Introduction

The avian heart is similar to the mammalian heart in many respects. Like other parts of the heart, the morphology of the atrium received many attentions from the researchers due to its unique musculature. The muscle of the atria consists of two layers; the superficial and deep layers. The superficial layers consist of circular muscle fibres that envelop both left and right atria together. The muscle fibres of the deep layer, also called the pectinate muscles, are oriented in a cranio-caudal fashion in the wall of the atria, travel along the interatrial septum and finally attach to the annulus fibrosus [6, 11, 15].

The wall of the left atrium is thicker than that of the right atrium in most species investigated. The wall of the atrium is also supported by pectinate muscles that are continuum between the left and the right atria [2, 6, 8, 12]. The pectinate muscles are less extensive in the wall of the left atrium. Therefore, the thickness of the left atrium wall is mostly due to connective tissue component rather than muscle [6]. The lumen of the right atrium is more voluminous than that of the left atrium and receives blood from the caudal vena cava, the right cranial vena cava and the left cranial vena cava [3, 8, 12]. The pectinate muscles form bridges at the opening of the venae cavae. The wall of the right atrium is even thinner at some areas where the pectinate muscles are absent [8].

The avian heart differs from the mammalian heart in few aspects. For example, there are 4-6 pulmonary veins in mammals [1, 3, 4]; on the other hand, there are two pulmonary veins in chicken [8, 12]. The cranial vena cava enters the right atrium as one major vessel in mammals; on the other hand, in chicken it enters the right atrium as two separate vessels: the right and the left cranial venae cavae. The avian heart has much higher heart rate than mammals. Moreover, the cardiac pathologies in chicken are interest to many researchers [5]. In addition the avian heart is under investigation as a model for human heart disases such as cardiac myopathies [16].

SUMMARY

In this study, the atrium wall of the chicken was investigated by Scanning Electron Microscopy (SEM) and routine histology. The wall of the left atrium was thicker and more uniform than that of the right atrium. However, the lumen of the right atrium was more voluminous than that of the left atrium. The average thickness of the pectinate muscles was 0.9 mm on the left atrium while 0.7 mm on the right atrium. The pectinate muscles were connected by the muscle bridges on the left atrium, but not on the right. The depressions on the right atrium wall were well defined and polygonal in shape; however, depressions on the left atrium were not as prominent.

KEY-WORDS : anatomy - atrium - avian - pectinate muscles - scanning electron microscope.

RéSUMÉ

Étude en microscopie électronique à balayage des parois des oreillettes cardiaques chez les volailles. Par D. YILDIZ et. M.E. GULTIKEN.

Dans cette étude, les parois des oreillettes ont été analysées par microscopie électronique à balayage et par histologie conventionnelle, chez le poulet. La paroi de l’oreillette gauche était plus épaisse et plus uniforme que celle de l’oreillette droite. Cependant, la lumière de l’oreillette droite était plus volumineuse que celle de l’oreillette gauche. L’épaisseur moyenne des muscles pectinés était de 0,9 millimètres sur l’oreillette gauche et de 0,7 millimètres sur l’oreillette droite. Les muscles pectinés sont reliés par des ponts musculaires sur l’oreillette gauche, mais pas dans le cas de la droite. Les dépressions sur la paroi de l’oreillette droite formaient des polygones bien définis, contrairement à celle de l’oreillette gauche.


SEM investigation of the avian atrium wall

D. YILDIZ and M.E.GULTIKEN

SUMMARY

In this study, the atrium wall of the chicken was investigated by Scanning Electron Microscopy (SEM) and routine histology. The wall of the left atrium was thicker and more uniform than that of the right atrium. However, the lumen of the right atrium was more voluminous than that of the left atrium. The average thickness of the pectinate muscles was 0.9 mm on the left atrium while 0.7 mm on the right atrium. The pectinate muscles were connected by the muscle bridges on the left atrium, but not on the right. The depressions on the right atrium wall were well defined and polygonal in shape; however, depressions on the left atrium were not as prominent.

KEY-WORDS : anatomy - atrium - avian - pectinate muscles - scanning electron microscope.
The heart have been investigated in detail by Scanning Electron Microscopy [10, 13, 14]. However, in animals especially in chicken, SEM studies were limited. Therefore, this study aims to investigate the surface and the musculature of the atria and their endocardial surfaces to contribute to understanding of the avian heart function.

Material and methods

Twenty adult Broiler chicken were used. Their hearts were taken out under general anaesthesia (50 mg/kg Ketamine HCl). The hearts were then washed with sodium phosphate buffer solution (PBS) and were cut immediately into small segments in the same solution. The segments were placed in 3 % glutaraldehyde phosphate (pH 7.2) at +4 °C for prefixation of two hours. They were then washed with 1 % osmium-tetroxide-PBS for two hours. The segments were washed again in PBS overnight and dehydrated through serial ethanol dilutions and air-dried overnight. The segments were mounted onto stubs as the endocardial surface can be analysed. They were sputter-coated with gold by Polaran SC-500 and finally examined with a JSM 5600 JEOL Scanning Electron Microscope. Histological sections were prepared, stained with the Malbrý’s triple and Haematoxylin-Eosin staining techniques and analysed with light microscopy [9].

Results

LEFT ATRIUM (ATRIUM SINISTRUM)

The left atrium was observed as it was separated from the right atrium by the interatrial septum. The wall of the left atrium was thicker than that of the right atrium and its lumen was less voluminous than that of the right atrium (Figure 1).

Pectinate muscles emerged from the inner surface of the interatrial septum. Muscle fibres that form the pectinate muscles had a quite large trunk that splits into two parts; one went to the roof of the atrium and the other went to the side wall. Muscle bundles originating from these two parts of the pectinate muscles spread throughout the wall (Figure 2). On the lateral face of the left atrium, two pulmonary veins entered the left atrium at the same level with the interatrial septum. The lumen of both vessels was quite large and their walls were supported by the pectinate muscles. A thick muscle band crossed the interatrial septum at the base of the atrium. This muscle band was continuous between both atria. The pectinate muscles took origins from this thick muscle band and spread throughout both atria in their respective sites. The pectinate muscles then extended toward the annulus fibrosus to which they are attached.

The average thickness of the pectinate muscle on the left atrium was 0.9 mm. The adjacent pectinate muscles were interconnected by muscle bridges which were located on the surface of the pectinate muscles and were 8-10 in number (Figure 2). The thickness of these muscle bridges varied. While the muscle bridge that was located close to the annulus fibrosus was 0.8 mm in thickness, the one that was located in the mid wall of the atrium was 0.4 mm in thickness. On the surface of the pectinate muscles, there were small depressions which could have been seen on the magnification of 650 times (Figure 3). In the region of the atrium where the pectinate muscles were absent, a layer of myocardium still supported the wall.

In the transverse histological sections all layers of the atrium wall were observed intact (Figure 7). The thickness of the wall is similar throughout the wall except where the pectinate muscles were present. The endocardium formed by endothelial and subendothelial connective tissue, which was present throughout the wall of the atrium.

RIGHT ATRIUM (ATRIUM DEXTRUM)

The right atrium had a larger lumen than the left atrium. The caudal vena cava opened into the right atrium at the base. The opening of the caudal vena cava was located at the base of the atrium. However, openings of the right and left cranial venae cavae were located in the roof of the atrium. The right atrium is thin-walled compared to the left atrium. However, the wall was relatively thicker in regions where the orifices of the vessels were located due to muscle bridges. The pectinate muscles were originated from the ventrally located thick muscle band similar to those of the left atrium. Compared to the pectinate muscles on the left atrium, the pectinate muscles on the right atrium branched out from the thick muscle band much closer to the interatrial septum. The muscle bridges observed in the left atrium connecting the adjacent pectinate muscles were absent in the right atrium (Figure 4).

The average thickness of the pectinate muscles was 0.7 mm. There were thin constrictions located transversally on the pectinate muscles (Figure 4). The portion of the pectinate muscle located between two constrictions appeared as ring-like structures observed at magnification of 18 times. When magnified 650 times, small well-defined polygonal depressions with smooth surfaces were observed on the surface of the pectinate muscles (Figure 5).

The histology of the right atrium was similar to that of the left atrium. The thin wall of the right atrium is quite visible where the pectinate muscles were absent. The subendothelial tissue is also absent in these thin areas of the wall (Figure 7). In some transverse sections, endocardium was observed as it projected into the pectinate muscles, causing constrictions on the pectinate muscles (Figure 6).

Discussion

The wall of the avian heart is similar to that of the mammalian, consisting of endocardium, myocardium and epicardium. As we also confirmed with this study the lumen of the right atrium is more voluminous than that of the left atrium [3, 8, 9, 12]. The wall of the left atrium is thicker and much more uniform than that of the right atrium, which is quite similar to the findings by WANG et al [15].

With SEM, dramatic polygonal depressions were observed on the surface of the right atrium. These depressions were observed as thin wall of the right atrium on the histological sections. On the other hand, the depressions on the surface of the left atrium were not as dramatic and polygonal in shape as those on the right atrium, which could be explained by the much more uniform structure of the left atrium wall observed.
FIGURE 1. — Schematic illustration of the avian atria viewed from the ventral aspect. Pectinate muscles (pm) are quite visible in the endocardial surface where the scanning electron microscopy samples were taken. la = left atrium, ra = right atrium, sp = septum, af = annulus fibrosus, cvc = caudal vena cava, lcrvc = left cranial vena cava, rcrvc = right cranial vena cava, a = aorta, tp = truncus pulmonalis.

FIGURE 2. — Endocardial surface of the left atrium. The adjacent pectinate muscles were connected by muscle bridges (arrows). Scanning electron microscope.

FIGURE 3. — Scanning electron micrograph of the endocardial surface of the left atrium. Small depressions (arrow) were present on the surface, which could have been seen with a magnification of 650 times.

FIGURE 4. — Endocardial surface of the right atrium. Pectinate muscles were transversally constricted (arrows), forming a ring-like structure between two constrictions. Scanning electron microscope.

FIGURE 5. — Scanning electron micrograph of the endocardial surface of the right atrium. Prominent depressions (arrows) were well-defined and polygonal in shape which were easily discernable compared to those located on the left atrium.

FIGURE 6. — Photomicrograph illustrating constrictions on the pectinate muscles of the right atrium. Connective tissue sleeves leaving off the endocardium (enc) projected into the pectinate muscles, causing constrictions (arrows) on the pectinate muscles (p). mc = myocardium; epc = epicardium. Malbry’s triple staining. Bar = 100 µm.
such specializations of the avian atrium contribute to conical depressions on the endocardial surface. We thought the left atrium, the right atrium possesses well-defined polygonal depressions on the endocardial surface. The wall of the left atrium is thicker and more uniform than that of the right. The muscle bridges over the pectinate muscles, the transverse histological sections were able to show few ring-like structures on some pectinate muscles of the right atrium. On the other hand, the pectinate muscles on the left atrium appeared to be more irregular. On the other hand, the pectinate muscles of the left atrium appeared to be more regular with light microscopy. The left atrium has been reported to possess fewer numbers of the pectinate muscles [5]. In this study we did not find such differences. However, differences were present in the thickness of the pectinate muscles. The average thickness of the pectinate muscles on the right atrium and the left atrium was 0.7 mm and 0.9 mm, respectively. In contrast, the pectinate muscles on the left atrium are thinner than those of the right atrium in mammals [6]. The number of pulmonary veins entering the left atrium in chicken is fewer than that of the mammals, which may contribute to such differences since the thickness of pectinate muscles is decreased where the vessels enter the atria.

The muscle bridges connecting the pectinate muscles were observed on the left atrium, but not on the right atrium. On histological sections pectinate muscles of the right atrium appeared to be more irregular. On the other hand, the pectinate muscles of the left atrium appeared to be more regular and uniform. The muscle bridges over the pectinate muscles most likely contribute to the uniformity of the wall of the left atrium. Because of the oblique orientations of the pectinate muscles, the transverse histological sections were able to show few ring-like structures on some pectinate muscles of the right atrium. The ring-like structure appears to be formed due to projections of the endocardium into the pectinate muscles.

With this study, we here presented the differences between the right and the left atria of the chicken. The wall of the left atrium is thicker and more uniform than that of the right. The pectinate muscles are connected to each other with muscle bridges in the left atrium, but not in the right. The thickness of pectinate muscles is also thinner in the left atrium. Unlike the left atrium, the right atrium possesses well-defined polygonal depressions on the endocardial surface. We thought such specializations of the avian atrium contribute to compensating the higher number of beats in the avian heart.

**Acknowledgement**

Authors would like to acknowledge Dr. Siyami KARAHAN of Faculty of Veterinary Medicine, Kırıkale University for his help in histological interpretation as well as in preparation of the revised manuscript.

**References**
