

Macroanatomic Investigations on the Venous Drainage of the Heart in Roe Deer (*Capreolus capreolus*)^[1]

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Summary

In this study, origin, course and termination of the veins in the hearts of 9 roe deer (*Capreolus capreolus*) (4 female and 5 male) with unknown ages were investigated. The animals, badly injured due to firearm or traffic accident, and that died despite all interventions after being referred to the faculty clinics, were used. To visualize heart veins, latex was injected into the left azygos vein. The results were indicated that venous drainage of the hearts was provided by the great cardiac vein, left marginal ventricular vein, middle cardiac vein, right cardiac veins and the smallest cardiac veins. The first three veins were particularly responsible for transporting venous blood to the coronary sinus. Furthermore it was observed that left distal ventricular vein was joined coronary sinus in one cadaver. The right cardiac veins were transported venous blood to the right atrium and the smallest cardiac veins supplied venous blood to the right atrium and right ventricle chambers. It was observed that the venous blood of the interventricular septum was collected by the great and middle cardiac veins.

Keywords: Cardiac veins, Coronary sinus, Heart, Roe deer

Karacada (*Capreolus Capreolus*) Kalbin Venöz Drenajı Üzerine Makroanatomik Araştırmalar

Özet

Bu çalışmada, yaşları bilinmeyen 9 adet (4 dişi ve 5 erkek) karaca (*Capreolus capreolus*) kalbindeki venöz damarların başlangıcı, seyri ve sonlanması incelendi. Çalışmada kullanılan karacaları, ateşli silah ya da trafik kazası nedeniyle kötü yaralanmış olarak fakülte kliniklerine getirilen ve tüm müdahalelere rağmen kurtarılamayan hayvanlar oluşturdu. Kalp venlerini gösterebilmek için *v. azygos sinistra*'ya latex enjekte edildi. Kalbin venöz drenajının *v. cordis magna*, *v. marginis ventricularis sinistri*, *v. cordis media*, *vv. cordis dextrae* ve *vv. cordis minimae* tarafından sağlandığı belirlendi. Özellikle ilk üç venin *sinus coronarius*'a venöz kanı toplamaktan sorumlu olduğu saptandı. Bir materyalde *v. distalis ventriculi sinistri*'nin *sinus coronarius*'a katıldığı gözlemlendi. *V. cordis dextrae*'nin venöz kanı *atrium dextrum*'a, *vv. cordis minimae*'nin ise venöz kanı *atrium dextrum* ve *ventriculus dexter* boşluklarına taşıdığı belirlendi. *Septum interventriculare*'nin venöz kanını *v. cordis magna* ve *v. cordis media*'nin topladığı gözlemlendi.

Anahtar sözcükler: Kalp venleri, Sinus coronarius, Kalp, Karaca

INTRODUCTION

Venous drainage of the heart has been provided by the great cardiac (*V. cordis magna*), middle cardiac (*V. cordis media*), right cardiac veins (*Vv. cordis dextrae*) and the smallest cardiac veins (*Vv. cordis minimae*) in various animals¹⁻⁴. The great and middle cardiac veins are ended at the coronary sinus which is a dilation of the left azygos vein formed at the ventral side of the caudal vena cava before opening to the right atrium^{3,5-7}. The length of the coronary sinus, which is important to determine the correct anatomic location to

perform diagnostic and therapeutic applications successfully^{8,9}, is 2.5 cm in sheep and 2.8 cm in goats¹⁰. The great cardiac vein is originated from the notch of cardiac apex and anastomosed with the the middle cardiac vein^{3,4,10}. The great cardiac vein and the paraconal interventricular branch of the left coronary artery are passed through the paraconal interventricular groove. Moreover, the middle cardiac vein and the subsinuosal interventricular branch of the left coronary artery are passed through the subsinuosal inter-



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ventricular groove^{1,3-7,10}. The left marginal ventricular vein (*R. intermedius*, *V. marginis ventricularis sinistri*) is started from the apex of the left ventricle, lengthens through the caudal side of the heart and ended at either the coronary sinus near to the left azygos vein or the point where the left azygos vein is united with the coronary sinus^{1,10}. This vein can also lead to the great cardiac vein^{2,4,10}. The right cardiac veins, 4-5 in number, are collected the venous blood of the right atrium and right ventricle and terminates at the right atrium^{2,3,10}. The smallest cardiac veins, which transported blood from the myocardium to the heart chambers, are 3-5 mm in length^{1,6,10}. These veins are generally ended at the pectinati muscles in the right atrium^{10,11}.

Although venous drainage of the heart have been examined in different species²⁻⁵, there is no available information about the venous drainage of the roe deer heart. The purpose of this study, therefore, is to present the information about subbranches and main vessels collecting to venous blood of the roe deer heart. In addition, this study will contribute to the anatomic literature and determine to the similarities and differences with other ruminants.

MATERIAL and METHODS

This study was carried out with permission taken from of the General Directorate of Nature Conservation and National Parks of the Ministry of Forestry and Water Affairs at 25.06.2012 date. Nine roe deer, 4 female and 5 male, were used in this study. They were admitted to the surgery clinic of faculty with firearm injuries or following a traffic accident and could not survive. Their weights were between 17 and 25 kg. Thoracic cavities of the animals were opened right after death. All of the heart vessels were washed with 0,9% saline solution via the thoracic aorta. Colored-latex (ZPK-580-S; Gerard Biological Center, Preston, UK) was injected via the left azygos vein after ligation of the caudal and cranial vena cava¹². The cadavers were left at room temperature for 24 hours and then fixated with 10% formalin. Veins were determined by dissection. An Olympus SZ61 TRC stereomicroscope and an Olympus C-5060 digital camera were used for the investigation of the smallest cardiac veins and vessels coursing intramyocardially. Other veins were photographed with the Olympus C-5060. *Nomina Anatomica Veterinaria*¹³ was used for anatomical nomenclature.

RESULTS

Venous drainage in roe deer heart was carried out by the following veins; the paraconal interventricular (*Figs 1a, 2a, 3a*) and left circumflex (*Fig. 1b*) veins, the main branches of the great cardiac vein (*Fig. 1c*), the subsinuosal interventricular vein (*Fig. 1d*), the main branch of the middle cardiac vein (*Fig. 1d'*), the left marginal ventricular vein (*Fig. 1e*), and the right (*Fig. 2A,B,C*), and the smallest (*Fig. 3**) cardiac veins. It was determined that apart from the left conal vein

(*Figs 1f, 2b*) and right cardiac veins (*Fig. 2c*) and left proximal collateral veins (*Figs 1g, 2d*), other subbranches of the subsinuosal and paraconal interventricular veins coursed intramyocardially (*Fig. 4**).

Veins leading to the coronary sinus (*Fig. 1h*) were determined as the great cardiac, left marginal ventricular (in eight cadavers) and middle cardiac veins, and left distal ventricular vein (in one cadaver) (*Figs 1i*). In addition, it was observed that one of the two veins (in four cadavers), originating from the caudomedial side of left atrium headed to the coronary sinus and the other led to the cranial vena cava (*Fig. 2D*). The left marginal ventricular vein was joined the left circumflex vein at the level of the caudal border of the heart, in one cadaver only. In the same cadaver, the left distal ventricular vein was opened into the coronary sinus at the same level as the great cardiac vein. There were differences between the opening sites of the great cardiac and left marginal ventricular veins, both approaching the coronary sinus. It was determined that the veins led to the coronary sinus at the same level in two cadavers (*Fig. 1B*). In six cadavers, left marginal ventricular vein led to coronary sinus 7.69 ± 3.6 mm after the great cardiac vein. In one cadaver, the distance between the two veins was approximately 14.12 mm and left marginal ventricular vein was opened close to the middle side level of the coronary sinus (*Fig. 1C*). The mean length of the coronary sinus was 27.24 ± 8.73 mm.

The Great Cardiac Vein

The great cardiac vein was began as the paraconal interventricular vein at the level of the notch of cardiac apex and anastomosed with the subsinuosal interventricular vein at the same level. The paraconal interventricular vein was formed by the subbranches coming from the left (distinct 2-3 subbranches) and right ventricles (distinct 3-4 subbranches) at the 1/3 distal part of the heart. Subbranches arising from the right ventricle, were anastomosed with the right distal ventricular (*Figs 1j, 2e*), right proximal ventricular (in two cadavers) (*Fig. 2f*), and right marginal ventricular veins (*Fig. 2g*). Subbranches bringing venous blood from the left ventricle to the paraconal interventricular vein at the 1/3 distal part of the heart, were anastomosed with the left marginal ventricular vein.

Subbranches starting from the left (distinct 2-4 subbranches) and right ventricles (distinct 3-5 subbranches) were joined to the paraconal ventricular vein at the 1/3 middle part of the heart. Two distinct veins coming from the right ventricle were associated with the right proximal ventricular vein. One of the these veins (*Figs 1k, 2h*), localized at the 1/3 middle part of the heart and at the distal side of the two thick veins coming from the left ventricle was the left distal collateral vein. The other thick vein could not be named. They were anastomosed with the vein of the left marginal ventricular vein, which reached up to the apex of the heart.

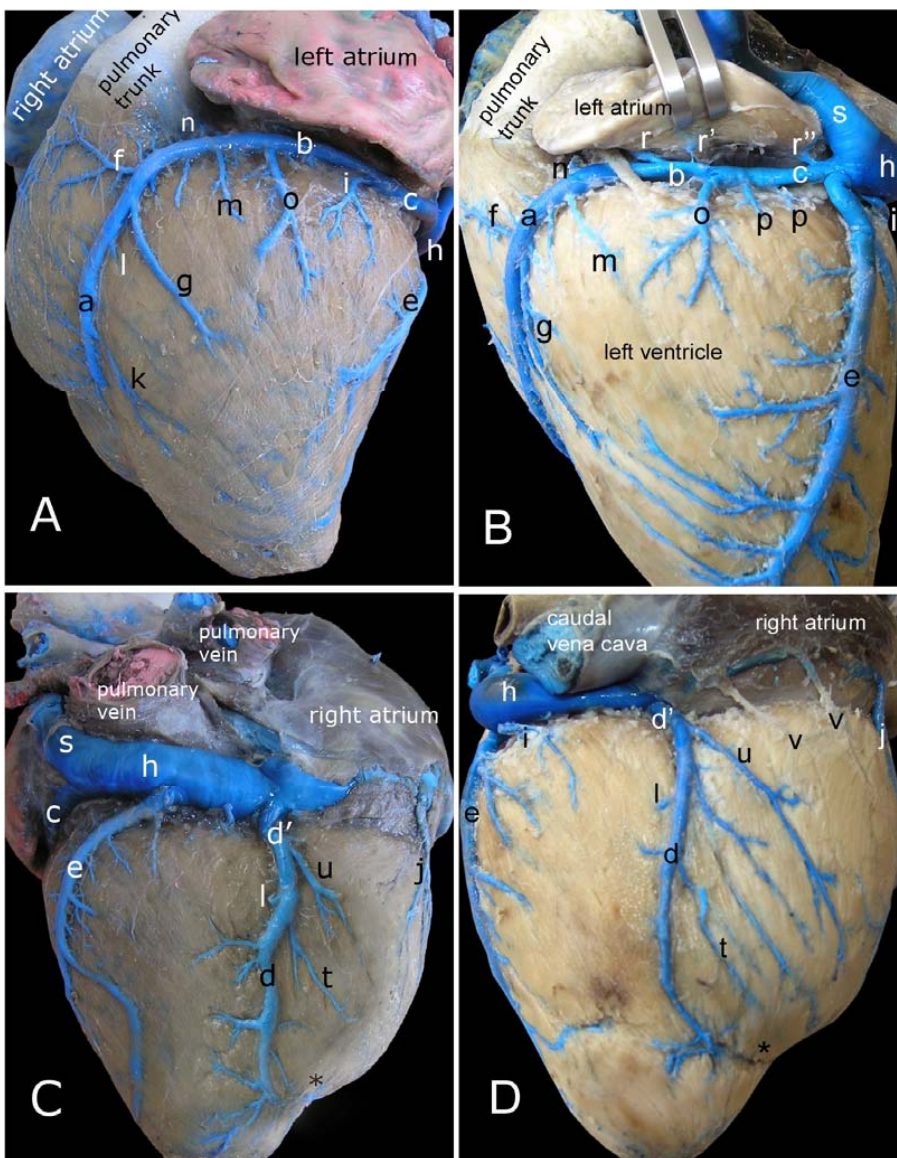


Fig 1. Cardiac veins in auricular surface (A-B) and atrial surface (C-D) of roe deer heart

a) paraconal interventricular vein, b) left circumflex vein, c) great cardiac vein, d) subsinuosal interventricular vein, d') middle cardiac vein, e) left marginal ventricular vein, f) left conal vein, g) left proximal collateral vein, h) coronary sinus, i) left distal ventricular vein, j) right distal ventricular vein, k) left distal collateral vein, l) interventricular septal vein, m) angular vein, n) branch collecting to venous blood from caudomedial part of conus arteriosus, o) left proximal ventricular vein, p) thin branches coming from proximal part of the left ventricle, r) left distal atrial vein, r') left intermedier atrial vein, r'') left proximal atrial vein, s) left azygos vein, t) right distal collateral vein, u) right proximal collateral vein, v) distinct two branches opening to right atrium after subsinuosal interventricular vein, *) notch of cardiac apex

Şekil 1. Karaca kalbinin facies auricularis (A-B) ve facies atrialis (C-D)'indeki kalp venleri

At the 1/3 proximal part of the heart, subbranches coming from the left and right ventricles joined to the paraconal interventricular vein. The left proximal collateral vein was the thickest vein coming from the left ventricle. This vein was anastomosed with the branch of the left marginal ventricular vein, which did not reach to the apex. It was observed that the two veins were present at the proximal and distal sides of the left proximal collateral vein. These veins named as interventricular septal vein (Fig. 1l) were collected venous blood from the interventricular septum. The left conal vein was the thickest one joined to the paraconal interventricular vein from the right ventricle. This vein was anastomosed with the right proximal ventricular vein in one cadaver (Fig. 2B).

The paraconal interventricular vein was coursed in the coronary groove as the left circumflex vein after receiving all these veins which were mentioned above. The left circumflex vein was entirely covered by the left atrium. The vein was described as the angular vein (Fig. 1m), which carries venous blood from the proximal part of the left ventricle, was joined

at the point where the paraconal interventricular vein passes into the left circumflex vein. Another thin vein (Fig. 1n), joining at the main vessel opposite the angular vein was observed. It was seen that this vein was carried venous blood from the caudomedial part of the starting level of the conus arteriosus.

The left circumflex vein had 2 thick and 4-5 thin veins collecting venous blood from the proximal part of the left ventricle. The first thick vein was the left proximal ventricular vein (Fig. 1o) which anastomosed with the angular vein. It was observed that after this vein, 2-3 thin branches (Fig. 1p) from the left ventricle wall and after these thin branches the thicker left distal ventricular vein were joined to the left circumflex vein. In one cadaver, it was determined that the left distal ventricular vein was collected venous blood from the proximal side of the left ventricle between the left marginal ventricular vein and the subsinuosal interventricular vein (Fig. 1B,D). The mentioned vein in this cadaver opened into the coronary sinus. There were also subbranches of the left circumflex vein collecting venous blood from the

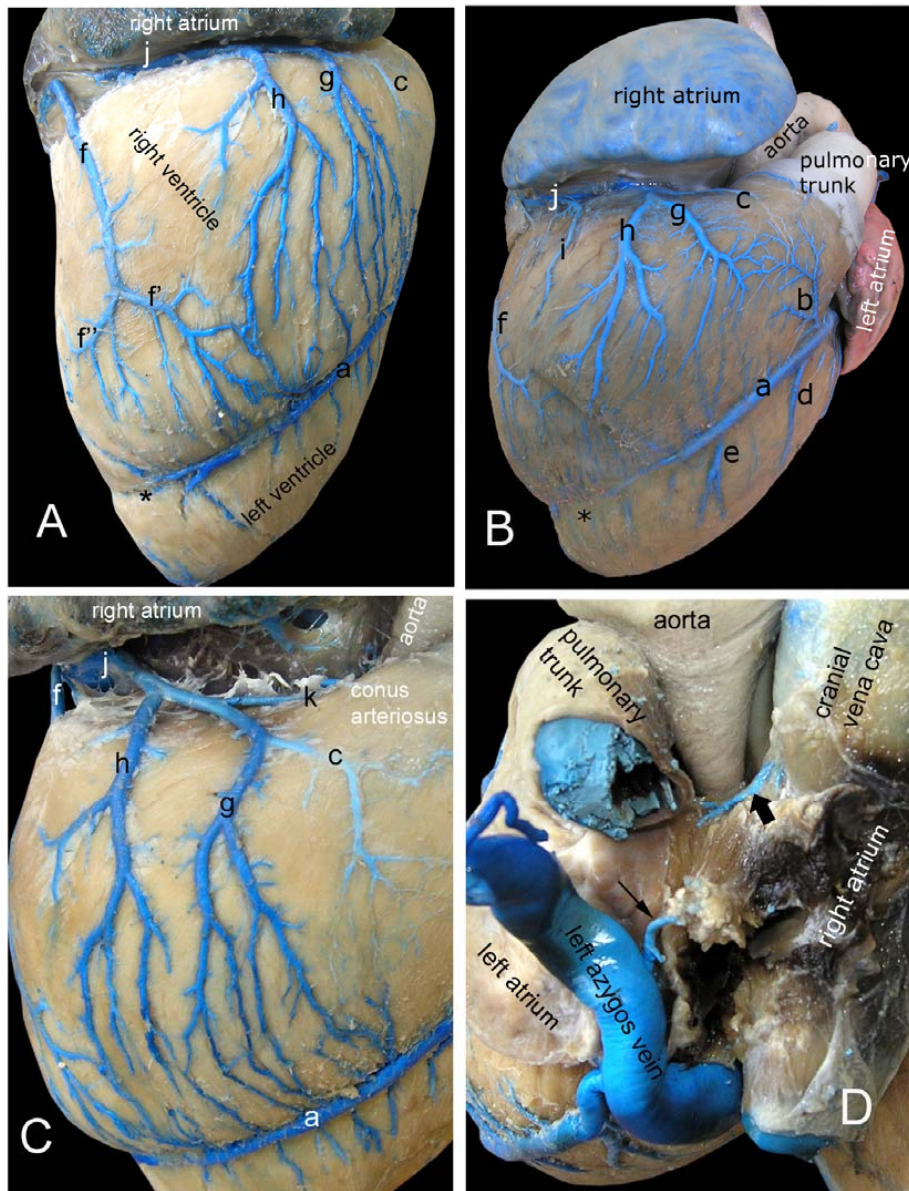


Fig 2. Right cardiac veins (A-B-C) and branches collecting venous blood from the caudomedial of the left atrium (D) in roe deer heart

a) paraconal interventricular vein, b) left conal vein, c) right conal vein, d) left proximal collateral vein, e) right distal ventricular vein, e') the branch coming from auricular surface of right distal ventricular vein, f) right proximal ventricular vein, g) right marginal ventricular vein, h) left distal collateral vein, i) right semicircumflex vein, j) distinct two branches after right distal ventricular vein, k) the branch coming from medial of conus arteriosus, →) branch opens into the coronary sinus, ⇨) branch opens into the cranial vena cava, *) notch of cardiac apex

Şekil 2. Karaca kalbinde vv. cordis dextrae (A-B-C) ve atrium sinistrum'un caudo-medial'inden venöz kanı toplayan kollar (D)

left atrium. These subbranches were the left distal (Fig. 1r), intermedier (Fig. 1r') and proximal atrial veins (Fig. 1r''). In four cadavers, the left distal atrial and left intermedier atrial veins united before opening into the left circumflex vein. The left proximal atrial vein was carried venous blood collected from the caudal part of the left atrium, to the great cardiac vein close to the side where the great cardiac vein leads to the coronary sinus. The great cardiac vein was joined to the coronary sinus at the same level as the left azygos vein (Fig. 1s) after taking these veins.

The Middle Cardiac Vein

Starting as the subsinuosal interventricular vein, which were the two branches coming from the heart apex, the middle cardiac vein was anastomosed with the paraconal interventricular vein. The subsinuosal interventricular vein was coursed intramyocardially from the apex to its distal half, and lied in the proximal direction in the anonymous

groove. Three or four distinct subbranches from the right ventricle and 4-6 distinct subbranches from the left ventricle were joined to the subsinuosal interventricular vein. Two of the subbranches coming from the right ventricle were the most distinct ones. Of these, the distal one was the right distal collateral vein (Fig. 1t) and the proximal one was the right proximal collateral vein (Fig. 1u). Between these two branches, a distinct branch collecting venous blood from the interventricular septum was present. It was determined that the middle cardiac vein was led to the coronary sinus after collecting these subbranches.

The Left Marginal Ventricular Vein

The left marginal ventricular vein was passed through the margo caudalis and headed to the coronary sinus after collecting venous blood from the atrial and auricular surfaces of the left ventricle and apex cordis, in 8 cadavers. In one cadaver, this vein was opened into to the left circumflex

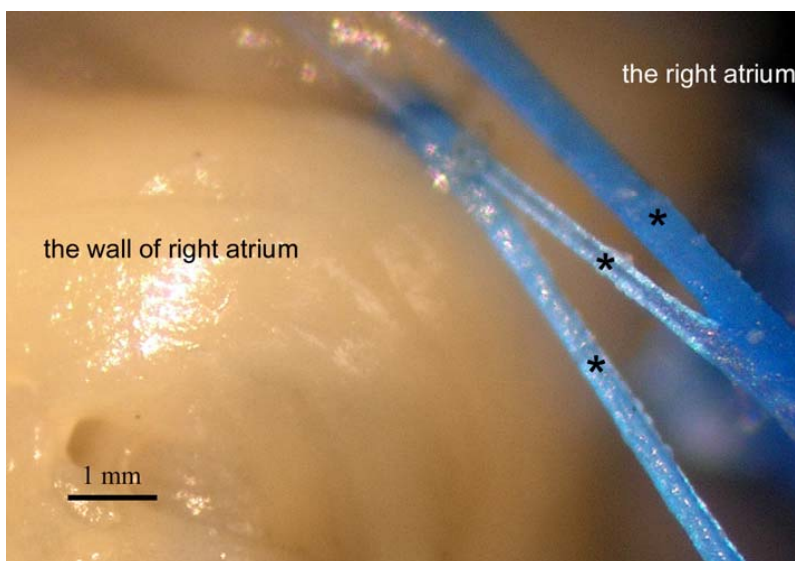


Fig 3. Smallest cardiac veins (*) in the right atrium of roe deer heart

Şekil 3. Karacada v. interventricularis paraconalis'in kalp kasi içindeki seyri

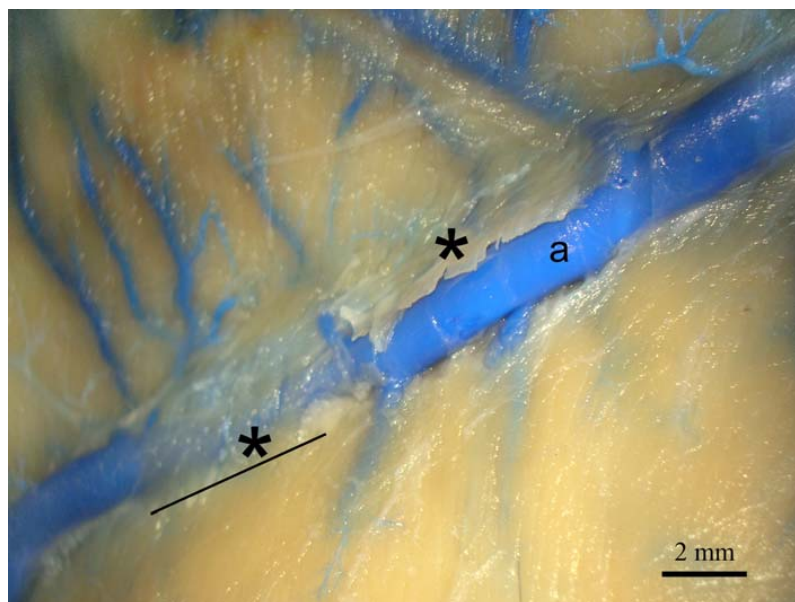


Fig 4. Intramyocardial course of the paraconal interventricular vein in roe deer

a) paraconal interventricular vein, *) muscle fibres

Şekil 4. Karacada v. interventricularis paraconalis'in kalp kasi içindeki seyri

vein at the level of the caudal border of the heart. The left marginal ventricular vein had many thin subbranches in the atrial and auricular surfaces of the left ventricle and two thick branches starting from the apex of heart and at the middle level of heart. All of these branches were anastomosed with the subbranches of the subsinuosal and paraconal interventricular veins, the left distal and proximal collateral veins and the left distal ventricular vein.

The Right Cardiac Veins

The right cardiac veins were consisted of thinner branches collecting venous blood of the right atrium wall and stronger branches collecting venous blood from the right ventricle wall. Branches collecting the blood of the right ventricle were the right distal and proximal ventricular veins, right marginal ventricular vein and right conal vein. Last three branches were formed to the right semicircumflex vein (Fig. 2-i). This vein was carried venous blood to the right atrium by also taking

the right atrial veins collecting venous blood from the right atrium wall. Differences were observed on the formation of the right semicircumflex vein by the last three branches. In two cadavers, the three branches were united at the same point of the proximal side of the right ventricle. In four cadavers, the first right proximal ventricular vein and the right conal vein were united (Fig. 2C). Further on, the right marginal ventricular vein was joined into these branches and formed the right semicircumflex vein. In three cadavers, the right semicircumflex vein was formed by the joining of the right conal vein to the common root made up of the union of the right marginal ventricular and the right proximal ventricular veins (Fig. 2B).

Apart from these branches there were also two branches (Fig. 1v) that collected venous blood from only the proximal part of the right ventricle, directly opened into the right atrium. After passing these branches, the right distal ventricular vein became dominant and coursed in an oblique direction

in the right ventricle. It was separated into two main branches close to the centre of the cranial border of the heart (Fig. 2A-e'e"). The right distal ventricular vein was opened directly into the right atrium. Two eminent branches were determined after the right distal ventricular vein in four of the cadavers. The thicker one (Fig. 2-j) was collected venous blood from the proximal half of the right ventricle and opened into the right semicircumflex vein.

The right conal vein was the thinnest among the branches forming the right semicircumflex vein. This vein was extended to the lateral of the conus arteriosus and anastomosed thereby with the left conal vein. In four cadavers, there was a thin branch collecting venous blood from the medial and caudal side of the conus arteriosus (Fig. 2k). This branch in some occasions was led to the right conal vein and sometimes to the common root formed by the union of the right conal and the right proximal ventricular veins. In one cadaver, the same thin branch was joined to the right proximal atrial vein.

The Smallest Cardiac Veins

The smallest cardiac veins (Fig. 3*) were especially prominent in the right atrium, at different dimensions and lengths. They were also prominent in the right ventricle in very small numbers. They were carried the venous blood collected directly from the myocardium to the heart compartments. The smallest cardiac veins were observed in neither the left atrium nor the left ventricle.

Except for these vessels, there were two vessels in four of the cadavers, collecting venous blood from the caudo-medial of the left atrium. One of these branches was led to the coronary sinus (Fig. 2 →) and the other one was opened into the cranial vena cava (Fig. 2 →).

DISCUSSION

Venous drainage of the roe deer heart was provided by the great cardiac, middle cardiac, right cardiac veins and the smallest cardiac veins as indicated by the literature¹⁻³. In the roe deer, the presence of the left marginal ventricular vein in the venous drainage of the heart was similar to Tuj⁴ and Akkaraman sheep and the Angora goat³. Although it is indicated that these main veins generally course sub-epicardially, some veins, especially the subsinuosal interventricular vein of the middle cardiac vein, are reported to course intramyocardially^{3,4}. It was determined that in the roe deer, near to this branch, the paraconal interventricular vein and its subbranches except for the left conal and left proximal collateral veins were coursed intramyocardially at the 1/3 distal part of the heart.

Hergazi¹⁰ is indicated that the length of the coronary sinus is 2.5 cm in sheep and 2.8 cm in goat. In this study, the mean length of coronary sinus was 27.24±8.73 mm. The blood flow of the great cardiac and the middle cardiac veins to the coronary sinus in the roe deer was in accordance to

the literature^{1,3-5,7}. It is also determined that the middle cardiac vein sometimes are led to the right atrium in some literatures^{1,10,11}. As well as these two veins, the left marginal ventricular vein (in 8 cadavers) and the left distal ventricular vein (in one cadaver) were terminated in the coronary sinus. This situation was similar to that in the Tuj sheep⁴ and in Porcupines¹⁴. While the same vein is received the left distal ventricular vein and opened into coronary sinus in Akkaraman sheep, it is led to the circumflex branch of the great cardiac vein in Angora goat³. In this study, it was seen that the marginal ventricular vein was not received the left distal ventricular vein and generally opened into the coronary sinus except for one cadaver. In one cadaver, this vein was led to the circumflex vein. The left distal ventricular vein was a separate branch and generally open into the circumflex vein in roe deer.

The left marginal ventricular vein is anastomosed with the left distal ventricular vein in Akkaraman sheep and with left distal collateral vein in Angora goat³. In this study, the left marginal ventricular vein was seen to unite with the subsinuosal interventricular vein, the left proximal and distal collateral veins and the left distal ventricular vein, which was similar to the case in the Tuj sheep⁴. The left marginal ventricular vein was additionally anastomosed with the left proximal ventricular vein in the roe deer.

The right cardiac veins are described as the right proximal and distal ventricular veins, the right marginal ventricular vein and the right conal vein in literature^{1,4}. Besoluk and Tırdamaz³ in the Akkaraman sheep and Angora goat, is depicted as the right cardiac veins as the right proximal ventricular, the right conal and the right proximal atrial veins. In this study, the right cardiac veins were determined as the right proximal and distal ventricular veins, the right marginal ventricular, the right conal and right atrial veins. The right cardiac veins are opened into the right atrium^{2-4,10,15} or the coronary sinus⁷. In roe deer, the right cardiac veins were opened into the right atrium. Four branches, collecting venous blood from the proximal part of the right ventricle wall, were detected in roe deer. Two of them were located before and the other two were situated after the right distal ventricular vein. Also, a thin branch collecting venous blood from the medial and caudal side of the conus arteriosus was observed. According to authors' knowledge, there is no information about these branches in literatures.

It is stated that there is differences of the branches constituted to the right semicircumflex vein among the animals species¹. In cat, the right semicircumflex vein is formed by the right proximal and distal ventricular veins and the right marginal ventricular vein, while same branch, in pig, is constituted by the right proximal ventricular, right conal and right proximal atrial veins¹. In this study, branches participating in the formation of the right semicircumflex vein were determined to be the right marginal ventricular, right proximal ventricular and right conal veins. This situation was similar to that determined in the Tuj sheep⁴.

The blood flow of the septal interventricular veins to both paraconal interventricular and subsinuosal interventricular veins in the roe deer was in accordance to the literature ⁴.

One branch, named as the angular branch, carrying venous blood from the proximal part of the left ventricle, was determined in roe deer. Until now, the presence of the angular branch is reported by Nikel et al.¹ in cat and horse and Aksoy et al.⁴ in Tuj sheep.

The smallest cardiac veins carrying venous blood from the myocardium to the heart chambers are differed greatly in the literatures ^{1,10,11}. The smallest cardiac veins are led only to the right atrium ^{10,11} or to all of the heart chambers ^{1,4}. Besoluk and Tıprıdamaz ³ is observed that the smallest cardiac veins are led to all of the heart chambers except for the left ventricle in the goat, but, in sheep, to the left ventricle and the left atrium. In this study, it was determined that the course of the smallest cardiac veins was similar to the case in the Akkaraman sheep ³.

In this study, venous blood was flowed from the caudo-medial aspect of the left atrium. Until now, only Aksoy et al.⁴ have reported that venous blood is flowed from the caudo-medial aspect of the left atrium. But, different from roe deer, Aksoy et al.⁴ is stated that the venous blood is collected at the same place and flowed to the left azygos vein and caudal vena cava. It was observed that these branches were flowed to the coronary sinus and cranial vena cava in roe deer.

In conclusion, it was determined that the great cardiac, middle cardiac and left marginal ventricular veins were headed to the coronary sinus, which was described as the continuation of the left azygos vein. The course of the veins provided the venous drainage of the heart in roe deer were similar to those in sheep in spite of a few small differences.

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