VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 82, No. 3, pp. 562–567
DOI: 10.5603/FM.a2023.0009

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Investigation of anastomoses between coronary arteries in Akkaraman sheep by plastic injection and corrosion method

E. Yalman[1], E. Unur[2], H. Güler[2]

[1]*Department of Nursing, Faculty of Health Sciences, Yozgat Bozok University, Yozgat, Turkey*
[2]*Department of Anatomy, Faculty of Medicine, Erciyes University, Kayseri, Turkey*

[Received: 4 October 2022; Accepted: 25 January 2023; Early publication date: 26 January 2023]

Background: *Since it is critical to understand the anatomy of the coronary arteries and the anastomoses between them in Akkaraman sheep, the coronary arteries will be examined using a plastic injection and corrosion technique.*

Materials and methods: *In our investigation, researchers used 20 Akkaraman sheep's hearts collected from slaughterhouses in and near Kayseri, and hearts from animals aged 2–3 years were included. The anatomy of the coronary arteries of the hearts was studied by plastic injection and corrosion method. The macroscopically examined patterns of the excised coronary arteries were photographed and recorded.*

Results and Conclusions: *This approach indicated arterial vascularisation of the heart in sheep, with a. coronaria dextra and a. coronaria sinistra developing from the commencement of the aorta. It was determined that a. coronaria sinistra, after leaving the initial part of the aorta, proceeds to the left and divides into two branches called r. interventricularis paraconalis and r. circumflexus sinister, forming a right angle between them, immediately after reaching the sulcus coronarius. Anastomosis of the branches of r. distalis atrii dextri with the branches of r. intermedius atrii dextri and r. ventriculi dextri; anastomosis of a thin branch separated from r. proximalis atrii sinistri with the branch of r. proximalis atrii dextri running in the initial part of the aorta; anastomosis of r. distalis atrii sinistri with r. intermedius atrii sinistri were detected. In one heart, the r. septalis protruded roughly 0.2 cm from the beginning of a. coronaria sinistra.* (Folia Morphol 2023; 82, 3: 562–567)

Key words: anastomosis, anatomy, coronary artery, heart, sheep

INTRODUCTION

The heart is the most crucial basic building unit of the body, pumping blood and ensuring proper circulation. It is critical that the heart is in good health so that all organs may work effectively and systematically. Cardiovascular diseases are the leading cause of death worldwide and in Turkey (http://www.saglik.gov.tr, 2018). The first two causes of death related to heart disorders are ischaemic heart disease and cerebrovascular diseases [23].

Arteria (a.) coronaria dextra and a. coronaria sinistra emerge from the ascending aorta to supply the heart [1–3, 6, 7, 9, 14, 15, 18, 22, 24–26, 31, 33]. A. coronaria dextra originates from the level of the valvula semilunaris dextra at the initial level of the aorta [3, 9, 15]. A. coronaria dextra runs between

Address for correspondence: Dr. E. Yalman, Yozgat Bozok University, Faculty of Health Sciences, Department of Nursing, 66000 Yozgat, Turkey, tel: +905076150277, e-mail: eylem.yalman@yobu.edu.tr

the truncus pulmonalis and the auricula dextra, then to the sulcus coronarius and back as the ramus (r.) circumflexus dexter [11, 18, 29, 30]. R. circumflexus dexter yields r. proximalis atrium dextri, r. intermedius atrii dextri and r. distalis atrium dextri for atrium dextrum, and r. coni arteriosi, r. proximalis ventriculi dextri, r. intermedius atrii dextri and r. distalis atrium dextri for ventriculus dexter, r. proximalis ventriculi dextri, r. marginis ventricularis dextri [9, 15, 21, 28, 32, 33].

Arteria coronaria sinistra is a branch of the aorta that begins slightly above the valvula semilunaris sinistra [9, 10, 29]. At the level of the sulcus coronarius, a. coronaria sinistra separates into r. circumflexus sinister and r. interventricularis paraconalis, making a right angle [5, 18, 20, 30, 32, 33]. The r. interventricularis paraconalis branches to the rr. septi interventriculares [12], r. coni arteriosi, r. collateralis sinister proximalis, and r. collateralis sinister distalis after its origin [11, 13, 18, 33]. Atria l branches of r. circumflexus sinister are r. proximalis atrii sinistri, r. intermedius atrii sinistri, and r. distalis atrii sinistri. Its ventricular branches are r. proximalis ventriculi sinistri, r. marginis ventricularis sinistri, and r. distalis venticuli sinistri [8, 11, 25, 30, 32, 33].

Polyester was employed in our study because it is abundant in the industry and inexpensive, and sheep's heart was used since it is accessible and one of the hearts closest to the human heart. Since it is critical to understand the anatomy of the coronary arteries and the anastomoses that connect them, it was decided to analyse the coronary arteries in Akkaraman sheep using a plastic injection and corrosion approach.

MATERIALS AND METHODS

This investigation was conducted in accordance with the principles of the "Ethics Committee," with 20 Akkaraman sheep's hearts procured from butchers or slaughterhouses in and around Kayseri. After the animals were slaughtered, the hearts and pericardia were removed from the thoracic cavity.

The hearts provided for the experiment were dissected in the laboratory for the plastic injection process. After the cannula was placed in the aorta, the solution was prevented from escaping between the cannula and the aorta by tying the periphery of the aorta with a thread. Vv. pulmonales were ligated. The polyester solution was prepared by adding 70% Polyester resin (Turkuaz Corolla Styrene Monomer TPY001), 30% Liquidizer (styrene), 2% Accelerator, 4% Freezer, Dye (Red dye) [4, 17].

After putting the prepared polyester solution into a 50 mL injector, it was injected into the aorta via the cannula inserted in the aorta until all of the coronary arteries were filled. During the injection, the periphery of the aorta was tied with a thread to prevent the solution from escaping between the cannula and the aorta. The hearts were stored at room temperature during 48–72 hours after the polyester injection to allow the polyester to harden in the artery. Following the solidification of the polyester, the hearts were immersed in 37.5% hydrochloric acid. Hearts were maintained in hydrochloric acid for a time interval of 48–72 hours. We observed that vascular integrity deteriorated in hearts that were kept in hydrochloric acid for a longer period of time. In this acid, the tissues were dissolved (corrosion). The collected materials were washed in tap water to remove any tissue remnants. As a result, the coronary artery mould was removed. Macroscopically, the patterns of the excised coronary arteries were analysed.

Ethical statement

It has been reported in writing by Erciyes University Animal Experiments Local Ethics Committee (20/045) that this study is not subject to HADYEK's permission.

RESULTS

The structure and anastomoses of the coronary arteries in 20 Akkaraman sheep aged 2–3 years and weighing 60–70 kg were studied. The arterial vascularisation of the heart in sheep was determined to be given by a. coronaria dextra and a. coronaria sinistra originating from the beginning of the aorta. An additional vessel was discovered at the ostium aortae level in one heart, originating between a. coronaria dextra and a. coronaria sinistra on the anterior surface of the aorta and supplying the anterior side of the left ventricle (the region where the sulcus interventricularis paraconalis is located). Based on the region it fed, this branch was named ramus septalis (Fig. 1).

Findings of arteria coronaria dextra

After exiting the aorta, a. coronaria dextra proceeded to the right and reached the sulcus coronarius, where it continued as r. circumflexus dexter in the subepicardial adipose tissue (Fig. 2). A. coronaria dextra was observed to give r. septalis to feed the septum interventriculare and r. coni arteriosi to feed the area where the conus arteriosus is located.

Figure 1. The branch that separates from the aorta (AO) between a. coronaria dextra (ACD) and a. coronaria sinistra (ACS); 1 — branch that separates from the aorta between a. coronaria dextra and a. coronaria sinistra (Ramus septalis).

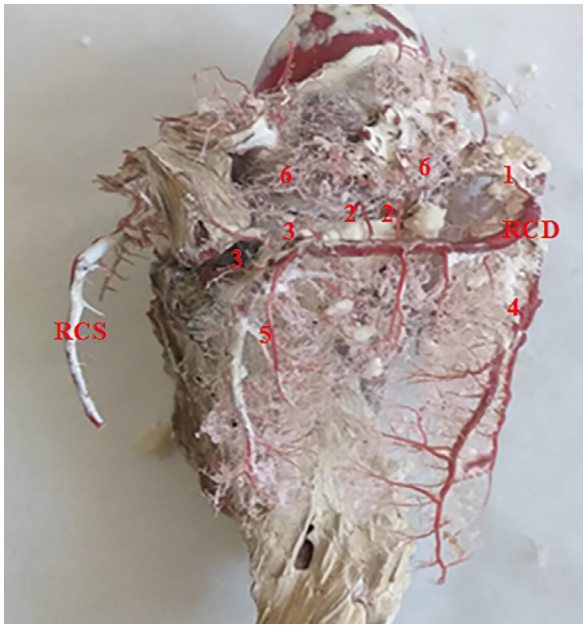

Figure 2. Ramus circumflexus dexter (RCD) is terminated by the formation of r. interventricularis subsinuosus; RCS — r. circumflexus sinister; 1 — r. proximalis atrii dextri; 2 — r. intermedius atrii dextri; 3 — r. distalis atrii dextri; 4 — r. marginis ventricularis dextri; 5 — r. distalis ventriculi dextri; 6 — r. intermedius atrii dextri anastomoses with r. proximalis atrii dextri and r. distalis atrii dextri.

The atrial dextrum was given the names r. proximalis atrii dextri, r. intermedius atrii dextri, and r. distalis atri dextri (Fig. 2). In 10 hearts, r. proximalis atrii dextri anastomoses with branches of r. intermedius atrii dextri, and a thin branch of it proceeds from the beginning of the aorta and anastomoses with a branch of r. proximalis atrii sinistri. The branches of r. intermedius atrii dextri that split before coming to margo venticularis dexter anastomoses with r. proximalis atri dexter, while the branches that divide after passing through margo ventricularis dexter anastomoses with r. distalis atri dexter (Fig. 2). It was determined that r. distalis atrii dextri was absent in one heart. The absence of this vessel was shown to be nourished by the r. ventriculi dextri, a branch of the r. interventricularis subsinuosus. The branches of r. distalis atrii dextri anastomose with those of r. intemedius atrii dextri and r. ventriculi dextri.

It was discovered that for ventriculus dexter, it gave r. proximalis ventriculi dextri, r. marginis ventricularis dextri, and r. distalis ventriculi dextri (Fig. 2). It was observed that r. proximalis ventriculi dextri dispersed in the middle and proximal regions of the ventriculus dexter and anastomose with the ventricular branches of the r. interventricularis paraconalis and the branches of the r. marginis ventricularis dextri. R. marginis ventricularis dextri was observed to anastomose with the branches provided by r. proximalis ventriculi dextri, r. distalis ventriculi dextri, and r. interventricularis paraconalis for ventriculus dexter. R. distalis ventriculi dextri anastomose with r. interventricularis paraconalis branches for ventriculus dexter.

Findings of arteria coronaria sinistra

After leaving the early segment of the aorta, a. coronaria sinistra proceeded to the left and reached the sulcus coronarius. It was discovered that 19 hearts split into two branches, r. interventricularis paraconalis and r. circumflexus sinister, immediately after reaching the sulcus coronarius, making a right angle between them. It divided into three branches in one heart, and the third branch, which emerged between the r. interventricularis paraconalis and the r. circumflexus sinister, was discovered to be the r. proximalis ventriculi sinistri (Fig. 3).

Ramus circumflexus sinister

The atrium sinistrum was given the titles r. proximalis atrii sinistri, r. intermedius atrii sinistri, and r. distalis atrii sinistri. In 2 hearts, a thin branch branching off from the r. proximalis atrii sinistri was found to anastomose with the branch of the r. proximalis atrii dextri running in the initial part of the

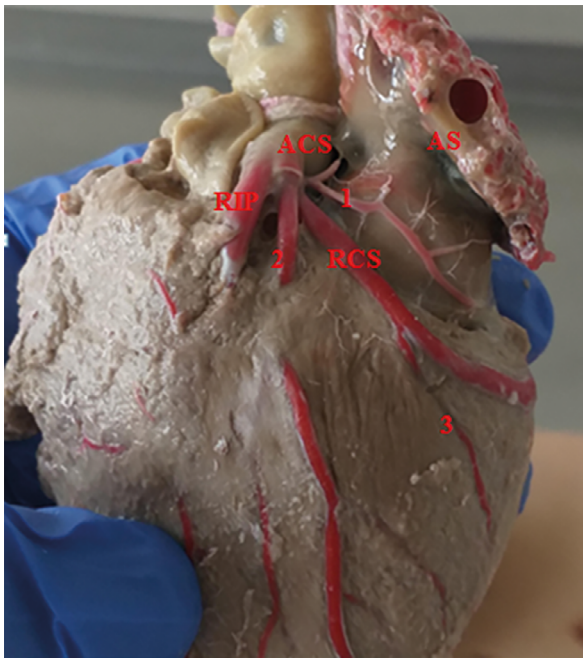

Figure 3. Division of a. coronaria sinistra (ACS) into three branches; AS — auricula sinistra; RCS — r. circumflexus sinister; RIP — r. interventricularis paraconalis; 1 — r. proximalis atrii sinistri; 2 — r. proximalis ventriculi sinistri; 3 — r. marginis ventricularis sinistri.

aorta. The r. intermedius atrii sinistri and r. distalis atrii sinistri were found to be absent in one heart, and the region it fed was identified to be nourished by the r. proximalis atrii sinistri (Fig. 3).

It was discovered that it was administered to the r. proximalis ventriculi sinistri, r. marginis ventricularis sinistri, and r. distalis ventriculi sinistri for ventriculus sinister. In one heart, a coronaria sinistra was found to be separated into 3 branches, with the third branch emerging between r. interventricularis paraconalis and r. circumflexus sinister being r. proximalis ventriculi sinistri. The r. proximalis ventriculi sinistri anastomosis with the r. marginis ventricularis sinistri and r. collateralis sinister proximalis was determined (Fig. 3). The r. distalis ventriculi sinistri anastomoses with the r. marginis ventricularis sinister and r. interventricularis subsinuosus. R. interventricularis subsinuosus gave a branch called r. ventriculi dextri about 0.3 cm from its beginning, and this branch anastomosed with r. distalis atri dextri. It was observed that 1 heart did not have r. distalis atrii dextri, and this region was fed by r. ventriculi dextri.

Ramus interventricularis paraconalis

It was determined that the r. coni arteriosi originating from the r. interventricularis paraconalis anastomose with the terminal branches of the vein of the same name separated from a. coronaria dextra. In addition, r. collateralis sinister proximalis anastomoses with r. proximalis ventriculi sinistri, r. collateralis sinister distalis anastomose with r. proximalis ventriculi sinistri, branches given for ventriculus dexter r. proximalis ventriculi districuli deximalis and its branches for the ventriculus sinister were found to anastomose with the r. marginis ventricularis sinistri.

DISCUSSION AND CONCLUSIONS

Coronary artery diseases are common in humans and these vessels are frequently intervened. Sheep are used as a common model in translational research on vessels. Therefore, it is valuable to know the coronary artery anatomy of these animals. In our study, we benefited from coronary artery studies conducted in both sheep and humans.

According to Stankovic and Jesic (2004) [28], a third coronary artery can emerge from the aorta in humans [27]. An additional vessel was discovered at the level of the ostium aortae in our investigation, emerging between a. coronaria dextra and a. coronaria sinistra on the anterior surface of the aorta and feeding the anterior surface of the left ventricle (the region where the sulcus interventricularis paraconalis is located). This finding lends credence to the notion that differences in coronary arteries are widespread.

In our study, it was discovered that a coronaria dextra gave a thin branch on its dorsal surface at the beginning of one of the sheep bowls, and this branch rose on the anterior surface of the aorta. R. marginis ventricularis dextri was shown to anastomose with r. proximalis ventriculi dextri and r. distalis ventriculi dextri. For ventriculus dexter, r. distalis ventriculi dextri anastomoses with the branches provided by r. marginis ventricularis dextri and r. interventricularis paraconalis. These anastomoses have not been described in the literature.

In the human heart [20] and in the African sheep [16], a coronaria sinistra separates into three branches [19, 32]. In line with this discovery, it was revealed in our investigation that it was variably divided into three branches. There was anastomosis between the ramus interventricularis paraconalis and the ramus circumflexus sinister. We have encountered similar anatomical variations that have been seen before. Therefore, we used similar nomenclatures in the literature in our study, since we did not observe a different vessel finding for the first time.

A thin branch originating from the dorsal surface of 2 (10%) hearts was shown to rise above the aorta 0.2 cm following the beginning of a. coronaria sinistra. There was no such finding in the literature. It has been determined that r. distalis atrii sinistri anastomoses with r. intermedius atrii sinistri, which was not previously discovered in the literature.

As a consequence, the coronary arteries supplying the hearts of Akkaraman sheep were identified, as well as the anastomoses between them. This study, which determines the anastomoses connecting the coronary arteries of Akkaraman sheep, is expected to contribute to anatomical studies by filling a gap in the literature. From this point of view, the anastomoses of the branches of r. distalis atrii dextri with the branches of r. intermedius atrii dextri and r. ventriculi dextri, which have not been reported in the literature so far and were detected for the first time in sheep with our study, anastomoses of r. distalis ventriculi dextri with r. marginis ventricularis dextri and r. interventricularis paraconalis branches for ventriculus dexter, in 2 hearts, the anastomoses of a thin branch separated from the r. proximalis atrii sinistri with the branch of the r. proximalis atrii dextri running in the beginning of the aorta and the anastomoses of the r. distalis atrii sinistri with the r. intermedius atrii sinistri may contribute to the literature. Castration of coronary vessels can also help in model building for educational purposes. As a result, it has been determined that it may aid in better recognizing coronary anastomoses and progressing in the resolution of heart disorders.

Acknowledgements

This study was produced from a doctoral thesis. We would like to thank the academicians and all staff of Erciyes University Faculty of Medicine, Department of Anatomy, who contributed to the study.

Conflict of interest: None declared

REFERENCES

1. Akhtar S, Hossain F, Siddiqui M, et al. Morphology and Morphometrical studies on Semi lunar Heart valves of Indigenous Cattle (*Bos indicus*). Int J Nat Sci. 1970; 1(1): 7–11, doi: 10.3329/ijns.v1i1.8608.
2. Aksoy G, Karadağ H. Evcil kedi ve Beyaz Yeni Zelanda tavşanlarında kalp ve kalp arteriaları üzerinde anatomik bir çalışma. Vet Bil Derg. 2002; 18(1-2): 33–40.
3. Aksoy G, Özüdoğru Z, Özdemir D. A macroanatomic investigation of the coronary arteries and myocardial bridges in Awassi sheep. Eur J Vet Sci. 2018; 34(3): 171–177, doi: 10.15312/eurasianjvetsci.2018.192.
4. Aycan K, Bilge A. Plastik enjeksiyon ve korrozyon metodu ile vaskuler sistem anatomisinin araştırılması. Erciyes Ü Tıp Fak Derg. 1984; 6: 545–552.
5. Bhargava I, Beaver C. Observations on the arterial supply and venous drainage of the bovine hearth. Anat Anz. 1970; 126: 343–354.
6. Bhimalli S, Dixit D, Siddibhavi M, et al. A study of variations in coronary arterial system in cadaveric human heart. World J Sci Technol. 2011; 1(5): 30–35.
7. Bisaillon A. Anatomy of the heart in the North American Beaver (Castor Canadensis). Anat Anz. 1982: 381–391.
8. Boumzebra D, Solem JO, Nakeeb S, et al. The sheep as a model for coronary artery surgery experimention beating heart. J Tehran Heart Center. 2006: 11–15.
9. Büll ML, Martins MF. Study of the arterial coronary circulation in the dog (Canis familiaris). Rev Chil Anat. 2002; 20(2), doi: 10.4067/s0716-98682002000200001.
10. Doğruer A, Özmen E. Kıvırcık Koyunlarında Koroner Arterler Üzerine Makroanatomik Bir Çalışma. Atatürk Üniversitesi Veteriner Bilimleri Dergisi. 2012; 7(1): 35–45.
11. Döven O, Yurtdaş M, Çiçek D. Congenital absence of left circumflex coronary artery with superdominant right coronary artery. Anadolu Kardiyol Derg. 2006; 6: 208–209.
12. Dursun N. Veteriner Anatomi II. Ankara Üniversitesi Veteriner Fakültesi, Medisan Yayınevi, Ankara 2002: 186–198.
13. Dursun N, Türkmenoğlu İ. Kangal köpeklerinde septum interventricularenin arteriel vaskularizasyonu. Vet Bil Derg. 1996; 12: 141–144.
14. Dyce KM, Sack WO, Wensing CJG. Textbook of Veterinary Anatomy. WB Saunders Company 1996.
15. Frackowiak H, Jasiczak K, Pluta K, et al. Coronary arteries of the roe deer (Capreolus capreolus; Linnaeus 1758) heart. Pol J Vet Sci. 2007; 10(2): 105–108, indexed in Pubmed: 17882934.
16. Gomez FA, Cortés LS, Ballesteros LE. Morphological characterisation of the coronary arteries in African sheep (Ovis orientalis). Differential analysis with those of humans and other animal species. Folia Morphol. 2019; 78(1): 63–70, doi: 10.5603/FM.a2018.0054, indexed in Pubmed: 30009370.
17. Gürbüz İ. Tuj ve Hemşin koyunlarında kalp ve koroner damarlar üzerine karşılaştırmalı makroanatomik araştırmalar. Kafkas Üniversitesi Sağlık Bilimleri Enstitütü, Doktora Tezi, Kars, 2015.
18. Hassa O. Korozyon preparatlarının normal ve patolojik piyeslerin polyester bloka alma tekniği. Veteriner Fakültesi Dergisi. 1967; 14: 378–386.
19. Koizumi M, Kawai K, Honma S, et al. Anatomical study of a left single coronary artery with special reference to the various distribution patterns of bilateral coronary arteries. Ann Anat. 2000; 182(6): 549–557, doi: 10.1016/S0940-9602(00)80102-8, indexed in Pubmed: 11125806.
20. Kura GG, Poerschke RA, Tumelero RT, et al. Myocardial bridges and left coronary artery trifurcation: a case report. J Morphol Sci. 2013; 30: 209–211.
21. Miller M, Christensen G, Evans H. Anatomy of the dog. WB Saunders Company, Philadelphia, London 1965: 267–285.
22. Nickel RA, Schummer A, Seiferle E. The anatomy of the domestic animals the circulatory system. Verlag Paul Parey, Berlin, Hamburg 1981.
23. Nigri GR, Di Dio LJ, Baptista CA. Papillary muscles and tendinous cords of the right ventricle of the human heart:

morphological characteristics. Surg Radiol Anat. 2001; 23(1): 45–49, doi: 10.1007/s00276-001-0045-7, indexed in Pubmed: 11370142.
24. Öngen Z, Yılmaz Y. Aterosklerozun Patogenezi. Türkiye Klinikleri Dahili Tıp Bilimleri Dergisi Kardiyoloji. 2006; 2(7): 1–9.
25. Ozgel O, Haligur AC, Dursun N, et al. The macroanatomy of coronary arteries in donkeys (Equus asinus L.). Anat Histol Embryol. 2004; 33(5): 278–283, doi: 10.1111/j.1439-0264.2004.00548.x, indexed in Pubmed: 15352880.
26. Şahin F. Merinos Koyunlarında Septum Interventriculare'nin Arteriyal Vaskülarizasyonu. Balıkesir Üniversitesi Sağlık Bilimleri Enstitütü, Yüksek Lisans tezi, Balıkesir, 2016.
27. Schummer A, Wilkens H, Vollmerhaus B, Habermehl KH. The circulatory system, the skin and the cutaneus organs of the domestic mammals. Verlag Paul Parey, Berlin, Hamburg 1981.
28. Stankovic I, Jesic M. Morphometric characteristics of the conal coronary artery. McGill J Med. 2020; 8(1): 2–6, doi: 10.26443/mjm.v8i1.507.
29. Tecirlioğlu S, Dursun N, Uçar Y. Mandada kalp ve kalp arteriaları üzerinde anatomik arastırmalar. Ankara Üniv Vet Fak Derg. 1977; 24: 361–374.
30. Teke B, Özüdoğru Z, Özdemir D, et al. Hasak Koyunlarında Kalp Kas Köprüleri ve Koroner Arterler. Bahri Dağdaş Hayvan Araştırmalar Dergisi. 2017; 6(1): 1–12.
31. Tıpırdamaz S. Akkaraman koyunları ve Kıl keçilerinde kalp ve kalp arteiaları üzerinde karsılastırmalı çalışmalar. Selçuk Veteriner Fakültesi Dergisi. 1987; 3: 179–191.
32. Veteriner Brüt Anatomik İsimlendirme Uluslararası Komitesi. Nomina Anatomica Veterineria (NAV), Beşinci baskı. Dünya Veteriner Anatomistleri Derneği, Hannover, Columbia, Gent, Sapporo, 2012.
33. Vladova D. Ventricular coronary pattern in the cat. Trakia J Sci. 2005; 3: 44–49.