JIVS JOURNAL OF ISTANBUL VETERINARY SCIENCES

A morphological study on sinus and atrioventricular nodes in Saanen goats

Sedef Selviler-Sizer[1]*, Yonca Betil Kabak[2], Murat Kabak[1]

1 Ondokuz Mayis University, Faculty of Veterinary Medicine, Department of Anatomy, Samsun 55200, Türkiye. **2.** Ondokuz Mayis University, Faculty of Veterinary Medicine, Department of Pathology, Samsun 55200, Türkiye. **Selviler Sizer S.** ORCID: 0000-0002-1990-4507; **Kabak Y.B.** ORCID: 0000-0002-3442-8377; **Kabak M.** ORCID: 0000-0003-4255-1372

Research Article

Volume: 6, Issue: 3
December 2022
Pages: 139-144

ABSTRACT

In mammals, the sinus node and atrioventricular node are defined as the heart's specific stimulus and conduction systems. The electrical stimulation that starts in the sinus node continues with the atrioventricular node, and the rhythmic stimulation occurs in this way. There are differences in the sinus and atrioventricular nodes' location, size, and cell structures between species. In this study, which was carried out to determine the morphological structures and locations of the sinus and atrioventricular nodes in Saanen goat hearts, nine hearts from healthy goats were used. After performing the routine tissue follow-up procedure for histological examinations, 5 µm-thick serial sections taken from paraffin-blocked samples were stained with Crossman Trichrome and Periodic Acid Schiff (PAS) and photographed. It was determined that the sinus node was in a subepicardial position near where the cranial vena cava opens up to the right atrium. The sinus node, with an average length of 8-10 mm was crescent-shaped. The atrioventricular node was located in the subendocardium layer in the right half of the interatrial and the interventricular septum, where the coronary sinus opened into the right atrium. An atrioventricular node with an average length of 4.5-5 mm was observed to be roughly oval. Two types of cells were identified in both nodes: cells with small, rounded with empty cytoplasm and rather large nuclei, and cells with thin, elongated structures and darker staining.

Article History

Received: 08.11.2022
Accepted: 05.12.2022
Available online: 31.12.2022

Keywords: atrioventricular node, morphology, Saanen goat, sinus node

DOI: https://doi.org/10.30704/http-www-jivs-net.1201093

To cite this article: Selviler Sizer, S., Kabak, Y.B., & Kabak, M. (2022). A morphological study on sinus and atrioventricular nodes in Saanen goats. ***Journal of Istanbul Veterinary Sciences, 6*(3), 139-144. Abbreviated Title*: J. İstanbul vet. sci.**

Introduction

The heart has a sinus node, an atrioventricular node, and many conduction pathways, which provide its stimulation and conduction system (Pawlina and Ross, 2018; Wiyarta and Karima, 2022). Electrical impulses are produced in the sinus node (Keith-Flack) (Ambesh and Kapoor, 2017; Lang and Glukhov, 2018; Treuting et al., 2017; Wiyarta and Karima, 2022). The impulse starting from the sinus node spreads along the internodal tracts consisting of the muscle fibers of the atria and modified cardiac muscle fibers and collects in the atrioventricular node (Aschoff-Tawara) (Pawlina and Ross, 2018). They are transmitted to the septum interventricular via the His bundles originating from the atrioventricular node. These bundles pass through the fibrous skeleton of the heart and divide into right and left branches at the interventricular septum (Pawlina and Ross, 2018; Wiyarta and Karima, 2022). The last branches of these bundles, divided into two, are Purkinje fibers (rami subendocardial) in the endocardium layer (Pawlina and Ross, 2018; Wiyarta and Karima, 2022).

While the sinus node is found where the cranial vena cava opens into the right atrium and below the epicardium in ruminantia (Ghazi and Tadjalli, 1996;

*Corresponding Author: Sedef Selviler Sizer
E-mail: sedef.selviler@omu.edu.tr

Ghonimi et al., 2015; James, 1965; Nabipur et al., 2000; Türkmenoğlu et al., 2017), horses (Bishop and Cole, 1967) and carnivores (Ghazi et al., 1998; James, 1962), it is located in the more caudal part of the terminal sulcus below the epicardium in guinea pigs (Nabipour, 2004) and rabbits (James, 1967a). In the horse (Bishop and Cole, 1967), dog (James, 1962), goat (Nabipur et al., 2000), and camel (Ghazi and Tadjalli, 1996; Ghonimi et al., 2015), the sinus node is surrounded by a connective tissue capsule. The cells in the node, which has a rich connective tissue matrix, are small, pale, and contain fewer sarcomeres and mitochondria than atrial muscle cells (Dobrzynski et al., 2013). These cells are P and T cells (Duan et al., 2012; Ghazi and Tadjalli, 1996; Ghonimi et al., 2015; Nabipour, 2012; Nabipur, 2002). P cells are called different names such as perinuclear clear zone, pacemaker, pale cell, and nodal cell. They are oval-shaped cells with light-colored cytoplasms and with getting together can be seen as a bunch of grapes (Duan et al., 2012; James, 1965; Mitrofanova et al., 2018). Impulses produced by P cells are believed to be delivered to the myocardium via T cells (James, 1967b). T cell with longitudinal course stains darker than P cell (Merideth and Titus, 1968; Nabipur, 2002). In some studies (Ghonimi et al., 2015; Mitrofanova et al., 2018), different from these cells (P and T cells) Purkinje-like cells are also mentioned. Purkinje-like cells are large cells located at the periphery of the node (Ghonimi et al., 2015; Mitrofanova et al., 2018). Numerous fibroblasts, nerve tissue, and capillaries are seen in the interstitium between P and T cells (James, 1977).

In domestic mammals such as goat (Nabipur, 2002), cattle (James, 1965), sheep (Frink and Merrick, 1974), yak (Duan et al., 2017) and buffalo (Türkmenoğlu et al., 2017), the atrioventricular node is located where at the junction of the interatrial septum and the interventricular septum, on the right side of the interatrial septum, at the end of the septal cusp of the tricuspid valve, anterior to the coronary sinus and under the the subendocardium. The cells in this node are similar to the cells in the sinus node, and only His bundles surrounded by connective tissue are observed in the continuation of the atrioventricular node (Duan et al., 2017; Türkmenoğlu et al., 2017). Purkinje fibers, which are smaller branches of the His bundles, distribute in the muscle layer of the right ventricle and left ventricle (Pawlina and Ross, 2018). Purkinje fibers provide rapid spread of electrical conduction in the right ventricle and left ventricle wall and contraction of both ventricles (Pawlina and Ross, 2018).

The morphological structure of the sinus node and atrioventricular node in many domestic mammals has been studied (Duan et al., 2017; Duan et al., 2012; George et al., 2017; Ghonimi et al., 2015; James, 1964, 1965; Nabipour, 2004, 2012; Nabipur et al., 2000; Türkmenoğlu et al., 2017). In the literature review, no information was found about the location and structure of these nodes in Saanen goat hearts. Therefore, with this study, it is aimed to determine the localization and morphological structure of the nodes mentioned in Saanen goat hearts in detail and to contribute to the anatomy literature.

Materials and Methods

In this study, a total of nine healthy Saanen goat hearts taken from the animal slaughterhouse were used. After the hearts were fixed in 10% formaldehyde solution, a routine tissue follow-up procedure was performed on the samples and embedded in paraffin. Serial sections of 5 µm thickness were taken from the embedded samples with a Leica (RM2125RT Leica, Wetzlar, Germany) microtome. Then these sections were stained with Crossman Trichome and Periodic Acid Schiff (PAS) (Luna, 1968). Histological examinations were performed using the Nikon Eclipse E600W (Nikon, Tokyo, Japan) light microscope, and microscopic photographs were taken with the Nikon DS Camera Head DS-5M imaging system.

Results

The localization and morphological structures of the sinus node and atrioventricular node, located in the heart-specific stimulation and conduction system, were determined. The sinus node was located at the lateral wall of the atrium, on the terminal crest, near the opening of the cranial vena cava to the right atrium, and in the subepicardial (Figure 1A). The mean length of the sinus node, which was observed as a crescent-shape in the subepicardial, was 8-10 mm (Figures 1B, 2A).

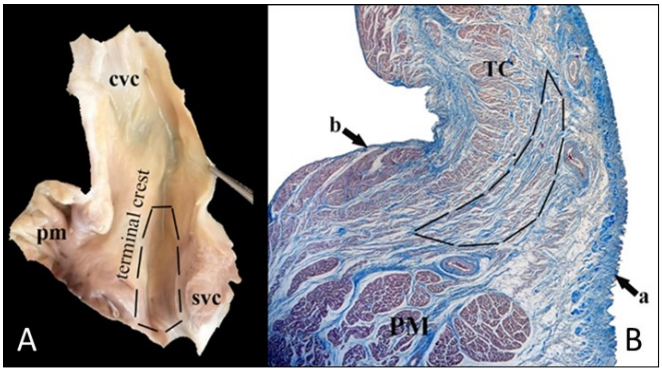

Figure 1. (**A**) Localization of the sinus node. The where cranial vena cava (cvc) opens into the right atrium, pectinate muscle (pm), sinus of vena cava (svc) and sinus node (dashed lines). (**B**) A histological view of the sinus node. Epicardium layer (a), endocardium layer (b), terminal crest (TC), pectinate muscle (PM), and sinus node (area delimited by dashed lines), 2X objective magnification (Crossman trichrome).

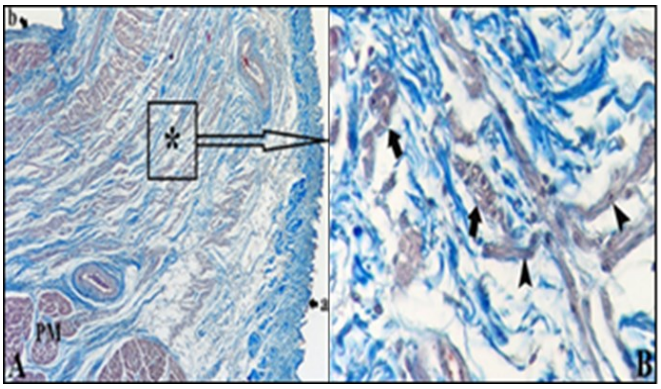

Figure 2. (**A**) A histological view of the sinus node. Epicardium layer (a), endocardium layer (b), pectinate muscle (PM) and sinus node (*), 4X objective magnification, (Crossman trichrome). (**B**) Different cell groups in the sinus node. Cell group I (arrow), cell group II (arrowhead), 40X objective magnification, (Crossman trichrome).

In histological examination, different cell groups were observed in the sinus node as well as structures such as connective tissue and nerve tissue (Figures 3A, 3B). One of these groups (cells group I) was cells with pretty large nuclei, which were small, round and had an empty cytoplasm (Figures 2B, 3A, 3B). These cells, in coming together in some places, were observed in a bunch of grapes shape (Figures 2B, 3B). The other cell group (cell group II) was elongated and darkly stained cells (Figures 2B, 3A, 3B). There was no intercalated disc in these cells. The connective tissue observed in the sinus node was densely located among the cells mentioned above. Arteriola and peripheral nerve fibers were found in the periphery of the node.

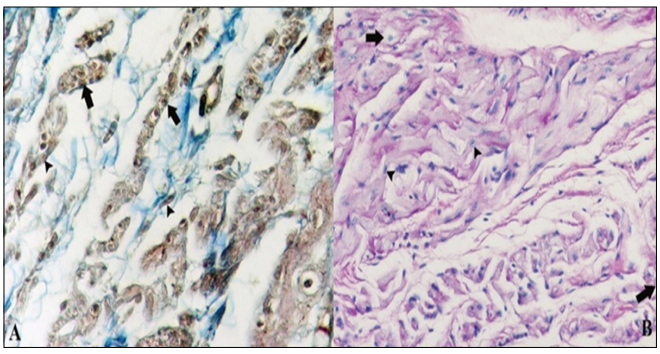

Figure 3. (A, B) Different cell groups in the sinus node, cell group I (arrow), cell group II (arrowhead), A: (Crossman trichrome) 40X objective magnification. B: (PAS) 20X objective magnification.

The atrioventricular node was located in the area extending from where the opening of the coronary sinus to the right atrium in the subendocardium to the junction of the interatrial septum and interventricular septum (Figure 4A). It was determined that this node was oval in shape at the base of the septal cusp of the tricuspid valve and had an average length of 4.5-5 mm (Figure 4B).

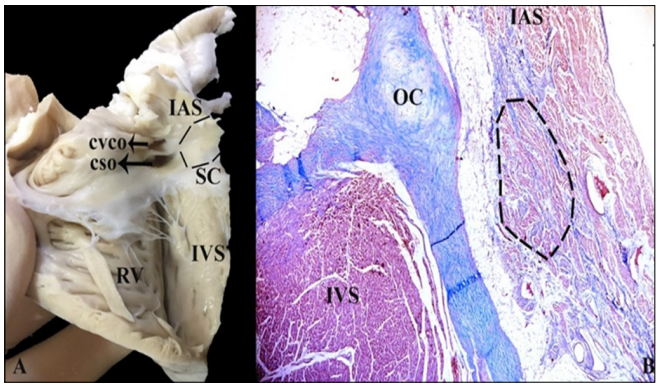

Figure 4. Localization of the atrioventricular node (**A**). Caudal vena cava ostium (cvco), coronary sinus ostium (cso), interatrial septum (IAS), interventricular septum (IVS), septal cusp (tricuspid valve) (SC), right ventricle (RV). Where atrioventricular node is found (dashed lines). Histological view of the atrioventricular node. (**B**) Atrioventricular node (area delimited by dashed lines), os cordis (OC), interatrial septum (IAS), interventricular septum (IVS), 2X objective magnification, (Crossman trichrome).

Cell groups residing in the sinus node were also found in the dense connective tissue layer of the atrioventricular node (Figure 5). Peripheral nerve fibers and a few arterioles were located around this node, as in the sinus node.

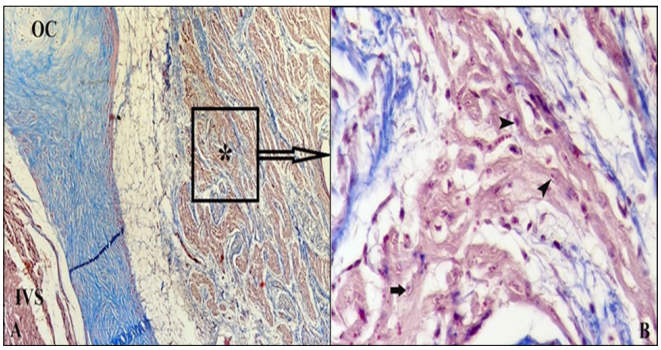

Figure 5. (**A**) A histological view of the atrioventricular node. Atrioventricular node (*), os cordis (OC), interventricular septum (IVS), 4X objective magnification, (Crossman trichrome). (**B**) Different cell groups in the atrioventricular node. arrow: cell group I, arrowhead: cell group II, 40X objective magnification, (Crossman trichrome).

His bundles were observed in the subendocardium layer of the interventricular septum after the atrioventricular node (Figures 6A, 6B). This structure consisted of interconnected light-colored and large cells surrounded by connective tissue.

Discussion

The conduction pathways originate from the sinus node (pacemaker) and atrioventricular node and spread to the heart for the heart's unique warning and conduction system (Pawlina and Ross, 2018). In domestic mammals, there are many studies on the location and macro anatomical structure of these

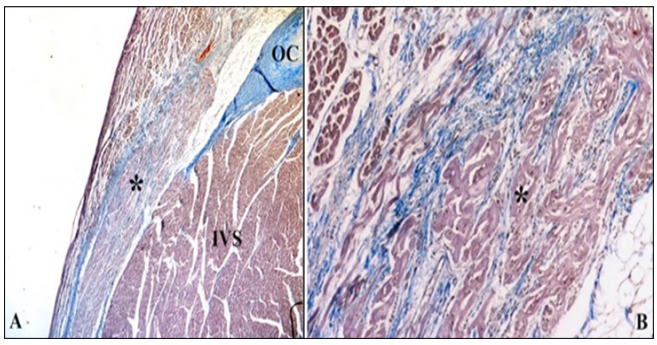

Figure 6. (**A**) Histological view of his bundles. His bundle (*), os cordis (OC), interventricular septum (IVS), 2X objective magnification, (Crossman trichrome). (**B**) Transition from the atrioventricular node to His bundles (*). 10X objective magnification, (Crossman trichrome).

histological appearance (Duan et al., 2017; Ghazi and Tadjalli, 1993; Ghonimi et al., 2015; Nabipour, 2012). In previous studies, it has been stated that the location of the sinus node in cattle (James, 1965), goats (Nabipur et al., 2000), camels (Ghazi and Tadjalli, 1996; Ghonimi et al., 2015), horses (Bishop and Cole, 1967), dogs (James, 1962), cats (Ghazi et al., 1998), water buffalo (Türkmenoğlu et al., 2017), and humans (Perde et al., 2016; Sanchez-Quintana et al., 2005) is at the cranial vena cava opening into the right atrium below the epicardium. This node is located in the caudal part of the terminal sulcus below the epicardium in guinea pigs (Nabipour, 2004) and rabbits (James, 1967a). The localization of sinus node in the Saanen goat was found to be similar to those of the above-mentioned species, except for guinea pigs and rabbits. The length of sinus node, which has different sizes among species, is specified as 2.75 mm in female cats (Ghazi et al., 1998), 2.78 mm in male cats (Ghazi et al., 1998), 10-20 mm in humans (Perde et al., 2016) or 15 mm (Merideth and Titus, 1968), 4 mm in guinea pigs (Opthof et al., 1987), 12.75 mm in goats (Nabipur et al., 2000), 3 mm in ferrets (Truex et al., 1974), 0.5-0.8 mm in rabbit (James, 1967a), 28.25 mm in camel (Ghazi and Tadjalli, 1996), and 18 mm in buffalo (Türkmenoğlu et al., 2017). In the study, the length of the sinus node was observed to be between 8-10 mm on average and was smaller than the lenght reported by Nabipur et al. (2000) in goats.

It has been reported that the surrounding of the sinus node consists of a collagen framework in horses (Bishop and Cole, 1967), dogs (James, 1962), goats (Nabipur et al., 2000), and camels (Ghazi and Tadjalli, 1996; Ghonimi et al., 2015). In this study, connective tissue was seen in the sinus node but did not form a clear border around the node. The shape of the sinus node has been reported to be oblong or spindle -shaped in the dog (James, 1962), elongated or bent oblong in the camel (Ghonimi et al., 2015), and almost triangular in the cat (Ghazi et al., 1998). This node was observed to be crescent-shaped in Saanen goats. It is stated that there is an artery responsible for the arterial nutrition of the same node, and this artery's location varies according to the species. The artery of a sinus node is located in the center of the node in dogs (James, 1962), horses (Bishop and Cole, 1967), camels (Ghazi and Tadjalli, 1996), and humans (James, 1977; Merideth and Titus, 1968; Perde et al., 2016; Sanchez-Quintana et al., 2005). In cattle (James, 1965), buffalo (Türkmenoğlu et al., 2017), sheep (Copenhaver and Truex, 1952), and goats (Nabipur et al., 2000), no artery has been found in the node's center, while arterioles have been determined around the node. This situation was consistent with our findings in Saanen goats.

In the literature (Ghonimi et al., 2015; James et al., 1966; Nabipur et al., 2000; Türkmenoğlu et al., 2017), it has been stated that there are different cells in the structure of both nodes. It has been reported that the cellular structure of the sinus node consists of pale staining cytoplasm and round-oval shaped P (perinuclear clear zone) cells, darker staining, and longitudinally courses T (transitional) cells, and pale staining atrial muscle cells (Ghonimi et al., 2015; James et al., 1966; Nabipur et al., 2000; Türkmenoğlu et al., 2017). The cell group I and II seen in the sinus node of the Saanen goat were similar to P and T cells mentioned in the literature, respectively. The collection of some cells in group I cells in the form of grape bunches was consistent with what Duan et al. (2012) and Nabipour (2012) reported about P cells. Other than these cells, Mitrofanova et al. (2018) have also mentioned the existence of Purkinje-like cells in humans and stated that these cells are considerably larger than P cells. These cells were not found in Saanen goats. It was observed that the modified muscle cells in the sinus node of the studied animals did not have intercalated discs. This was consistent with that reported in humans (James, 1961), cats (Ghazi et al., 1998), dogs (James, 1962), horses (Bishop and Cole, 1967), camels (Ghazi and Tadjalli, 1996), and cattle (James, 1965). While many nerve fibers are found in and around the sinus node in cats (Ghazi et al., 1998), horses (Bishop and Cole, 1967), dogs (James, 1962), and humans (James, 1961), it is observed that nerve fibers around the node in cattle (James, 1965) and camels (Ghazi and Tadjalli, 1996) are similar to our study.

The location of the other node of the heart, the atrioventricular node, differs between species. In goats (Nabipur, 2002), cattle (James, 1965), and sheep (Frink and Merrick, 1974), yak (Duan et al., 2017), buffalo (Türkmenoğlu et al., 2017), and human (Titus et al., 1963), it is stated that the border of an atrioventricular node is at the right side of the interatrial septum, above the septal cusp of the tricuspid valve, anterior of the coronary sinus and located in the subendocardium. Researchers reported that in hedgehogs (Nabipour, 2010) and sheep fetuses (Nabipour, 2007), the atrioventricular node is located in a position similar to the above literature. The only difference is that the node extended to the aorta in these animals. The location of the atrioventricular node in the Saanen goat was consistent with what has been reported in the literature except for hedgehog and sheep fetuses (Duan et al., 2017; Frink and Merrick, 1974; James, 1965; Nabipur, 2002; Titus et al., 1963; Türkmenoğlu et al., 2017). The length of an atrioventricular node is 7.5 mm in humans (Titus et al., 1963), 9 mm in buffalo (Türkmenoğlu et al., 2017), 2 mm in weasels (Truex et al., 1974), 4.23 mm in goats (Nabipur, 2002), 2.2-4.5 mm in the yak (Duan et al., 2017), 0.13 mm in the sheep fetus (Nabipour, 2007), and approximately 2 mm

node varied between 4.5-5 mm. In our study, the cell diversity in the atrioventricular node and the cell configuration in the sinus node were similar and consistent with what was reported by and Duan et al. (2017).

The shape of the atrioventricular node, which varies between species, is ovoid in the cattle (James, 1965), oval in the hedgehog (Nabipour, 2010), roughly oval or fan-shaped in the human (Titus et al., 1963), roughly oval in the yak (Duan et al., 2017), elongated oval-shaped in goats (Nabipur, 2002), and almost spherical-shaped in sheep fetuses (Nabipour, 2007). In the current study, the shape of the atrioventricular node was observed to be roughly oval. While the nerve fiber density in the atrioventricular node is reported to be low in humans (Titus et al., 1963), guinea pigs (Nabipour, 2004), and dogs (James, 1964), it was observed in our study that nerve fiber was quite dense as in cattle (James, 1965), goats (Nabipur, 2002), and yaks (Duan et al., 2017). Duan et al. (2017) reported that intercalated discs were not observed in the yak atrioventricular node, while James (1965) mentioned the presence of ganglia around the node in cattle. The absence of intercalated discs and peripheral nerve fibers around the node was detected in Saanen goats. It is mentioned that the His bundle, seen in the continuation of the atrioventricular node, consists of cells connected by chain style, surrounded by connective tissue (Duan et al., 2017; Machida et al., 2005). The appearance of her bundles in the present study was consistent with the abovementioned literature (Duan et al., 2017; Machida et al., 2005). The transition between His bundles and the node could not be determined.

Conclusion

The localization of the sinus node, one of the nodes of the special conduction system of the heart, was determined to be subepicardial near the opening of the cranial vena cava to the right atrium. The other node, the atrioventricular node, was located subendocardial on the right side of the interatrial septum and interventricular septum, where the coronary sinus opened to the right atrium. The absence of an artery in the center of the oval-shaped atrioventricular node and the crescent-shaped sinus node was noted. The cellular configuration of the sinus node, which varies between 8-10 mm in length, and the atrioventricular node, which varies between 4.5-5 mm in length, was similar and consisted of P, T, and atrial muscle cells. This study, in which the length, position, and cellular structure of the atrioventricular node and sinus node were determined, was carried out for the first time in Saanen goats. We think that the obtained data will contribute to the veterinary anatomy literature.

Acknowledgment

This study is a part of a doctoral thesis supported by the The Scientific and Technological Research Council of Turkey (TUBITAK) (grant number 118O758).

References

Ambesh, P., & Kapoor, A. (2017). Biological pacemakers: Concepts and techniques. *National Medical Journal of India, 30*(6), 324-326.

Bishop, S., & Cole, C. (1967). Morphology of the specialized conducting tissue in the atria of the equine heart. *The Anatomical Record, 158*(4), 401-415.

Copenhaver, W., & Truex, R. (1952). Histogy of the atrial portion of the cardiac conduction system in man and other mammals. *The Anatomical Record, 114*(4), 601-625.

Dobrzynski, H., Anderson, R. H., Atkinson, A., Borbas, Z., D'Souza, A., Fraser, J. F., Inada, S., Logantha, S. J., Monfredi, O., & Morris, G. M. (2013). Structure, function and clinical relevance of the cardiac conduction system, including the atrioventricular ring and outflow tract tissues. *Pharmacology & Therapeutics, 139*(2), 260-288.

Duan, D., Yu, S., Cui, Y., & Li, C. (2017). Morphological study of the atrioventricular conduction system and Purkinje fibers in yak. *Journal of Morphology, 278*(7), 975-986.

Duan, D., Yu Sijiu, & Cui Yan. (2012). Morphological study of the sinus node and its artery in yak. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary *Biology, 295*(12), 2045-2056.

Frink, R., & Merrick, B. (1974). The sheep heart: Coronary and conduction system anatomy with special reference to the presence of an os cordis. *The Anatomical Record, 179*(2), 189-199.

George, S. A., Faye, N. R., Murillo-Berlioz, A., Lee, K. B., Trachiotis, G. D., & Efimov, I. R. (2017). At the atrioventricular crossroads: dual pathway electrophysiology in the atrioventricular node and its underlying heterogeneities. *Arrhythmia & electrophysiology review, 6*(4), 179.

Ghazi, S., & Tadjalli, M. (1993). Coronary arterial anatomy of the one-humped camel (Camelus dromedarius). *Veterinary Research Communications, 17*(3), 163-170.

Ghazi, S., & Tadjalli, M. (1996). Anatomy of the sinus node of camels (Camelus dromedarius). *Anatomia Histologia Embryologia, 25*(1), 37-41.

Ghazi, S., Tadjalli, M., & Baniabbas, A. (1998). Anatomy of the sinus node of domestic cats (Felis catus). *Journal of Applied Animal Research, 14*(1), 57-64.

Ghonimi, W., Balah, A., Bareedy, M. H., Salem, H. F., Soliman, S. M., Elbaz, A., Helal, A., & Abuel-Atta, A. A. (2015). Sinu-atrial node of mature dromedary camel heart (Camelus dromedarius) with special emphasis on the atrial purkinje like cardiomyocytes. *Cell Biology, 3*(2), 25-33.

James, T. N. (1961). Anatomy of the human sinus node. *The Anatomical Record, 141*(2), 109-139.

James, T. N. (1962). Anatomy of the sinus node of the dog. *The Anatomical Record, 143*(3), 251-265.

James, T. N. (1964). Anatomy of the A–V node of the dog. *The Anatomical Record, 148*(1), 15-27.

James, T. N. (1965). Anatomy of the sinus node, AV node and os cordis of the beef heart. *The Anatomical Record, 153*(4), 361-371.

James, T. N. (1967a). Anatomy of the cardiac conduction system in the rabbit. *Circulation Research, 20*(6), 638-648.

James, T. N. (1967b). Cardiac innervation: anatomic and pharmacologic relations. Bulletin of the New York Academy of Medicine, 43(12), 1041.

James, T. N. (1977). The sinus node. *The American journal of cardiology, 40*(6), 965-986.

James, T. N., Sherf, L., Fine, G., & Morales, A. R. (1966). Comparative ultrastructure of the sinus node in man and dog. *Circulation, 34*(1), 139-163.

Lang, D., & Glukhov, A. V. (2018). Functional microdomains in heart's pacemaker: A step beyond classical electrophysiology and remodeling. Frontiers *in Physiology, 9*, 1686.

Luna, L. G. (1968). *Manual of histologic staining methods of the Armed Forces Institute of Pathology.* New York. US: Blakiston Division, McGraw-Hill.

Machida, N., Katsuda, S., Kobayashi, Y., & Mitsumori, K. (2005). A histological study of the cardiac conduction system in a heifer with complete atrioventricular block. *Journal of Comparative Pathology, 133*(1), 68-72.

Merideth, J., & Titus, J. (1968). The anatomic atrial connections between sinus and AV node. *Circulation, 37*(4), 566-579.

Mitrofanova, L. B., Gorshkov, A. N., Konovalov, P. V., & Krylova, J. S. (2018). Telocytes in the human sinoatrial node. Journal *of Cellular and Molecular Medicine, 22*(1), 521-532.

Nabipour, A. (2004). Histology of the atrio-ventricular bundle in the heart of guinea pig (Cavia percellus). *Iranian Journal of Veterinary Research, 5*(1), 203-205.

Nabipour, A. (2010). The anatomy and histology of the atrioventricular conducting system in the hedgehog (Hemiechinus auritus) heart. *Turkish Journal of Zoology, 34*(2), 237-242.

Nabipour, A. (2012). Comparative histological structure of the sinus node in mammals. *Turkish Journal of Veterinary and Animal Sciences, 36*(5), 463-469.

Nabipour, A., Shahabodini MR (2007). Histological study of the atrioventricular node and bundle in the heart of ovine fetus. *Iranian Journal of Veterinary Research*, 34, 237-242.

Nabipur, A. (2002). Anatomy and histology of the atrio-ventricular node of goats (Capra hircus). *Journal of Applied Animal Research, 22*(2), 255-260.

Nabipur, A., Khanzadi, S., & Moradi, G. (2000). Anatomy and histology of the sinu-atrial node of goats (Capra hircus). *Journal of Applied Animal Research, 18*(2), 153-158.

Opthof, T., De Jonge, B., Jongsma, H., & Bouman, L. (1987). Functional morphology of the mammalian sinuatrial node. *European Heart Journal, 8*(11), 1249 -1259.

Pawlina, W., & Ross, M. H. (2018). *Histology: a text and atlas: with correlated cell and molecular biology*.Philadelphia, US: Lippincott Williams & Wilkins.

Perde, F. V., Atkinson, A., Yanni, J., Dermengiu, D., & Dobrzynski, H. (2016). Morphological characteristics of the sinus node on postmortem tissue. *Folia Morphologica, 75*(2), 216-223.

Sanchez-Quintana, D., Cabrera, J., Farre, J., Climent, V., Anderson, R., & Ho, S. Y. (2005). Sinus node revisited in the era of electroanatomical mapping and catheter ablation. *Heart, 91*(2), 189-194.

Titus, J. L., Daugherty, G. W., & Edwards, J. E. (1963). Anatomy of the normal human atrioventricular conduction system. *American Journal of Anatomy, 113*(3), 407-415.

Treuting, P. M., Dintzis, S., & Montine, K. S. (2017). *Comparative anatomy and histology: a mouse, rat, and human atlas*. Cambridge, US: Academic Press.

Truex, R. C., Belej, R., Ginsberg, L. M., & Hartman, R. L. (1974). Anatomy of the ferret heart: an animal model for cardiac research. The *Anatomical Record, 179*(4), 411-422.

Türkmenoğlu, İ., Çevik Demirkan, A., Akosman, M. S., Akalan, M. A., & Özdemir, V. (2017). Macroanatomical, subgross and stereological ınvestigation of the nerve nodes in the buffalo heart. *Kocatepe Veterinary Journal, 10*(4) 241-246.

Wiyarta, E., & Karima, N. (2022). Basic science and clinical implications. In T. Aslanidis, C. Nouris (Ed) *Heart Autonomic Nervous System. (pp. 1-12).* London, UK: IntechOpen.