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Some macromorphological studies on the ventricular musculature of the heart of the donkey

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The present work was conducted on 25 hearts of healthy donkeys of both sexes. Three methods were adopted to clarify the musculature of the ventricles; nitric acid method, acetic acid method and flour paste method. The ventricular myocardium was arranged into three layers: superficial, middle and deep. The superficial layer consists of eleven bundles arranged longitudinally from the base to the apex of the heart. Moreover, a thin subepicardial layer separated it from the epicardium. The middle layer on the right ventricle was horizontally oriented, while on the left ventricle it was represented by three bands; (A), (B) and (C). The deep layer on the right ventricle was formed of two bands (A) and (B) while on the left ventricle consisted of a single band (C), in addition to some fibers derived from the superficial layer. The intervrentricular septum was formed from fibers extended from the middle and deep layers. The papillary muscles were four in the right ventricle and two in the left one.

The muscular architecture of the ventricular wall is a very interesting topic that attracted the attention of many investigators to study it in man (McCallum, 1900; Mall, 1911; Cunninghams, 1958; Williams and Warwick, 1980), hog and dog (Thomas, 1957, 1959), buffalo (Hammoda, 1988 and Ragab, 1989), donkey (Ragab, 1989 and El-Bagary, 1993), camel (Karkoura, 1989) as well as goat (Alloush, 2001).

The present study is an attempt to add some anatomical views on the structure of the ventricular wall of the heart of the donkey which may be helpful for further studies in different fields of cardiology.

Material and Methods

Hearts. Twenty five hearts of recently condemned healthy donkeys were examined. They were collected with their great vessels then thoroughly washed by running water. Three methods were adopted to clarify the musculature of the ventricles; nitric acid method acetic acid method, and flour paste method.

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Nitric acid method (McCallum, 1900)**.** The specimens were immersed in a fluid formed of 40% conc. Nitric acid, 40% glycerin and water in a ratio of 1: 1: 2 respectively for 4 days. The specimens were preserved in 5% formalin. By this method the muscle fibers were clearly seen and the connective tissue and cardiac fat were easily removed by running water. For more clearing of the muscle fascicles, the specimens were soaked in 50% hydrogen peroxide for about 24 h.

Acetic acid method (Mall, 1911)**.** The specimens were immersed in equal parts of 96% glacial acetic acid, 34% hydrochloric acid and water for one month.

Flour paste method (Cunningham, 1958)**.** The cavities of the heart were filled with the paste of flour and water and boiled for 15 min. The boiling expands the paste, softens the fibrous tissues and hardens the muscular fibers. The specimens were examined after being placed for 24 h. in cold water.

Examination of papillary muscles. Two incisions were done to examine the papillary muscles. The first one was at the right ventricular border parallel to the interventricular paraconal. The second one was along the caudal margin of the left ventricle.

The Nomenclature: It was adopted according to the Nomina Anatomica Veterinaria (N.A.V) (1994).

Results

The superficial layer. The superficial layer of the ventricular musculature (Fig. 1-5) was represented by a thin, common layer encircling both ventricles in a spiral rope and in a centrifugal direction from the base to the apex. It originated from the atrial and atrioventircular fibrous rings in addition to the right and left fibrous trigones in the form of eleven longitudinal bundles. Each bundle consisted of a varying number ranging from 20-22 rootlets. The rootlets were compacted to each other at the right atrioventricular fibrous ring and right fibrous trigone. They were solitary at the left atrioventricular and left fibrous trigone leaving spaces through which the underlying layer is clearly seen. The outer surface of this layer was directly in contact with the epicardium except at the subepicardial layer.

The subepicardial layer. It was formed of some rootlet fibers of the superficial layer of the right ventricle lying directly under the epicardium separating it from the superficial layer of that ventricle and consisted of two bundles, transverse and conal.

The transverse subepicardial layer (Fig. 6) was in the from of a broad layer arose from some rootlet fibers of the fifth bundle that pass transversely on the atrial, cranial and auricular faces along the upper half of the right ventricle. These fibers reached the upper half of the anterior interventricular sulcus crossing it and continued caudoventrally on the auricular face of the left ventricle to terminate at the caudal border of the apex.

The conal subepicardial layer (Fig. 6) was represented by a narrow layer arose from the transverse subepicardial layer, passing obliquely on the cranial border of the right ventricle and the conal region. It ended on the cranial half of the left arch of the pulmonary fibrous ring.

The right ventricle. The superficial layer of the right ventricle was formed of five bundles (I-V) .The rootlets of them arose from the right and left fibrous arches of the pulmonary and right atrioventricular ring.

Bundle I (Fig. 1) was formed of fine rootlets fibers arising from the caudal half of the left arch of the pulmonary fibrous ring present at the upper third of the cranial interventicular sulcus. They pass in a caudoventral direction and unite together to form a dense compact 4-5 bundles crossing over the anterior interventricular sulcus to reach the left ventricle at which it was re-arranged into fine fibers connected with the rootlets of the bundle XI of the left ventricle.

Bundle II (Fig.1) was formed of rootlets fibers that arose form the cranial half of the left arch of the pulmonary fibrous ring. The fibers passed in a nearly vertical manner then curved caudoventrally towards the anterior interventricular sulcus and continued on the left ventricle reaching the caudal border of the apex.

Bundle III (Fig. 1,2) was in the form of some rootlets fibers arising from the right arch of the pulmonary fibrous ring and the adjacent border of the right atrioventricular fibrous ring. They join each other then passed cranioventrally till reaching the cranial interventricular sulcus where they changed their direction caudoventrally to cross over the upper part of the distal third of the sulcus in a slightly spiral manner to reach the caudal border of the apex of the heart.

Bundle IV (Fig. 2) was formed of rootlets fibers that arose from the cranial half of the outer border of the right atrioventricular fibrous ring. They passed ventrally in a nearly vertical direction then continued caudoventrally in a spiral direction to reach the cranial border of the apex of the heart.

Bundle V (Fig. 2) was represented of the rootlet fibers arising from the caudal half of the outer border of the right atrioventricular fibrous ring. It passed ventrally in a caudo-ventral direction towards the upper third of the posterior interventricular sulcus. It was reinforced with some fibers from the sixth bundle. Both rootlets formed a common (y) shaped bundle (Fig. 2) which passed cranioventrally to reach the cranial border of the apex of the heart.

The left ventricle. The superficial layer on the left ventricle was formed of six bundles (VI-XI). They arose from the lateral border of the right fibrous trigone, the caudal border of the left atrioventricular fibrous ring and the lateral border of the left fibrous trigone.

Bundle VI (Fig.2) was formed of rootlets arising from the cranial third of lateral border of right fibrous trigone. They dense, close to each other being directed cranioventrally about 2cm crossing the posterior interventicular sulcus to reach the

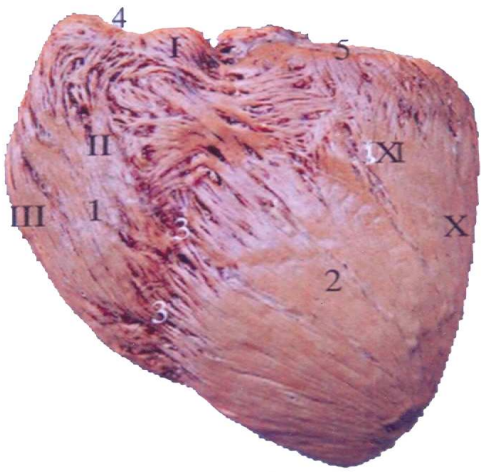

Fig. (1): The arrangement of myocardial fasciales of the superficial layer on the auricular surface of the ventricular mass (Left aspect).
1. Ventriculus dexter.
2. Ventriculus sinister.
3. Suculus interventricularis paraconalis.
4. Orifice of pulmonary trunk.
5. Trigona fibrosa sinister.
I-XI The muscle bundles of the ventricular mass.

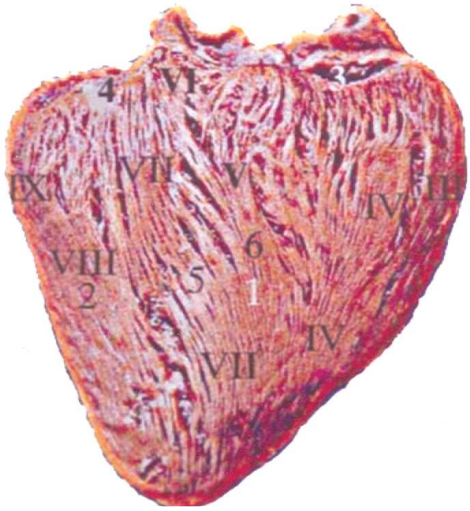

Fig. (2): The arrangement of myocardial fasciales of the superficial layer on the atrial surface of the ventricular mass.
1. Ventriculus dexter.
2. Ventriculus sinister.
3.Osteum atrioventricular dexter.
4. Trigona fibrosa dexter.
5. Sulcus interventricularis subsinosi.
6. Y- shaped bundle.
III-XI The muscle bundles of the ventricular mass.

Fig. (3): The arrangement of myocardial fasciales of the superficial layer on the left ventricle (Caudal border).
VIII-X. The muscle bundle of the ventricular mass.

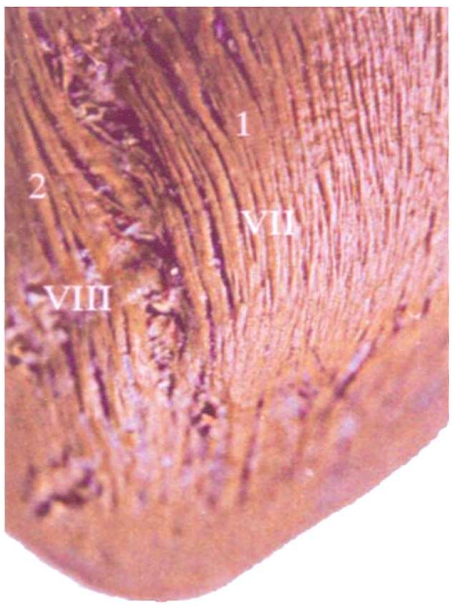

Fig. (4): The arrangement of the superficial layer of the myocardial fasciales on the aatrial face of the apex of the heart.
1. Ventriculus dexter.
2. Ventriculus sinister.
VII-VIII. The muscle bundles of the outer layer.

right ventricle at which the fibers were reinforced with other rootlets of the fifth bundle.

Bundle VII (Fig. 2,4) was in the form of rootlet fibers which emerged from the middle third of the lateral border of the right fibrous trigone. The fibers were compact and passed cranioventrally crossing the posterior interventricualr sulcus to reach the apex of the right ventricle.

Bundle VIII (Fig. 2, 3,4) consisted of some rootlet fibers which arose form the caudal third of lateral border of right fibrous trigone, directed carnioventrally and vertically till it reached the distal third of the posterior interventricular sulcus. It continued towards the apex of the heart.

Bundle IX (Fig. 2,3) was formed of rootlets fibers which emanated from the caudal border of the left atrioventricular fibrous ring. They were formed from 3-4 muscle fascicles descending on the caudal border of the left ventricle in a slightly curved manner where they united with each other and descended to reach the caudal part of the apex of the heart.

Bundle X (Fig. 1,3) originated from the caudal angle and the caudal half of the outer border of the left fibrous trigone. It descended cranioventrally on the caudal border of left ventricle to about its middle, then spirally curved to reach the caudal part of apex of the heart.

Bundle XI (Fig. 1) was formed of the rootlet fibers which originated from the cranial half of lateral border of left fibrous trigone. They passed caudoventrally to the caudal part of the apex of the heart.

The apex of the heart (Fig. 4, 5)**.** The superficial layer on the right aspect of the apex was represented mainly by fibers of the seventh bundle (Fig. 2, 4). They passed cranioventrally and slightly vertically to the left ventricle. On the apex of the heart, the fibers that covered both ventricles except the first bundle became aggregated ventrally around the apical part of the left ventricle. They whirled out forming the Vortex cordis into two horns, anterior and posterior (Fig. 5). Their apices were located towards the left and right surfaces of the heart; both horns were formed by the rootlets of the bundles on the right and left sides respectively. The former rootlets were composed of the IV and VII bundles and some cranial rootlets from the VIII bundle in addition to the vertical fibers of the transverse subepicardial layer. The posterior horn was formed of the residual rootlets of the outer layer except the first bundle. They terminated on the left and right sides of the apex respectively. They dipped deeply under each other to line the deep face of the left ventricle, forming the left ventricular papillary muscle. Finally they terminated its distribution by merging into the arches of the aortic and borders of left atrioventricular rings.

The middle layer. The middle layer of the ventricular musculature (Figs.7, 8, 9, 10) constituted the second layer located between the superficial and deep layers except at the caudal border of the left atrioventricular fibrous ring and left fibrous trigone.

The right ventricle. The middle layer of the right ventricle (Fig. 7) was represented by a broad rope of parallel transverse fibers emerging from the right arch of the aortic fibrous ring. They descended in the interventricular septum towards the anterior interventricular sulcus to cover the right ventricle till its apex. It was formed of short, intermediate and long fibers (Fig. 7). The former represented the upper fibers of this layer emerging from the upper fourth of the anterior interventricular sulcus. It passed cranially under the left arch of the pulmonary fibrous ring and turned posteriorly to be inserted at the junction between the right and septal arches of the ring.

The intermediate fibers emerging parallel to the above fibers springing from the middle part of the anterior interventricular sulcus passed cranially and transversely on the right ventricle for about 2-3 cm. They then ascended obliquely to attach to the anterior border of the right atrioventricular fibrous ring.

The long fibers emerged parallel to the preceding fibers and passed transversely on the cranial surface of the right ventricle. Its upper 1-2cm ascended dorsally near the posterior interventricular sulcus to be inserted into the middle and caudal thirds of the right fibrous trigone.The lower fibers crossed the posterior interventicular sulcus transversely, continued obliquely caudodorsally on the caudal surface of the left ventricle to reach the left atrioventricular fibrous ring.

The left ventricle. The left ventricular wall (Fig. 8, 9, 10) was formed of three bands, according to their origin.

The first band (Fig. 8) was represented by those fibers arising from the lateral angle of the left

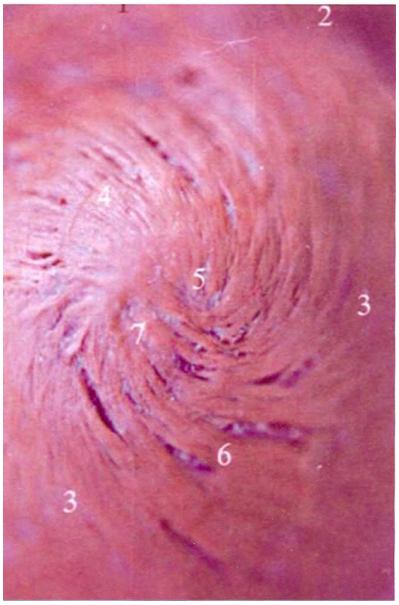

Fig. (5): The arrangement of the superficial layer of the Vortex cordis (Apical view).

1. Ventriculus dexter.
2. Suculus interventricularis paraconalis.
3. Left ventricle ventriculus sinister.
4. Anterior horn.
5. Apex of No. (4).
6. Posterior horn.
5. Apex of No. (6).

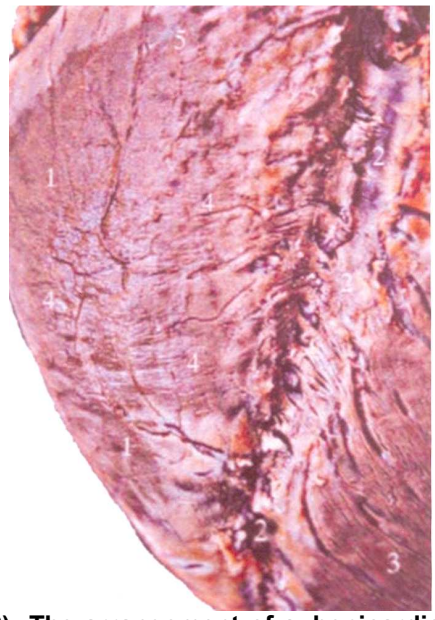

Fig. (6): The arrangement of subepicardial layer on the right ventricle (auricular face).

1. Ventriculus dexter.
2. Suculus interventricularis paraconalis.
3. Ventriculus sinister.
4. Transverse subepicardial layer.
5. Conal subepicardial layer.

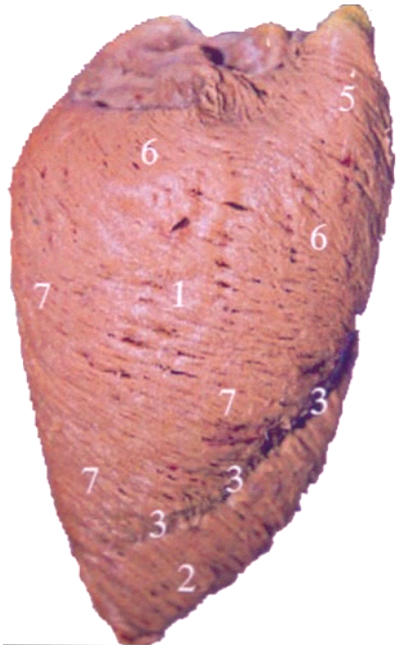

Fig. (7): The arrangement of the middle layer on the myocardial fasciales on the ventricular mass (Cranial view).

1. Ventriculus dexter.
2. Ventriculus sinister.
3. Suculus interventricularis paraconalis.
4. Osteum trunci pulmonalis.
5. Short fibrous layer.
6. Intermediate fibrous layer.
7. Long fibrous layer.

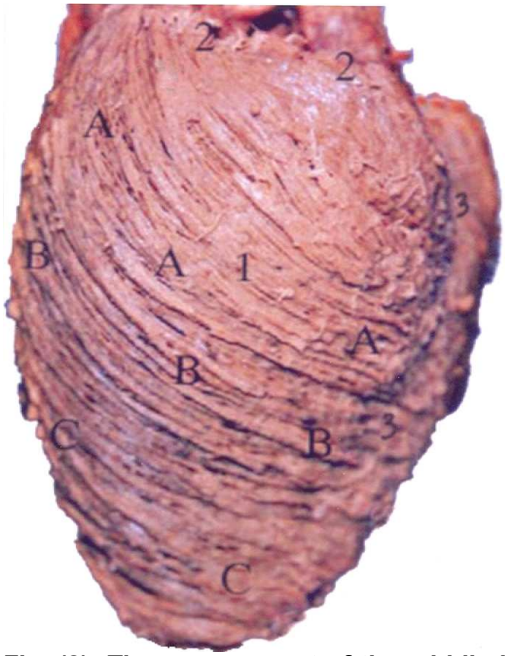

Fig. (8): The arrangement of the middle layer on the myocardial fasciales on the ventricular mass (Caudal view).

1. Ventriculus dexter.
2. Ventriculus sinister.

A, B and C Muscles fasciales of the 1st, 2nd and 3rd bands of the left ventricle.

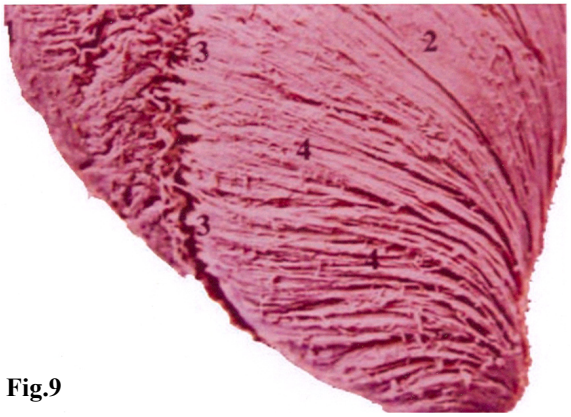

Fig.9

Fig.10

Fig. (9,10): The arrangement of the middle layer at the apex of the heart (auricular view).
1. Ventriculus dexter. 2. Ventriculus sinister. 3. Suculus interventricularis paraconatis. 4. Third band C.

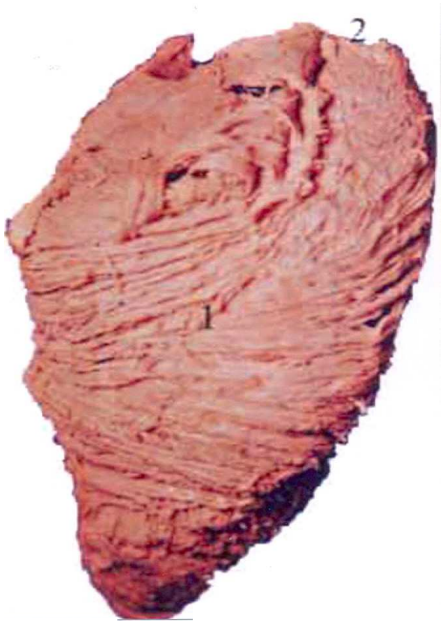

Fig. (11): The arrangement of myocardial fasciales on the deeper layer of the right ventricle (Anterior view).
1. Ventriculus dexter.
2. Orifice of pulmonary trunk.

Fig. (12): The interior surface of the left ventricle (endocardium intact).
1. M.papillaris subauricularis.
2. M.papillaris subatrialis.
3. Chordae tendenae.
4.Mitral valve (septal cusp;*Cupis septalis*)
5. Mitral valve(parietal cusp; *Cupis parietalis*) (divided).
6. Apex cardia.
7.Trabecula sepomarginalis sinistra.

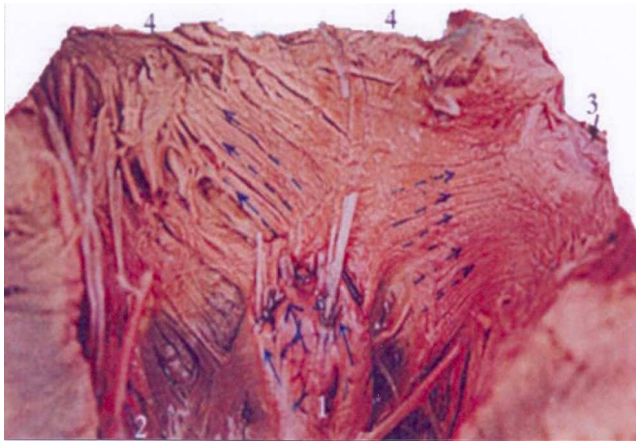

Fig. (13): The upper half of the interior of the left ventricle (endocardium is partially removed).

1. M.papillaris subauricularis.
2. M.papillaris subatrialis.
3. Aortic orifice.
4.Ostium artrioventricular sinistrum

Arrows indicate the apices of (1).

Dotted arrows indicate the anterior and posterior divisions of the fibers of papillary muscle subauricularis.

Fig. (14): The septum interventriculare as seen from the right ventricle (endocardium is removed).

1. Ventriculus dexter.
2. Band B (B).
3. Middlee layer of (1).
4. Band C (C).
5. Deep layer of the left ventricle (ventriculus sinister).
6.Apex cordis.

Fig. (15): The interior of the right ventricle (endocardium is intact).

1. Ventriculus dexter.
2. M.papillais magnus.
3. M.papillais subarteriosus.
4. M.papillais parvi.
5. Cupis angularis.
6. Chorde tendenae.
7. Septum interventriculare.
8. Trabecula Septomarginalis dextra.

Fig. (16): The right ventricle (opened) (endocardium is intact).

1. Ventriculus dexter (lateral wall).
2. M.papillais magnus.
3. M.papillais parvi.
4. Cupis parietalis(cranial scallop).
5. Cupis parietalis(caudal scallop).
6. Septum interventriculare.
7. M.papillaris accessories.

trigone. It passed on the auricular face of the left ventricle up to the middle third of the posterior interventricular sulcus. It entered into the formation of the large papillary muscle of the right ventricle.

The second band (Fig. 8). It consisted of those fibers originated from the cranial aspect of the aortic ring under cover of the middle layer of the right ventricle. They passed ventrally and diagonally, emerged from the upper half of the anterior interventricular sulcus where it appeared nearly horizontal on the caudal face of left ventricle reaching the distal third of the posterior interventricular sulcus. It shared into the formation of the deep layer of the right ventricular mass.

The third band (Fig. 8). It was in the form of a broad layer, originating from the caudal border of the right atrioventricular fibrous ring. It descended vertically forming the outer layer of the septal wall of the right ventricle, extended ventrally towards the ventral half of the anterior interventricular sulcus at which it shared into the formation of the Trabeculae carnae. It emerged from the latter sulcus on the distal third of the left surface of left ventricle where it passed caudoventrally to the apex of latter ventricle in a centripetal direction. It shared into the formation of the left ventricular deep layer with fibers of the superficial layer.

The deep layer.

The right ventricle. The deep layer of the right ventricular wall (Fig. 11) varied in its distal and proximal halves of the wall of the ventricle.

The distal half of this layer of the right ventricle was derived from the fibers of the middle layer of the left ventricle specially the second band. On the distal third of the posterior interventricular sulcus it proceeded deeply into the right ventricle where it splited into fibers to the ventricular and septal walls. Those of the ventricular wall covered the ventral half of the Conus arteriosus on its left side. The fibers passed obliquely and caudodorsally to be oriented on the septal arch of the pulmonary fibrous ring. The muscle fibers of the second band, forming the septal wall passed deeply to form 6-7 muscular ridges along the anterior interventricular sulcus. These fibers formed the Trabeculae carnae and entered into the formation of the papillary muscles.

The proximal half of the ventricular wall was formed of fibers of the right arch of the aortic fibrous ring where they passed cranioventrally to form the supraventricular crest, and then continued cranioventrally on the right ventricular wall. It fanned out to encircle the right atrioventricular ring and then continued obliquely caudally to be inserted into the right fibrous trigone and the left atrioventricular fibrous ring.

The left ventricle. The deep layer of the left ventricular wall (Fig. 12) was derived from merging fibers of both superficial layer and the third band of the middle layer of its apex. The fibers ascended deeply lining its deep face spirally, to terminate in the aortic and left atrioventricular fibrous ring. The fibers of the cranial horn of the Vortex cordis with some fibers of the third band, passed through the apex of the latter horn deep to the fibers of the caudal horn (Fig.5). It then ascended craniodorsally and deeply on the ventricular wall to line the right side of the ventricular and septal parts of the ventricular wall. It terminated on the left atrioventricular fibrous ring and the septal and right arches of the aortic fibrous ring. The fibers of the caudal horn of the Vortex cordis passed through its apex, deep to the fibers of the cranial horn. It ascended deeply on the left and caudal sides of the ventricular wall. The majority of these fibers aggregated to form the subauricular and subatrial papillary muscles (Fig. 12).

The interventricular septum. The muscle fibers forming the interventricular septum (Fig. 14) were derived from the muscular coats of both ventricles. The upper half of the interventicular septum was formed of thick muscular bundles extended from the left face of the left ventricular wall to the opposite one, the inner layer of the left ventricle, the second and third bands of the left ventricular wall as well as the middle layer of the right ventricle. While the lower half of the interventricular septum consisted of the same arrangement with the exception of the second band of the left ventricle.

The papillary muscles of the right ventricle.

M. papillaris magnus (Fig. 15, 16) was a broad quadrilateral muscular projection of about 2.5-3cm length, 2-3cm/width, located in the middle area of the outer part of the ventricular wall ventral to the parietal cusp of tricuspid valve. It was attached to the wall by its base but its body was free. The apical part of the muscle was divided into two horns right and left. Both were connect the

chordae tendenae to the angular and parietal cusps of the tricuspid valve. The large papillary muscle was formed by fibers of the first band of the middle layer of the left ventricle, which passed from its entrance to the right ventricle horizontally to reach the base of papillary muscle.

M.papillaris subarteriosus (Fig. 15)**.** It was a conical muscular elevation ventral to the supraventricular crest and the angular cusp of tricuspid valve by about 0.5-0.8cm. It was attached by its base and body to the septal wall completely. On the other side it was attached to the septal and angular cusps of the tricuspid valve by the Chordae tendnae. It was formed of fibers emerging from the left half of the right arch of the aortic fibrous ring. It passed deeply between the Conus arteriosus and bundle of the supraventricular crest, under the short conal bundles of the middle layer of the right ventricle. The fibers proceeded cranially to encircle completely the Conus arteriosus. Two-three cm from the anterior interventricular sulcus, it merged between the fibers of the middle layer of the right ventricle and those of the outer division of the third band. On the septal wall, the fibers passed cranioventrally up to the level of the supraventricular crest. They turned dorsally to enter the base of the papillary muscle.

M. papillaris parvi (Fig.15,16). It was formed from a conical muscular aggregation ventral to the septal cusp of the tricuspid valve. It measured about 2-2.5 cm in length, 1.5-2 cm width and attached incompletely to the septal wall. The Chordae tendinae were attached to the septal and caudal parts of the parietal cusp of the tricuspid valve. The papillary muscle was formed from fibers of the first two Trabeculae carnae which emerge near the apex of the right ventricle and ascended vertically with a slight curvature on the septal wall to form its body.

M. papillaris accessories (Fig.16)**.** It was represented by a small muscular thickening located at the middle point of the septal wall ventral to the septal cusp of tricuspid valve. It measured about 0.8-0.9 cm in length, 0.3-0.5 cm in width being completely embedded in the septal wall. It detached one Chordae tendinae to the septal cusp of the tricuspid valve. It was formed from fibers of the third Trabeculae carnae which ascended vertically and slightly curving on the septal wall of the right ventricle. It reached the base of the latter papillary muscle where some fibers of it curved to the central point of the septal wall to form the body of the accessory papillary muscle.

The papillary muscles of the left ventricle. They were formed of the fibers springing from the posterior horn of the Vortex cordis. It passed deeply through the apex of the horn to the fibers of anterior one. The majority of the fibers ascended on the left and caudal aspects of the ventricular wall, aggregated to form a huge sized subauricularis and subatrialis papillary muscles.

M. papillaris subauricularis (Fig. 12, 13)**.** It was a large sized lotus shaped muscle attached through its base to the left side of the ventricular wall ventral to the commissure between the septal and angular cusps of the mitral valve. It measured about 7.5-8.5 cm in length and 1.7-2 cm in width. It possessed three apical prominences. Each sends the Chordae tendinae which was attached to the septal and parietal cusps of the mitral valve. The fibers of the muscle terminated in the cusps of the mitral valve by the Chordae tendinae (Fig.12), other fibers passed in an anterior and posterior division. The fibers of the anterior division passed obliquely craniodorsally to be attached to the right arch of the aortic fibrous ring. The fibers of the posterior division passed obliquely caudodorsally to be attached to the left border of the atrioventricular fibrous ring.

M. papillaris subatrialis (Fig. 12, 13)**.** It was in the from of an elongated, conical thickening that erupted ventral to the parietal cusp of the mitral valve. It was attached to the caudal face of the ventricle by its body and base. It measured about 6.0-7.5 cm in length, 2.0-2.3 cm in width. Its Chordae tendinae was attached to the parietal and septal cusps of the mitral valve.

There were single septomarginal band (Moderator band) seen in the right ventricular cavity, and two branched ones in the left ventricle.

Discussion

The current investigation had revealed that, the ventricular musculature was arranged into three layers: superficial, middle and deep. Similar observations was recorded in man, dog, donkey, goat, camel, bull, pig and other domestic animals (Miller *et al*., 1964; Schummer *et al*., 1976; Greenbaum *et al*., 1981; Terran and Hurle, 1982; Karkora, 1989; Prives *et al*., 1989; El-Bagary *et al*., 1993; Evans, 1993; Sanchez-Quintana *et al*.,

1994, 1999; Alloush, 2001)

Thomas (1957) recorded that the ventricular musculature consisted of four layers in pig and dog; an outer, a middle, a cylindrical and an inner one.

On the other hand, Ghoshal (1975) reported only two layers forming the wall of the ventricles in domestic animals; superficial subepicardial and deep subendocardial.

The superficial layer of the ventricular musculature in the present work covers spirally both ventricles. It originated from the atrial and atrioventricular fibrous rings as well as the right and left fibrous trigone and then extended towards the apex of the heart. Similar findings were also reported in dog, donkey, pig, goat, and domestic animals (Thomas, 1957; Miller *et al*., 1964; Ghoshal, 1975; El-Bagary, 1993; Alloush, 2001). It is to add that, the superficial layer in the donkey was formed by eleven longitudinal bundles seen from the base of the heart. An observation which was not recorded by any of the previously mentioned authors. Moreover, the directions of the first and second as well as the last three bundles were variable, while those from the third to eighth had the same cranioventral direction towards the right ventricle. It may be relevant to point out that, the direction of later group of bundles simulated the general direction of the superficial layer as recorded by Schaller (1992) in domestic animals, El-Bagary (1993) in the donkey and Alloush (2001) in the goat.

The current investigation revealed that, the superficial layer of the ventricular wall formed thick bundles that bridged over the interventricular grooves without passing into the interventricular septum. On the contrary, few fibers of the superficial layer pass in the interventricular paraconal and subsinosal grooves where they terminated into the interventricular septum in goat and donkey (El-Bagary, 1993 and Alloush, 2001).

In the donkey, the bundles of the superficial layer, except the first bundle, form the anterior and posterior horns of the vortex cordis. Similar findings of two horns were reported by El-Bagary (1993) in the donkey and Sanchez-Quintana *et al*., (1994) in the bull. In this connection, Alloush (2001) in the goat recorded the presence of two Vortex cordis for either ventricle and Karkoura (1989) in the camel reported that the right Vortex cordis was formed from two horns; cranial and caudal. These findings could not be detected in any of the examined specimens in the present work.

The middle ventricular muscular layer in the donkey was common for both ventricles. On the contrary, the middle ventricular layer was independent for each ventricle in goat, camel and donkey (Karkoura, 1989; El-Bagary, 1993; Alloush, 2001).

In agreement with Thomas (1957) in the pig and dog the middle layer of the right ventricle in the donkey made a broad parallel transverse short, intermediate and long fibers extending up to the apex. The middle layer of the left ventricular wall was formed of three bands (A, B and C) simulating to those given by Thomas (1957) in pig and dog. The first two band (A and B) simulating the interventricular one while the third one (C) simulated the left septal band described by Thomas (1957).

The observation recorded in man, goat and camel that the middle layer of both ventricles was similarly arranged in a more spirally horizontal direction than that of the superficial layer (Terran and Hurle 1982; Karkora, 1989; Alloush, 2001), could be accepted in the present work for the right ventricle only, while the direction of this layer on the left ventricle varied from caudoventral (band A and C) to horizontal (band B).

The present work revealed that, the major part of the deep myocardial layer of the distal half of the right ventricle was derived from the band (B) of the middle layer of the left ventricle. Such finding was not detected in any of the available literatures. On the other hand, the corresponding layer of the left ventricle was formed of the continuation of the superficial layer as well as the band (C) of the middle layer of the same ventricle. Similar arrangement was also recorded by Thomas (1957) in pig and dog. The later author also added that, some fibers from the inner layer of the right ventricle shared into the formation of the corresponding layer of the left one. This finding could not be detected in the present investigation.

The interventricular septum of the donkey was formed by some fibers derived from the deep layer and the middle layers of both ventricles. On the 95 :r hand, Greenbaum *et al*., (1981) in man reported that the septal wall consisted of the subendocardial fibers of both ventricles.

The current investigation revealed four papillary

muscles in the right ventricle; the Magnus, subarteriosus, Parvi and accessory ones. Similar finding were observed in man and donkey (El-Fadaly, 1986; Ragab, 1989).

On the other hand, three papillary muscles only with the absence of the accessory one are found in goat, sheep, buffalo and camel (May, 1970; Karkoura, 1989; Ragab, 1989; Alloush, 2001).

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بعض الدراسات المورفولوجية علي التركيب العضلي لبطين قلب الحمار

أجريت هذه الدراسة على قلوب خمسة و عشرين من الحمير البالغة من الجنسين. وقد عولجت القلوب بثلاث من الطرق التقنية لدراسة هيئة وبيان تركيب العضلة البطينية. وقد أوضحت الدراسة أن العضلة البطينية تكون من ثلاث من الطبقات العضلية: سطحية و وسطى و غائرة.

الطبقة السطحية: تتكون من إحدى عشرة حزمة من الحزم الطويلة التوضع التى تمتد من قاعدة القلب إلى قمتة.

الطبقة الوسطى: و قد تميزت فيها ألياف البطين الأيمن بتوضعها أفقياً بينماً تميزت الألياف فى البطين الأيسر بإنحدارها منحرفة تجاة الأخاديد بين البطينية للقلب.

الطبقة الغائرة: أظهرت الدراسة أن معظم ألياف هذة الطبقة الخاصة بالبطين الأيمن تكونت نتيجة امتداد ألياف كلاً من الشريط (أ ،ب) المكونين للطبقة الوسطى للبطين الأيسر. أما بالنسبة للبطين الأيسر فقد تكونت طبقتة الغائرة من معظم الألياف السطحية بالأشتراك مع ألياف الشريط (ج) الخاص بالبطين الأيسر.

*** وجد أربعة من العضلات الحلمية فى البطين الأيمن لقلب الحمير: هى العضلة الحلمية الكبرى، العضلة الحلمية تحت الشريانية ، العضلة الحلمية الصغرى و العضلة الحلمية الأضافية.**

*** أما البطين الأيسر فوجد عضلتان حلميتان: هما العضلة الحلمية تحت الأذنية و العضلة الحلمية تحت الأذينية.**

و قد أستخدمت المسميات التشريحية المتبعة دولياً طبقاً لـ (N.A.V.) لسنة ١٩٩٤