

The Venous Drainage of the Heart in the Tuj Sheep

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Summary

This research aimed at observing the veins of the hearts of 10 Tuj sheep by latex injection. The results documented that the veins draining the heart of Tuj sheep were the great and middle cardiac veins, the right cardiac veins, and the minute cardiac veins. The coronary sinus was determined to be the continuation of the left azygos vein, receiving the great and middle cardiac veins. The left marginal ventricular vein in one heart and the veins draining the left atrium in five hearts were observed to terminate in the coronary sinus. In one cadaver, venous blood of the left atrium was shown to be emptied both into the left azygos vein and the caudal vena cava. Moreover, the left distal ventricular vein was displayed to discharge the venous blood into the coronary sinus in five hearts and into the great cardiac vein in two hearts, yet was not present in three hearts. Venous blood of the left atrium near the aortic arch was displayed to empty into the cranial vena cava in two cadavers. There was another vein ending within the angle where the paraconal interventricular vein became the left circumflex vein, which reflected the angular vein present in the cat and horse. The right semicircumflex vein was seen to be constituted by the right marginal ventricular vein and the right proximal ventricular vein and the right conal vein. The right distal ventricular vein was determined to drain directly into the right atrium. There were also eminent anastomoses between the branches of the cardiac veins observed.

Keywords: Cardiac veins, Heart, Sheep

Tuj Koyununda Kalbin Venöz Drenajı

Özet

Bu araştırma, 10 adet Tuj koyununda kalbin drenajını gerçekleştiren venaların lateks enjeksiyonu ile ortaya çıkarılmasını amaçladı. Araştırma sonucunda kalbin drenajının; v. cordis magna, v. cordis media, vv. cordis dextrae ve vv. cordis minimae tarafından sağlandığı tespit edildi. Sinus coronarius'un v. azygos sinistra'nın devamı olduğu ve v. cordis magna ile v. cordis media'nın sinus coronarius'a açıldığı belirlendi. Aynı zamanda, bir kalpte v. marginis ventricularis sinistri'nin ve beş kalpte atrium sinistrum'u drene eden damarların da sinus coronarius'a döküldüğü saptandı. Bir materyalde atrium sinistrum'un venöz kanının hem v. azygos sinistra'ya hem de v. cava caudalis'e boşaldığı tespit edildi. V. distalis ventriculi sinistri'nin beş kalpte sinus coronarius'un oluşumuna katıldığı, iki kalpte v. cordis magna'ya açıldığı ve üç kalpte de bulunmadığı görüldü. Atrium sinistrum'un arcus aorta'ya yakın bölümünün venöz kanının iki kadvrada v. cava cranialis'e döküldüğü saptandı. V. interventricularis paraconalis'in v. circumflexa sinistra haline geldiği yerden ayrılan ve kedi ile attaki v. angularis'i anımsatan bir vena tespit edildi. V. marginis ventricularis dextri, v. proximalis ventriculi dextri ve v. coni arteriosi olarak isimlendirilen damarların birleşerek v. semicircumflexa dextri'yi meydana getirdikleri görüldü. V. distalis ventriculi dextri'nin ise, doğrudan atrium dextrum'a drene olduğu belirlendi. Koroner venlerin dalları arasında belirgin derecede anastomozların şekillendiği gözlemlendi.

Anahtar sözcükler: Koroner venler, Kalp, Koyun

INTRODUCTION

The veins mostly responsible for the venous drainage of the heart in mammals are the great cardiac vein, the middle cardiac vein, the right cardiac veins, and the minute cardiac veins¹⁻⁴. The

great and middle cardiac veins terminate in the coronary sinus^{1,5-7}. Yet, the minute cardiac veins draining the interventricular septum in cattle and sheep open either into the coronary sinus or join



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the anterior cardiac veins ⁸. Likewise, the left marginal ventricular vein in ruminants enters the last part of the coronary sinus ². Finally, Yadm and Gad ⁴ and Hegazi ⁹ have indicated that the left marginal ventricular vein in goats is a main branch of the great cardiac vein. Moreover, Hegazi ⁹ and May ¹⁰ have reported that the middle cardiac vein in sheep drains directly into the right atrium.

The coronary sinus in general is located immediately ventral to the opening of the caudal vena cava, discharging the venous blood to the right atrium ^{1,11}. The average length of the coronary sinus is 2-2.5 cm in goat ⁴ while it is wider but shorter in sheep ⁶.

The great cardiac vein originates from the apex of the heart, and advances in the paraconal interventricular groove through the basis of the heart ^{1,8}. As a veiled structure with lipid tissue, it courses in the coronary groove, as being wrapped with the left auricle, and terminates in the coronary sinus ¹¹. During this course, it drains subbranches from the left atrium and the right and left ventricles ⁹.

Collecting the atrial surface, the middle cardiac vein also arises from the apex of the heart, advances in the subsinuosal interventricular groove through the basis of the heart, and subsequently opens into the coronary sinus ^{1,2,7}. It drains subbranches from both atrial and auricular surfaces of the heart ⁶.

A number of 4-5 right cardiac veins ⁴ draining the right ventricles, open directly to the right atrium ^{1,4,6,9,10}. Contrarily, Dursun ⁷ has reported that these vessels terminate generally in the coronary sinus.

Very small and thin minute cardiac veins return directly from the myocardial substance without joining the venous flow, terminating in nearby cardiac cavity ^{1,6,10,11}. Besoluk and Tipirdamaz ¹ have documented that these vessels lack in the left atrium and ventricle of the sheep while are present in those of the goats. On the other hand, Nickel et al.² have indicated the presence of these vessels in both the left atrium and ventricle.

Tuj sheep is mainly raised in northeast Anatolia. Its body is covered with white wool, and while male has horn female does not. The sheep is also called Tuchin in south of Russia, and Caucasia. It has a short and fatty tail ¹².

Sheep is mainly regarded as an appropriate

model for cardiovascular surgery because of its ease of handling, size, and vascular anatomy which possesses very close resemblance to that of human being ¹³⁻¹⁵. A study ¹⁶ on the intrarenal arterial pattern of the Tuj sheep has found significant variation as compared to those of other sheep species. There has been no literature report so far on revealing the cardiac venous current on this animal. With those in mind, this study has therefore been performed to observe the venous drainage of the heart macroanatomically in the Tuj sheep.

MATERIAL and METHODS

The study examined macroanatomically the hearts of ten mature Tuj sheep, weighing 45-60 kg, regardless of the sex, since the preliminary results showed no sex-related variation. The animals were exsanguinated through the abdominal aorta under deep anesthesia with a combination of xylazine HCl (Rompun, 0.2 mg/kg/IV, Bayer; Istanbul, Turkey) and ketamine HCl (Ketalar, 2.2 mg/kg/IV, Parke-Davis; Istanbul, Turkey). The thoracic cavities were firstly opened, and heparin (5.000 IU/ml) was administered through the caudal vena cava to prevent blood coagulation. Vessels were then washed with 0.9% saline via the abdominal aorta, hearts were removed, and the related vessels were ligated. The colored-latex (ZPK-582-G, Educational & Scientific Products Ltd.; West Sussex, UK) was injected through the left azygos vein, as suggested by the literature ¹⁷. The vessels were kept in 10% formaldehyde fixative solution at room temperature for 48 hours for polymerization. Finally, dissection was performed and the undermined vessels were grossly observed. *Nomina Anatomica Veterinaria* ¹⁸ was used for the anatomical nomenclature.

RESULTS

The veins draining the heart of the Tuj sheep were the great cardiac vein (*Figs 1-3, 5, 6C, 4, 9B*), the middle cardiac vein (*Figs 1I, 2, 3, 5H, 6E, 7C*), the right cardiac veins (*Figs 7G, 7H, 8B, 8C, 8D, 8E*) and the minute cardiac veins. More subepicardial fat tissue was located in the intersectional areas between the coronary groove and paraconal and subsinuosal interventricular grooves. The main veins coursed subepicardially while subbranches were situated intramyocardially.

However, the left marginal ventricular vein was located subepicardially. In two hearts, the sub-sinuosal interventricular vein lied subepicardially during the proximal 2/3 of its course in the groove while the rest was intramyocardial. The veins draining the interventricular septum and joining the paraconal interventricular vein were larger and much more in number than those opening into the subsinuosal interventricular vein.

The coronary sinus (*Figs 1-3, 5, 6B, 7A*) appeared to be the continuation of the left azygos vein (*Figs 1-6, 9A*). It terminated in the right atrium (*Figs 3, 5, 6b, 7, 8a*), distal to the opening of the caudal vena cava (*Figs 1, 3, 5L, 2K, 6G, 7, 9I*). The great and middle cardiac veins opened into the coronary sinus. Moreover, in five hearts, veins draining the area (*Figs 1K, 5G*) where the pulmonary veins opened into the left atrium also terminated in the coronary sinus.

The great cardiac vein originating from the notch apex of heart advanced in the paraconal interventricular groove through the coronary groove. Whereby forming an angular shape, it advanced at caudal direction as covered by the left auricle (*Figs 1-5a*). Consequently, the vessel drained into the coronary sinus nearly at the level of the left

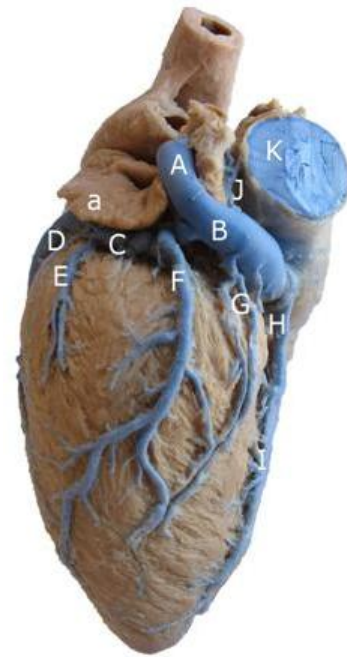


Fig 2. The veins of the heart (auricular surface)

a: left auricle, **A:** left azygos vein, **B:** coronary sinus, **C:** great cardiac vein, **D:** paraconal interventricular vein, **E:** left proximal ventricular vein, **F:** left marginal ventricular vein, **G:** left distal ventricular vein, **H:** middle cardiac vein, **I:** subsinuosal interventricular vein, **J:** the vein draining the left atrium and opening into both the left azygos vein and caudal vena cava by vein dividing into the two subbranches, **K:** caudal vena cava

Şekil 2. Kalbin venleri (facies auricularis)

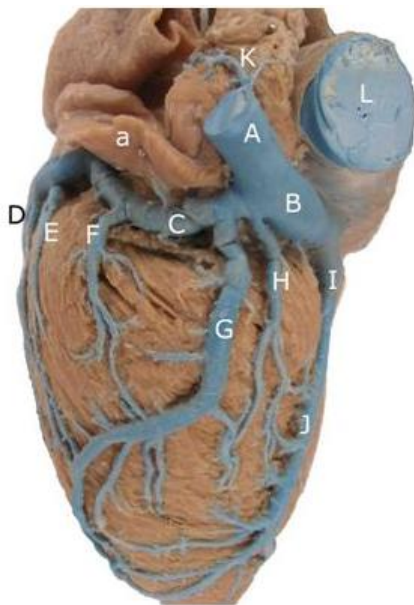


Fig 1. The veins of the heart (auricular surface)

a: left auricle, **A:** left azygos vein, **B:** coronary sinus, **C:** great cardiac vein, **D:** paraconal interventricular vein, **E:** the vein joining the drainage of the left ventricle, like the angular vein in the cat and horse, **F:** left proximal ventricular vein, **G:** left marginal ventricular vein, **H:** left distal ventricular vein, **I:** middle cardiac vein, **J:** subsinuosal interventricular vein, **K:** the vein draining the left atrium and opening into the left azygos vein, **L:** caudal vena cava

Şekil 1. Kalbin venleri (facies auricularis)

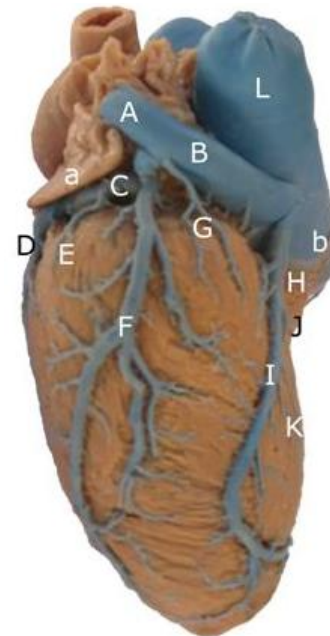


Fig 3. The veins of the heart (caudal surface)

a: left auricle, **b:** right atrium, **A:** left azygos vein, **B:** coronary sinus, **C:** great cardiac vein, **D:** the vein joining the drainage of the left ventricle, like the angular vein in the cat and horse, **E:** left proximal ventricular vein, **F:** left marginal ventricular vein, **G:** left distal ventricular vein, **H:** middle cardiac vein, **I:** subsinuosal interventricular vein, **J:** right proximal collateral vein, **K:** right distal collateral vein, **L:** caudal vena cava

Şekil 3. Kalbin venleri (facies caudalis)

ventricular border. During its course, the great cardiac vein was named paraconal interventricular vein (Figs 1, 2, 4D) in the paraconal interventricular groove, and left circumflex vein in the coronary groove. Right after its origin from the notch of the apex of the heart, the vessel anastomosed with the initial branches of the middle cardiac vein on the auricular surface. The great cardiac vein drained both the left and right ventricles. It also received smaller veins from the interventricular septum.

Branches draining the left ventricle were the followings:

The left distal collateral vein (Fig. 4E) originating from the distal one-third of the left ventricle approached obliquely to the paraconal interventricular vein. It anastomosed with the initial branches of the left marginal ventricular vein and left proximal collateral vein. It terminated in the paraconal interventricular vein below the other collateral branch.

The left proximal collateral vein (Fig. 4F) stemming from the middle one-third of the left ventricle anastomosed with the branches which formed the left marginal ventricular vein. It was thicker than the left distal collateral vein and drained into the

paraconal interventricular vein near the coronary groove.

The left conal vein (Figs 4G, 9F) draining the conus arteriosus hereby was a thick branch opening into the paraconal interventricular vein.

Along with the named veins, there were also other thinner branches draining both the right and left ventricles. Moreover, a vein (Figs 1E, 3D, 4, 9C) was present ending within the angle where the paraconal interventricular vein became the left circumflex vein. It reflected the angular vein present in the cat and horse. It drained a part of the left ventricle between the left proximal collateral and left proximal ventricular veins.

Among the ventricular branches joining the left circumflex vein, the left proximal ventricular vein (Figs 1F, 2, 3E, 5, 9D) was fairly thin, draining the proximal one-third of the left ventricle. It anastomosed with the initial branches of the left marginal ventricular vein.

The strong left marginal ventricular vein (Figs 1G, 2, 3F, 4H, 5, 6D, 9E), draining the both auricular and atrial surfaces, originated from the

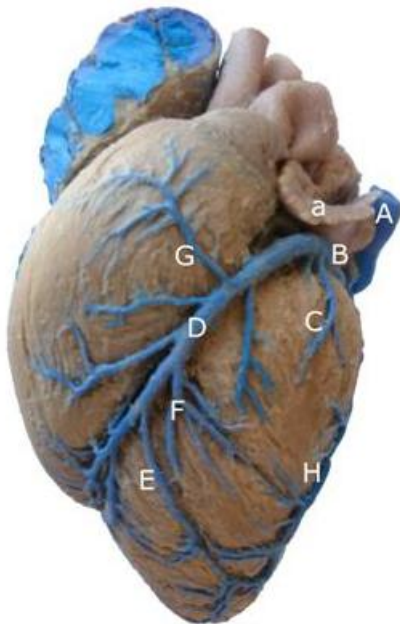


Fig 4. The veins of the heart (cranial surface)

a: left auricle, **A:** left azygos vein, **B:** great cardiac vein, **C:** the vein joining the drainage of the left ventricle, like the angular vein in the cat and horse, **D:** paraconal interventricular vein, **E:** left distal collateral vein, **F:** left proximal collateral vein, **G:** left conal vein, **H:** left marginal ventricular vein

Şekil 4. Kalbin venleri (facies cranialis)

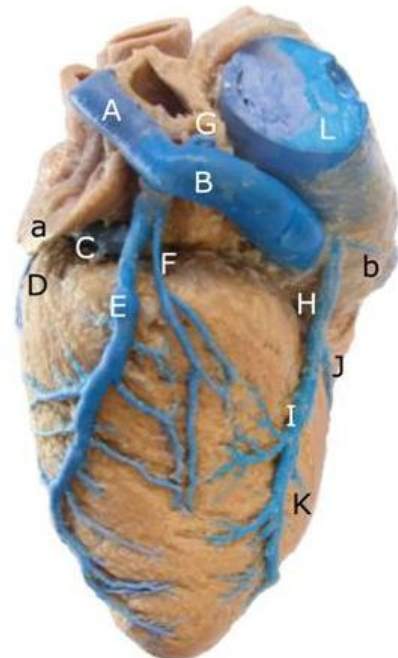


Fig 5. The veins of the heart (caudal surface)

a: left auricle, **b:** right atrium, **A:** left azygos vein, **B:** coronary sinus, **C:** great cardiac vein, **D:** left proximal ventricular vein, **E:** left marginal ventricular vein, **F:** left distal ventricular vein, **G:** the vein terminating in the coronary sinus, **H:** middle cardiac vein, **I:** subsinuosal interventricular vein, **J:** right proximal collateral vein, **K:** right distal collateral vein, **L:** caudal vena cava

Şekil 5. Kalbin venleri (facies caudalis)

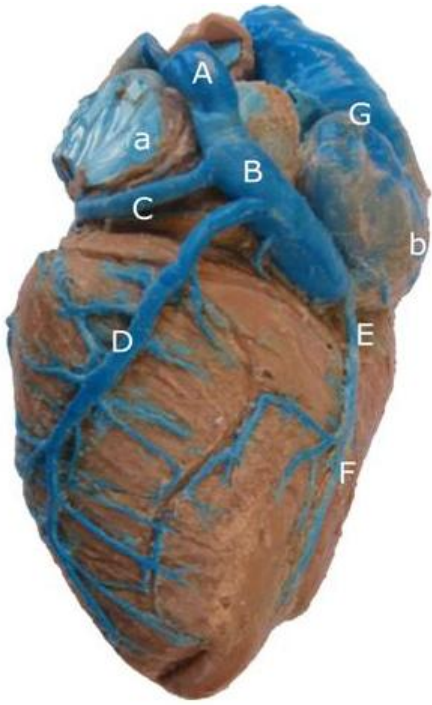


Fig 6. The veins of the heart (caudal surface)

a: left atrium, **b:** right atrium, **A:** left azygos vein, **B:** coronary sinus, **C:** great cardiac vein, **D:** left marginal ventricular vein, **E:** middle cardiac vein, **F:** subsinuosal interventricular vein, **G:** caudal vena cava

Şekil 6. Kalbin venleri (facies caudalis)

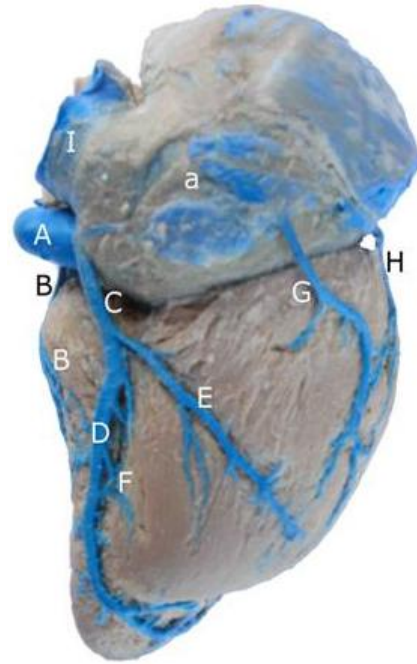


Fig 7. The veins of the heart (atrial surface)

a: right atrium, **A:** coronary sinus, **B:** left distal ventricular vein, **C:** middle cardiac vein, **D:** subsinuosal interventricular vein, **E:** right proximal collateral vein, **F:** right distal collateral vein, **G:** right distal ventricular vein, **H:** right marginal ventricular vein, **I:** caudal vena cava

Şekil 7. Kalbin venleri (facies atrialis)

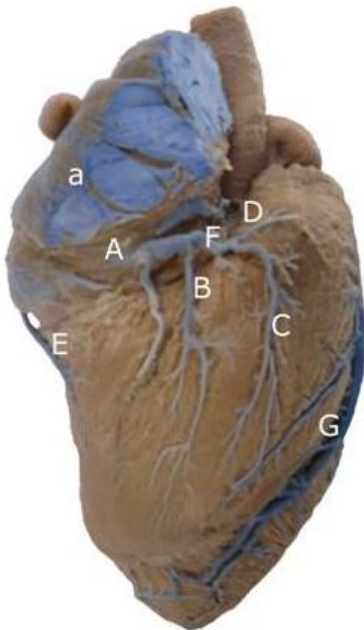


Fig 8. The right cardiac veins (atrial surface)

a: right atrium, **A:** right semicircumflex vein, **B:** right marginal ventricular vein, **C:** right proximal ventricular vein, **D:** right conal vein, **E:** right distal ventricular vein, **F:** a trunk, **G:** paraconal interventricular vein

Şekil 8. Vv. cordis dextrae (facies atrialis)

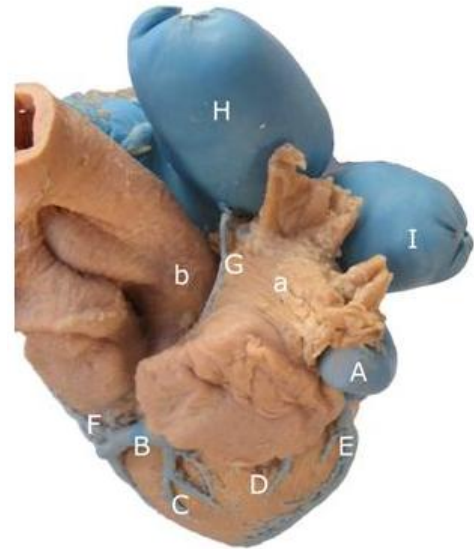


Fig 9. The veins of the heart (auricular surface)

a: left atrium, **b:** aorta, **A:** left azygos vein, **B:** great cardiac vein, **C:** the vein joining the drainage of the left ventricle, like the angular vein in the cat and horse, **D:** left proximal ventricular vein, **E:** left marginal ventricular vein, **F:** left conal vein, **G:** the vein joining the drainage of the left atrium near the aortic arch, **H:** cranial vena cava, **I:** caudal vena cava

Şekil 9. Kalbin venleri (facies auricularis)

apex of the heart, lied on the caudal border, and terminated in the left circumflex vein. Its commencing branches united with the left proximal and left distal collateral veins, the left distal ventricular vein, and the subsinuosal interventricular vein. In one cadaver, it (*Fig. 6D*) opened directly into the coronary sinus.

The left distal ventricular vein originating from the middle one-third of the left ventricle anastomosed with the branches joining the formation of the subsinuosal interventricular vein. It drained the area between the left marginal ventricular vein and the subsinuosal interventricular vein. Yet, it was determined to open into the coronary sinus in five cadavers (*Figs 2, 3G, 7B*), and into the great cardiac vein in two cadavers (*Figs 1H, 5F*). The left distal ventricular vein was not formed in three hearts that were examined and the left marginal ventricular vein drained the area that was supposed to be drained by this vein.

Several very thin veins draining the left atrium, including the proximal, intermedius, and distal veins of the left atrium, joined the left circumflex vein. In one cadaver, venous blood of the left atrium (*Fig. 2J*) was determined to drain into the both left azygos vein and caudal vena cava by a vein dividing into the two subbranches. Besides, venous blood of the left atrium (*Fig. 9G*) near the aortic arch was displayed to empty into the cranial vena cava in two cadavers.

The middle cardiac vein, which is called the subsinuosal interventricular vein (*Figs 1J, 2, 3, 5I, 6F, 7D*) during the course in the subsinuosal interventricular groove, was formed by the branches stemming from the auricular surface of the apex of the heart. Originally, there were two strong branches. It also took the branches from the interventricular septum. Branches from originating both the right and left ventricles also joined this vein; of those the right proximal collateral vein (*Figs 3, 5J, 7E*) was highly thick, while the right distal collateral vein (*Figs 3, 5K, 7F*) was thinner.

The veins comprising the right cardiac veins were observed to be from different origins. The veins draining the right atrium were shown to be very thin. Those draining the right ventricle were stronger. The right marginal ventricular (*Figs 7H, 8B*), the right proximal ventricular (*Fig. 8C*) veins

and the right conal vein (*Fig. 8D*), all draining the right ventricle, united to form the right semi-circumflex vein (*Fig. 8A*). This vein, in turn, lied caudally in the coronary groove, and opened into the right atrium at the level of the right ventricular border. The right proximal ventricular vein formed a trunk (*Fig. 8F*) with the right conal vein before opening into the right semicircumflex vein. The right distal ventricular vein (*Figs 7G, 8E*), originating from the distal one-third of the right ventricle, advanced caudodorsally, anastomosed with the right marginal ventricular vein, and terminated directly in the right atrium.

The number of the minute cardiac veins observed grossly was higher in the right atrium and ventricle than in the left atrium and ventricle.

DISCUSSION

Reports have indicated that the venous cardiac veins including the great and middle cardiac veins terminate in the coronary sinus ^{1,5-7}. On the other hand, Hegazi ⁹ and May ¹⁰ have reported these vessels in sheep to drain directly into the right atrium. Our study has also found that these veins in the Tuj sheep drain into the coronary sinus. Besoluk and Tipirdamaz ¹ have observed that the left marginal ventricular vein in sheep terminates in the coronary sinus. Yadm and Gad ⁴ and Hegazi ⁹ have reported this vein in goat to be a branch of the great cardiac vein. Even though, Nickel et al.² have also said that the left marginal ventricular vein is a very thin vessel which opens into the last part of the coronary sinus, in our study we observed this vein to be a very thick vessel joining the great cardiac vein. However, the vessel in just one cadaver was determined to open directly into the coronary sinus.

In five cadavers, the veins collecting the venous blood of the area nearby the opening of the pulmonary veins into the left atrium were observed to terminate in the coronary sinus. Likewise, the left distal ventricular vein was also opened into the coronary sinus in five cadavers. So far, no such data have been reported on the sheep in the literature. Although, Besoluk and Tipirdamaz ¹ have suggested the coronary sinus to be the continuation of the left azygos vein, Yadm and Gad ⁴ and Ghoshal et al.⁶ have proposed it to be the cranial continuation of the great cardiac vein. Our

findings in this study have led us to think in parallel with Besoluk and Tipirdamaz ¹.

McKibben and Christensen ⁸ have reported that the great cardiac vein in sheep reaches as far as the proximal two-thirds of the paraconal interventricular groove. However, the great cardiac vein observed in our study advanced as far as the distal one-third of the paraconal interventricular groove. This report has also documented that the venous blood of the cranial one-third of the interventricular septum is usually drained either directly into the coronary sinus or into an anterior cardiac vein. Contrarily, our study revealed that the venous blood of the interventricular septum was emptied into either the paraconal or subsinuosal interventricular veins.

It is very interesting to mention hereby that the vein observed in our study, supposedly called v. angularis, is present in the cat and horse ², and as far as to our knowledge, no literature report has mentioned the presence of such a structure in small ruminants.

Tipirdamaz et al.³ have indicated that the distal one-third of the middle cardiac vein in sheep lies intramyocardially, while the proximal half is subepicardial. Our study revealed that the proximal two-thirds of the middle cardiac vein in two hearts coursed subepicardially, while distal one-third distended intramyocardially.

In our study, the venous blood of the left atrium was determined to drain both into the left azygos vein and caudal vena cava in one heart, and into the cranial vena cava in two hearts. No such findings have been reported so far in the literature.

The right cardiac veins with different numbers have been documented to drain either into the right atrium ^{1,3,4,6,9} or into the coronary sinus ⁷. We displayed that this vein opened directly into the right atrium. There was no such vein observed in this study opening directly into the coronary sinus as indicated by Dursun ⁷. Nickel et al.² have informed that the right semicircumflex vein is formed by the right proximal ventricular vein, the right conal vein and the right proximal atrial vein, and the right marginal ventricular vein drains directly into the right atrium. On the other hand, we documented in our study that the right semicircumflex vein was formed by the right

marginal ventricular vein, the right proximal ventricular vein and the right conal vein, and this vein drained into right atrium. Yet, the right distal ventricular vein opened directly into the right atrium. This was similar to that reported by Tipirdamaz et al.³ in sheep.

Studies ^{1,2} have reported different and contradictory cases on the presence of the minute cardiac veins. Yet, our study observed grossly that it was higher in number in the right atrium and ventricle as compared to the left atrium and ventricle.

Consequently, the coronary sinus was determined to be the continuation of the right azygos vein. Broad variation was observed among the veins draining the heart. The results obtained hereby will surely contribute to the anatomy of sheep, as well as to the clinical researches using the heart as a model and conducted on animals and human beings.

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