium when the heart was pulsating, but circulation was not established. The appearance of the myofilaments and synthesis of Z lines was concomitant. There was a rapid proliferation and differentiation of most of the organelles by the eleventh day of gestation and during the subsequent days. The myofilaments became organised into fully formed striated fibrils. Intercalated discs appeared as small wavy lines on the eleventh day and became plicated in later stages and served as cell boundaries and points of attachment for myofilaments and fibrils. There was a tangible change in the number and morphology of mitochondria from the tenth to eleventh day and during later stages of development when the heart became functional. Similarly, there was a rapid proliferation and differentiation of granular endoplasmic reticulum and Golgi complexes. Large quantities of free ribosomes were dispersed in the cytoplasm of tenth-days myocardium. However, in later stages there was a progressive reduction in the distribution of these organelles. An intimate assembly of ribosomes and polysomes with the developing myofibrils was discernible.

The T-system and sarcoplasmic reticulum began to appear in myocytes at eleventh day. The embryonic myocardium displayed intense mitotic activity throughout its development. A unique feature of embryonic myocardial cells was the simultaneous occurrence of myofilament synthesis and mitotic activity within the same cells (Chacko, 1976).

The embryonic development of the heart of rat was greatly dependent on the myocyte's proliferation, which continued postnatally. The myocardium regeneration during postnatal period varied directly with the potential of cell proliferation. The electron microscopy showed myocytes well fixed with well-developed sarcomers disposed in an irregular form in the myocyte cytoplasm. The cardiac interstitium showed fibroblasts with characteristics of a great proteic synthesis. It suggested many binucleate cardiomyocytes during foetal period in the rat (Xavier-Vidal *et al,* 1997).

The internal cellular structures of the ventricular myocardium had been comparatively studied by transmission and scanning electron microscopy in sheep. The scanning electron microscopy demonstrated the relationships between organelles like mitochondria, sarcoplasmic reticulum, and nuclear envelope better than can be obtained by other methods (Sybers and Ashraf, 1975).

Myklebust *et al* (1975) investigated the sheep cardiac muscle cells using scanning and transmission electron microscopy. Later, Sheldon *et al* (1976) studied scanning electron microscopy in foetal and postnatal period in sheep between 90 days gestational age and 36 days postnatal age. Development of the transverse tubular system was visible as early as 90 days gestational age. Myofibrils in the 90-days foetus showed elongated mitochondria with constrictions and the mature myofibrils in later stages became oval and assumed their adult position in the perinuclear and interfibrillar regions. Myofibrillar development was sparse at 90 days and was most apparent in the subsarcolemmal region. Gradually the lateral addition of fibrils resulted in central displacement of the older myofibrils causing the sarcolemma to be drawn inward at its point of attachment at the Z-lines to form the T-tubules. At birth however, they resembled the adult configuration.

Kim *et al* (1992) studied the ultrastructure development of human foetal heart. Myofibril formation occurred by attachment of thin filaments into amorphous Z materials which were present in sarcolemmal plaques, sarcoplasmic condensations, desmosomes and in Z lines. Myofibrils radiated from these Z centers in many directions, branched, and anastomosed with further development. The myofibrillar growth pattern persisted throughout the entire foetal period. Mitochondria were well developed.

A transverse tubule system was clear in later foetal development in human. It occurred by invagination of sarcolemma into myocardial cells and by the formation of developed microvessels were found throughout the whole foetal period. Binucleated myocytes appeared by 32 weeks gestation, and this suggested that myocyte proliferation might cease before birth in humans. Development of the myocyte was an ongoing process (Kim *et al,* 1992).

Few studies were taken in the first, second and third trimesters of gestation of the camel foetus heart using scanning and transmission electron microscopy (Marwa-Babiker *et al,* 2015a; Marwa-Babiker *et al*, 2019a). Scanning electron microscopy (SEM) showed that during the early stages of the first trimester the heart of camel foetus was semi-triangular in shape (Fig 6) (Marwa-Babiker *et al*, 2015b). Both the coronary and longitudinal grooves were not clear. In addition, the atria were not clear at 84 days of gestation (6.8 cm CVRL) (Fig 6). The pectinate muscles were also not well developed, and the heart was only in the form of two ventricles separated by longitudinal grooves during that stage. During the intermediate stages of the first trimester, the longitudinal grooves and branches of the coronary arteries were clearly observed. The coronary groove was not observed until the end of the first trimester. Type II MBs were observed in this stage (Fig 7). Transmission electron microscopy (TEM) at (101 – 115 days) showed cardiomyofibres striations as irregular Z lines. Cardiomyofibres showed numerous mitochondria of different sizes and shapes around the nucleus and between fibrils. Rough endoplasmic reticulum was observed in the cytoplasm of cardiomyofibres in the form of few cisternae (Marwa-Babiker *et al,* 2015).

A comparative ultrastructure of the dromedary camel heart between second and third trimesters of gestation (131-426 days) has been studied (Marwa-Babiker *et al,* 2019a). At the second and third trimesters, the atrial pectinate muscles showed gradual development and appeared as large branching and anastomosing plexiform cords. Pectinate muscles were thicker in the second trimester than in the third trimester (Fig 8); (Marwa-Babiker *et al,* 2019a). Whereas Z lines with irregular striations were present in the second trimester, intercalated discs were not observed in this stage; they latter first appeared in the third trimester. Mitochondria were numerous around the myocyte's nuclei and between the fibrils. The sarcomere in the third trimester was thicker than in the second trimester. The length and width of mitochondria in the second and third trimester were constant. The organelles development started clearly in the second trimester and continued in the third trimester. Moreover, the transverse tubular system of the myocardium of the atria and ventricles showed obvious developmental changes during the second and third trimesters, (Marwa-Babiker *et al,* 2019a).

Ultrastructural measurements of the prenatal development in the ventricular myocardium and myocardial bridges of the dromedary camel

Measurements were done using the electron microscope processing software that included the dimensions of myofibrils nuclei, mitochondria of myofibrils at (X10000). Sarcomeres were measured at (X3000). The nuclei being oval, or semi oval were measured at the longest line (length) and the vertical line at the narrowest region (width), (Babiker, 2016).

Measurements at the 1st trimester was included the length of myofibril nuclei was 6.69±2.30 µm and the width was 3.19±1.60 µm. The length of mitochondria of myofibril was 1.13±0.29 µm and the width 0.55±0.12 µm. The sarcomere was measuring 1.19±0.23 µm (Babiker, 2016).

Measurements at the 2nd trimester included the length of myofibril nuclei of the ventricular myocardium was 6.29±1.29 µm and the width was 3.11±0.37 µm. The mitochondrial length was 0.85±0.23 µm and width was 0.75±0.02 µm. The sarcomere was measuring 1.21±0.16 µm (Babiker, 2016).

The length of the myocardial bridges myofibril nuclei was 6.71±1.52 µm while the width was 3.68±1.06 µm. The length of mitochondria of myofibril was 0.98±0.28 µm and its width was 0.83±0.23 µm. The sarcomere was measuring 1.08±0.17 µm.

Myofibril nuclei measurements of the ventricular myocardium of the 3rd trimester were 6.64±2.46 µm in length and 2.45±1.17 µm in width. Mitochondria of myofibril were measuring 0.45±0.25

µm for length and 0.40±0.08 µm in width. The sarcomere was measuring 1.8±0.04 µm (Babiker, 2016).

Nuclei of the myocardial bridges in the 3rd trimester were measuring; 8.81±1.45 µm and 2.73±0.10 µm in length and width, respectively. Mitochondria were measuring 1.05±0.16 µm, and 0.77±0.14 µm in length and width, respectively. The sarcomere was measuring 1.86±0.88 µm (Babiker, 2016).

Conclusion

During development of foetal camel hearts at the first, second, and third trimesters of gestation, many adipocytes were observed. The AVN was found close to the atrioventricular opening in the first trimester and close to the opening of the coronary sinus in the second and third trimesters. The AVB was embedded in the myocardium in the second trimester either between the endocardium and myocardium or within the myocardium in the third trimester. The PF were embedded in the myocardium in the first trimester and either between the endocardium and myocardium or within the myocardium in the second and third trimesters. The MBs were observed only histologically in the second and third trimesters. Type II MBs were observed in the late stages of the first trimester with SEM. MBs had a less developing transverse tubular system than the myocardium in the same stages. Pectinate muscles were thicker in the second trimester than in the third trimester. Mitochondria in the first trimester was longer than that in the second and third trimesters. Connective tissue nuclei in the first trimester were longer than those of the second and third trimesters. Connective tissue cell nuclei of MBs were longer in the third trimester than those of myocardium. It is concluded that the development of the camel heart had unique features during the three gestational stages.

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