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The Anatomy of the Cardiac Veins in Storks (*Ciconia ciconia*)

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Summary

This study was carried out to describe the origin, course and ramifications of the cardiac veins in storks. For this purpose, coloured latex injection method was applied on heart of nine adult storks. The results indicate that venous drainage of the heart was provided by the *v. cardiaca sinistra*, the *v. cardiaca media*, the *vv. cardiaca dextrae* and the *vv. cardiaca minimae*. The coronary sinus was not found in all samples. The *v. cardiaca sinistra* and *v. cardiaca media* were opened into the *v. cava cranialis sinistra*. The *v. cardiaca sinistra* was the largest vein providing to venous drainage of heart which consisted of two main parts *pars interventricularis* and *v. cardiaca circumflexa sinistra*. The *v. cardiaca circumflexa sinistra* was collected to venous blood of the ventriculus sinister and atrium sinistrum by means of several vessels. One branch of the *v. cardiaca circumflexa sinistra* coming from ventriculus sinister was much larger than rest and drained big part of ventriculus sinister. The *v. cardiaca media* was a single vein. The *vv. cardiaca dextrae* were opened directly into the right atrium. The *vv. cardiaca minimae* were collected venous blood from the wall of atrium dextrum and interventricular septum and emptied into the right chambers of heart. The venous blood of the interventricular septum was collected by the *vv. septales* of *pars interventricularis* and *v. cardiaca media*. It was concluded that circulation of cardiac veins in stork closely resembles that of rodent and is unlike both fowl and ostrich patterns.

Keywords: Anatomy, Cardiac veins, Heart, Stork

Leyleklerde (*Ciconia ciconia*) Kalp Venlerinin Anatomisi

Özet

Bu çalışmada, leylekte koroner venlerin başlangıç, seyir ve dallanmaları incelendi. Bu amaçla dokuz adet yetişkin leyleğe renklendirilmiş latex verildi. Kalbin venöz drenajının *v. cardiaca sinistra*, *v. cardiaca media*, *vv. cardiaca dextrae* ve *vv. cardiaca minimae* tarafından sağlandığı tespit edildi. Sinus coronarius'un bulunmadığı belirlendi. *V. cardiaca sinistra* ve *v. cardiaca media*'nin *v. cava cranialis sinistra*'ya açıldığı görüldü. *V. cardiaca sinistra*'nın kalbin venöz kanını toplayan en güçlü ven olduğu tespit edildi. Bu damarın, *pars interventricularis* ve *v. cardiaca circumflexa sinistra* olarak iki bölümden oluştuğu görüldü. *V. cardiaca circumflexa sinistra*'nın bir çok damar aracılığı ile ventriculus sinister ve atrium sinistrum'un venöz kanını topladığı görüldü. Ventriculus sinister'den çıkan *v. cardiaca circumflexa sinistra*'nın bir dalının diğer dallardan güçlü olduğu ve ventriculus sinister'in büyük bir bölümünü drenajını sağladığı tespit edildi. *V. cardiaca media*'nin tek olarak şekillendiği belirlendi. *Vv. cardiaca dextrae*'nin doğrudan atrium dextrum'a açıldığı belirlendi. *V. cardiaca minimae*'nin atrium dextrum duvarı ve septum interventriculare'nin venöz kanını topladıkları ve kalbin sağ boşluklarına açıldığı görüldü. Septum interventriculare'nin drenajını *v. cardiaca media* ile *pars interventricularis*'in *vv. septales*'inin yaptığı tespit edildi. Sonuç olarak leyleğin koroner ven dolaşımı tavuk ve devekuşundan ziyade kemirgenlere daha çok benzediği görüldü.

Anahtar sözcükler: Anatomi, Kalp venleri, Kalp, Leylek

INTRODUCTION

The venous drainage of the heart is provided by the *v. cardiaca sinistra*, the *v. cardiaca media*, the *vv. cardiaca dextrae* and the *v. cardiaca minimae* in birds^[1,2]. The *v. cardiaca sinistra* of birds are formed by the *pars interventricularis* and the *pars basilaris*^[1-3]

The *pars interventricularis* is started near the apex of the heart and run in the paraconal interventricular groove. The *pars interventricularis* at the coronary groove border continues as the *pars basilaris*, which lies on the base of the heart, between the conus arteriosus and bulbus aortae



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and opened into right atrium^[1-4]. However, the *pars basilaris* is not found in some samples of fowl^[1].

Vena cardiaca circumflexa sinistra is begun by the fine superficial tributaries from the proximal part of the left aspect of the ventriculus sinister. Then, it runs in the coronary groove and opened into atrium dextrum^[1,3]. *V. cardiaca media* was begun just above the apex of the heart. After it was received many ventral and dorsal tributaries from the adjacent wall of the ventriculus sinister and ventriculus dexter, led to right atrium^[1-4]. *Vv. cardiaca dextrae* are consisted by veins draining the ventriculus dexter and led to the atrium dextrum. *Venae cardiaca minimae* are found constantly in the wall of atrium dextrum and the interventricular septum^[1].

Generally, the coronary sinus collecting of principal cardiac veins is a large blood vessel or dilation of right atrium^[5]. Although the coronary sinus is emphasized to exist in ostrich^[3,6], some authors state that domestic birds^[1,4] have not a coronary sinus.

Birds are the most diverse group of animals rather than mammals which are alive today^[7]. Although venous drainage of heart has been well documented in mammalian, there is no study about the venous drainage of bird's heart, except fowl (*Gallus domesticus*)^[1,8-10] and ostrich^[3]. Therefore, this study aimed to reveal the conformation and branching of the cardiac veins in stork (*Ciconia ciconia*) which is wild and a migrant bird.

MATERIAL and METHODS

Nine adult storks of both sexes and weighing between 2.5 and 3 kg were utilized for the study. The animals used in the study were obtained from Mustafa Kemal University and Adana Veterinary Control and Research Institute. Animals which were could not survive due to badly injured or suspected various diseases were used. All experimental procedures were approved by Adana Veterinary Control and Research Institute's Animal Experiments Local Ethics Committee (Approval no. 02.02.2012/15).

Coloured latex injection was applied in order to describe the coronary veins as suggested by literatures^[11,12].

Coelom of the storks were opened right just after death. The heart was removed from the coelom. Plastic catheters were inserted into the *v. cava caudalis*. All cardiac vessels and chambers were washed with 0.9% saline (NaCl). After, two *v. cava cranialis* were clamped. After then, blue (Setacolor TM, Cobalt blue, num. 20; PEBEO Cedex, France) colored latex (Rubber latex TM; MERCAN, Istanbul, Turkey) was injected into the *v. cava caudalis*. The hearts were then immersed in 10% formalin for 3 days. After solidification of latex solution, the cardiac veins were investigated macroscopically using a dissection microscope (Nikon SMZ-2T; Nikon Corp., Tokyo, Japan). Photographs were

taken digitally and stored on a personal computer. The vessels were measured with a digital caliper (DV892 calipers, Tecnotest corp., Germany) sensitivity of 0.1% mm.

Nomina Anatomica Avium^[2] was used for anatomical nomenclature.

RESULTS

The veins draining the heart of the stork were the *v. cardiaca sinistra*, the *v. cardiaca media*, the *vv. cordicae dextrae* and the *vv. cordicae minimae*. The coronary sinus was absent in all of the studied samples.

The *vena cardiaca sinistra* (Figs. 1,2/1): In all the samples, the *v. cardiaca sinistra* was the largest vein carrying the venous blood of the heart and emptied into the *v. cava cranialis sinistra*. During its course, the *v. cardiaca sinistra* was named as the *pars interventricularis* (Figs. 1,3/2) in the paraconal interventricular groove and the *v. cardiaca circumflexa sinistra* (Figs.1,2/3) in the coronary groove.

The *pars interventricularis* (Figs. 1,3/2): The *pars interventricularis* began at the level of the apex of the heart and anastomosed with the *v. cardiaca media* (Fig. 3/→) at the same level. The *pars interventricularis* was formed by the 5-6 *vv. ventriculares* (Fig. 1/4) coming from the ventriculus sinister and 4-5 *vv. ventriculares* (Fig. 1/5) from ventriculus dexter. The terminal branches of the *pars interventricularis* of *v. cardiaca sinistra* anastomosed with the branches of *vv. cordicae dextrae* (Fig. 3/→). Along its course, the *pars interventricularis* also received 6-7 small *vv. septales* (Fig. 1/6) from interventricular septum. A strong *v. septalis* draining the proximal half to a third of the interventricular septum was also joined the *pars interventricularis* in three samples. Just before continuing as *v. cardiaca circumflexa sinistra*, the *pars interventricularis* also received the *v. conalis* (Fig. 1/7) draining the left part of conus arteriosus and proximal portion of the ventriculus dexter. The terminal branches of *v. conalis* were found to anastomose with the *v. conalis* (Fig. 1/→) of *vv. cordicae dextrae* in the four of the investigated hearts.

The *vena cardiaca circumflexa sinistra* (Figs. 1,2/3): The *pars interventricularis* coursed in the coronary groove as the *v. cardiaca circumflexa sinistra*. It was entirely covered by the auricula sinistra. Along its course, the *v. cardiaca circumflexa sinistra* received 3-4 thin *vv. ventriculares* (Figs. 1,2/8) starting from the proximal part of the ventriculus sinister. In all hearts, it was noted that one of the *vv. ventriculares* coming from the ventriculus sinister was the most distinct one. In all samples, this vein (Figs. 1,2/9) started from the apex of the heart and flowed towards the base of the heart on the ventriculus sinister, parallel to the *v. cardiaca media*. Along its course, it collected several subbranches from the wall of ventriculus sinister. Its

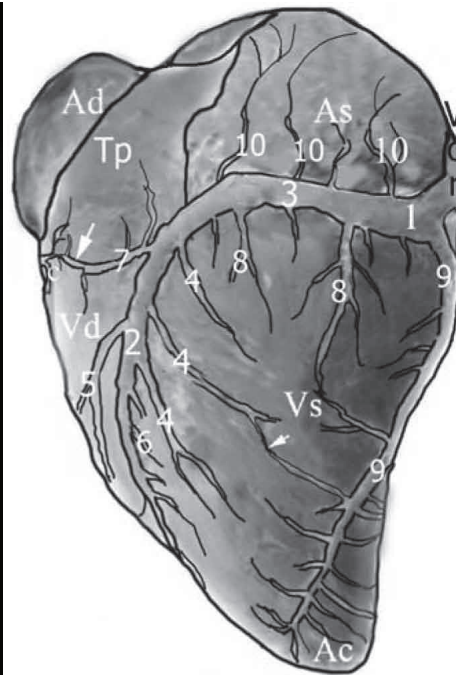
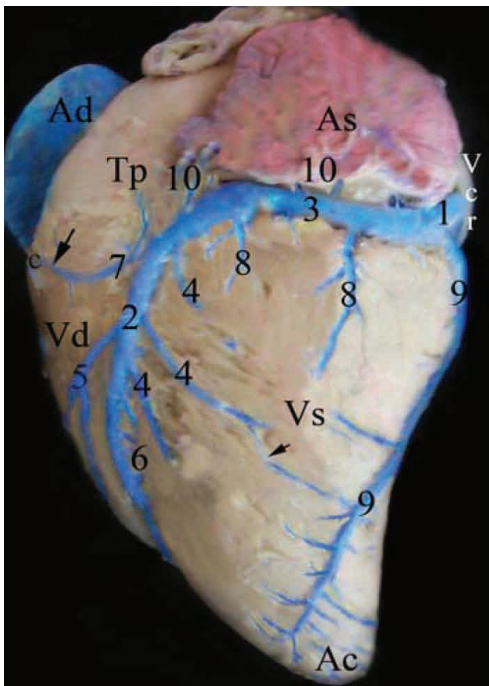


Fig 1. The *pars interventricularis*, the *v. cardiaca circumflexa sinistra* and their branches (cranial surface)

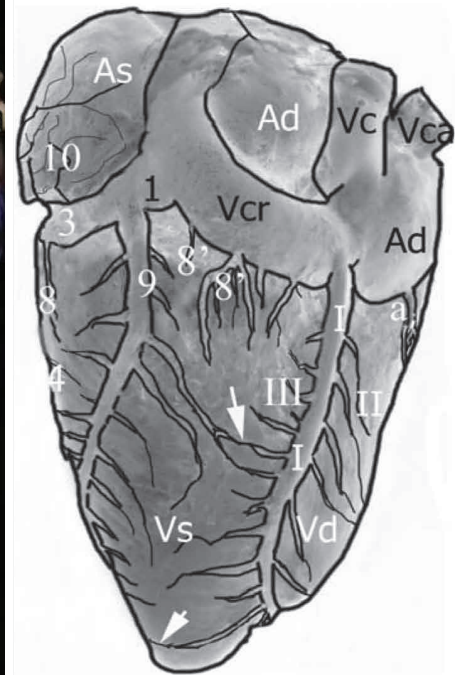
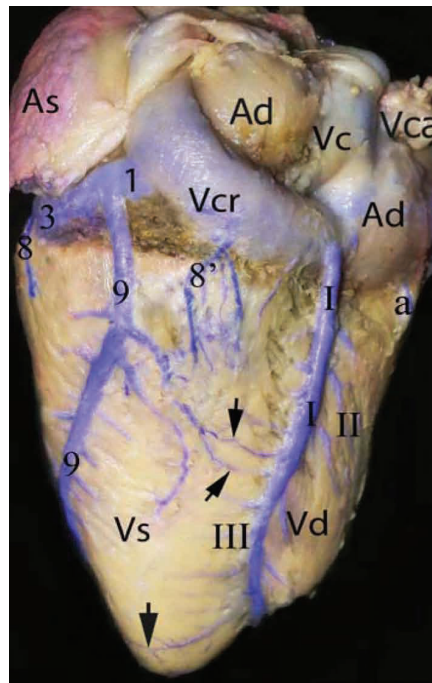
Şekil 1. *Pars interventricularis* ile *v. cardiaca circumflexa sinistra*'nin dalları (cranial yüz)

1: *v. cardiaca sinistra*, 2: *v. pars interventricularis*, 3: *v. cardiaca circumflexa sinistra*, 4-5: The *vv. ventriculares* of *pars interventricularis*, 6: The *vv. septales* of *pars interventricularis*, 7: The *v. conalis* of *pars interventricularis*, 8: The *vv. ventriculares* of *v. cardiaca circumflexa sinistra*, 9: The strong vein of *v. cardiaca circumflexa sinistra*, 10: The *vv. atriales* of *v. cardiaca circumflexa sinistra*, c: The *v. conalis* of *v. cardiaca circumflexa sinistra*, Tp: *truncus pulmonalis*, As: *atrium sinistrum*, Ad: *atrium dextrum*, Vd: *ventriculus dexter*, Vs: *ventriculus sinister*, AC: *apex cordis*, Vcr: *v. cava cranialis sinistra* and arrows: anastomose

Fig 2. The *v. cardiaca sinistra* and the *v. cardiaca media* and their branches (caudal surface)

Şekil 2. *V. cardiaca sinistra* ve *v. cardiaca media*'nin dalları (caudal yüz)

1: *v. cardiaca sinistra*, 3 *v. cardiaca circumflexa sinistra*, 8: The *vv. ventriculares* of *v. cardiaca circumflexa sinistra* 8': The *vv. ventriculares* of *v. cava cranialis sinistra*, 9: The strong vein of *v. cardiaca circumflexa sinistra*, 10: The *vv. atriales* of *v. cardiaca circumflexa sinistra*, I: *v. cardiaca media*, II,III: The *vv. ventriculares* of *v. cardiaca media*, a: The *vv. ventriculares* of *vv. cardiaca dextrae*, As: *atrium sinistrum*, Ad: *Atrium dextrum*, Vd: *ventriculus dexter*, Vs: *ventriculus sinister*, Vcr: *v. cava cranialis sinistra*, Vca: *v. cava cranialis dextra*, Vc: *v. cava caudalis* and arrows: anastomose



terminal branches were also seen to reach the papillary muscle in all samples. In one heart, it was also larger than the *v. cardiaca media*, according to its subbranches and diameter. Its branches also anastomosed with the *pars interventricularis* (Fig. 1/→) and *vv. ventriculares* of *v. cardiaca media* (Fig. 2/→). In five samples, 2 or 3 fine *vv. ventriculares* (Fig. 2/8') which were located on the proximal of *ventriculus sinister* were also seen to open directly into *v. cava cranialis sinistra*. The *v. cardiaca circumflexa sinistra* also received dorsally directed 5-6 thin *vv. atriales* (Figs. 1,2/10) from the wall of *atrium sinistrum*. The *v. cardiaca circumflexa sinistra* led into *v. cava cranialis sinistra*.

The *venae cardiaca media* (Fig. 1/I): The *v. cardiaca media* was formed by the branches stemming from the apex of the heart and ascending towards the base of the heart in the subsinuosal interventricular groove. It was opened into the *v. cava cranialis sinistra*. The *v. cardiaca media* was thinner than the *v. cardiaca sinistra* and a single vein. Six or seven *vv. ventriculares* (Fig. 3/II) from the *ventriculus dexter* and 5-7 *vv. ventriculares* (Fig. 2/III) from the *ventriculus sinister* joined to the *v. cardiaca media*. The *v. cardiaca media* was also carried to the *vv. septales* (Fig. 4/IV) from the interventricular septum. These *vv. septales* were smaller and fewer in number than those opening to the *pars interventricularis*.

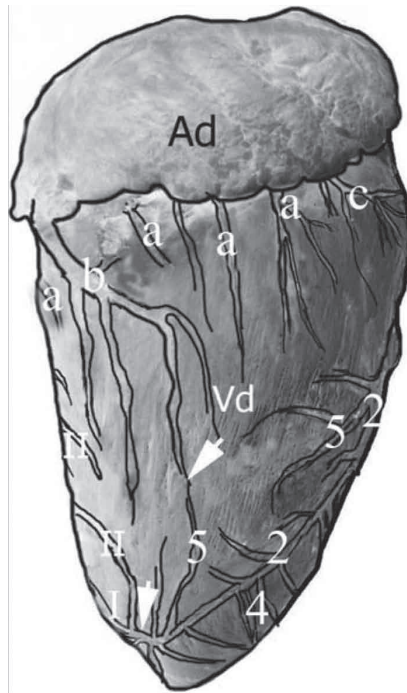
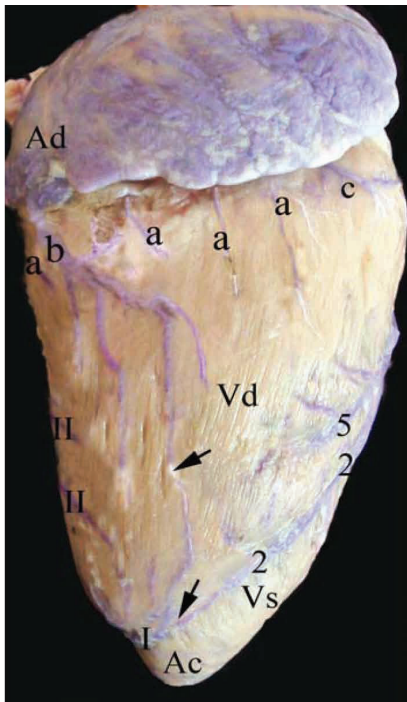


Fig 3. Vv. cardiacae dextrae (atrial surface)

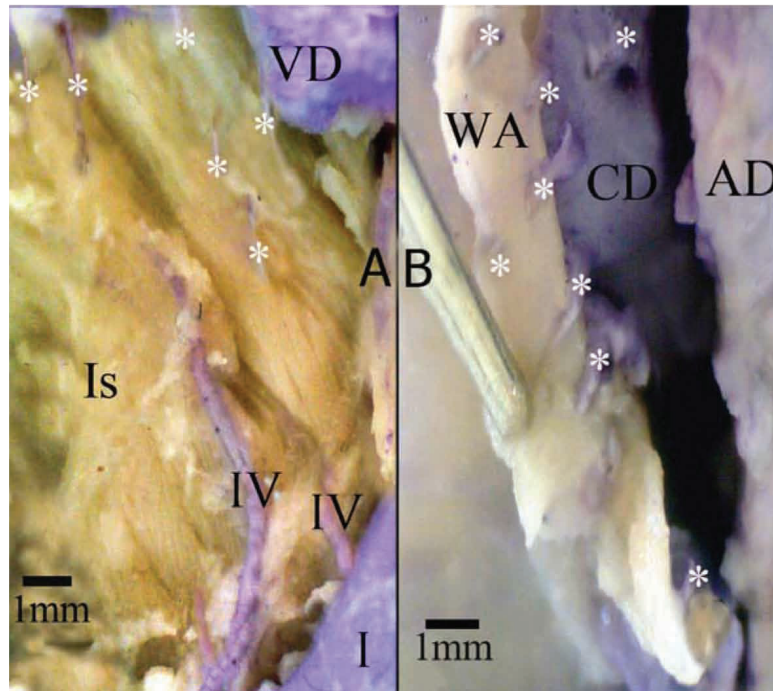
Şekil 3. Vv. cardiacae dextrae (atrial yüz)

I: v. cardiaca media, II: The vv. ventriculares of v. cardiaca media, a: The vv. ventriculares of vv. cardiacae dextrae, b: The strong vein of vv. cardiacae dextrae, c: v. conalis, 2: pars interventricularis, 5: The vv. ventriculares of pars interventricularis, Ad: Atrium dextrum, Vd: ventriculus dexter, AC: apex cordis and arrows: anastomose

Fig 4. The vv. septales and the vv. cardiacae minimae in the interventricular septum (A), The vv. cardiacae minimale on the wall of atrium dextrum (B)

Şekil 4. Septum interventriculares'te vv. septales ve vv. cardiacae minimae (A), Atrium dextrum duvarında vv. cardiacae minimae (B)

I: v. cardiaca media, IV: The vv. septales of v. cardiaca media, Is: interventricular septum, VD: The ventriculus dexter, CD: The cavity of atrium dextrum, AD: atrium dextrum, Aw: The wall of atrium dextrum and *: vv. cardiacae minimae



The venae cardiacae dextrae (Fig. 3/a,b,c): The vv. cardiacae dextrae consisted of 4-5 vv. ventriculares, v. conalis and 3-4 fine veins draining the right atrioventricular valve. The vv. ventriculares were joined to the vv. cardiacae dextrae at the distal border of the proximal third of the ventriculus sinister. After their origin, the vv. ventriculares run toward base of heart and emptied directly into right atrium (Fig. 3/a). In six specimens, one of vv. ventriculares was longer than the others. This vein (Fig. 3/b) originated from the 1/3 distal part of the ventriculus dexter and collected venous blood from the distal and middle part of wall of ventriculus

dexter. In addition to vv. ventriculares, another vessel involved in the formation of the vv. cardiacae dextrae was v. conalis. The v. conalis (Fig. 3/c) was formed by the thin branches stemming from the right part of conus arteriosus and the proximal portion of ventriculus dexter.

The venae cardiacae minimae (Fig. 4/*): The vv. cardiacae minimae were identified only on the right half of the heart. They seemed to play a role in the venous drainage of the interventricular septum and the wall of atrium dextrum. These veins were opened into the cavity of the

ventriculus dexter (Fig. 4-A/*) and the atrium dextrum (Fig. 4-B/*).

During their course, the *v. cardiaca circumflexa sinistra*, the *v. cardiaca media*, a thick subbranch of *v. cardiaca circumflexa sinistra* and the *pars interventricularis* were seen to course subepicardially. However, the thin branches of *v. cardiaca sinistra* and *v. cardiaca media* were situated intramyocardially. Although the *vv. ventriculares* of *vv. cardiaca dextrae* were located intramyocardially, the some thin branches belonging to *vv. cardiaca dextrae* were found subepicardially.

DISCUSSION

The *vena cava cranialis sinistra* is usually absent in carnivore, equine, ruminant [5]. However, this vein could be constant observed in birds [1-4], rat [13], beaver [14], mice [15], rabbit [12,16,17], marsupial [18]. In fowl, the *v. cava cranialis sinistra* is also termed the left precaval vein [1]. In the present study, the *v. cava cranialis sinistra* collected a great amount of venous blood of the heart, as reported in rabbits [12,16] beaver [14], mice [15] but does not correspond to the finding of Lindsay [1] who stated that the cardiac veins generally empty directly into the atrium dextrum in the fowl.

The coronary sinus is a tubular dilatation of the right atrium or it is the rudiment of the right sinus horn of the embryonic heart in some domestic animals [5,19] and humans [19]. Some researchers are reported that a great amount of venous blood is collected by coronary sinus, domestic animals [5,20], roe deer [21], porcupines [11] and human [19]. However, the coronary sinus was absent in stork, as observed in the domestic birds [1,4] and rat [13], beaver [14], mice [15], rabbit [12,16,17].

As indicated in the birds [1-3,22], the *v. cardiaca sinistra*, the *v. cardiaca media*, the *vv. cardiaca dextrae* and the *vv. cardiaca minimae* were identified in the stork heart.

In birds [1-3] *v. cardiaca sinistra* is constituted by two main veins, the *pars interventricularis* and the *pars basilaris*. In most fowl [1,22] and ostrich [3], after the *pars interventricularis* reaches to the junction of the paraconal interventricular groove and coronary groove, it advances caudally as the *pars basilaris* in the fat-filled space between the atrium sinistrum and truncus pulmonalis and aorta, and empties into the left recess of the atrium sinistrum. These arrangement and distribution are also reported in marsupial [21]. However, the *pars basilaris* was not found in our samples. The *pars interventricularis* was continued as the *v. cardiaca circumflexa sinistra* in coronary groove in all samples. Same finding is reported by Nickel et al. [5], Yoldas and Nur [12], Yadm and Gad [17], Aksoy et al. [20], Kabak and Onuk [21], Beşoluk and Tıpırdamaz [23] in mammalian and by Lindsay [1] and Kaupp [22] in some fowl.

The *pars interventricularis* of *v. cardiaca sinistra* is single vein that beginning at the level of the notch of cardiac apex in fowl [1]. This vein is a double vein in 13 percent of ostrich [3]. The one of them lies paraconal interventricular groove. The other one runs caudally to it on the wall of the ventriculus sinister. However, in the present study, the *pars interventricularis* was observed to be a single vein all samples. On the other hand, Lindsay [1] is reported that in 6 percent of fowl the *pars interventricularis* is not found.

In mammalian [5], two branches of paraconal interventricular vein is confirmed to be distributed to the wall of the ventriculus sinister that are called the left proximal collateral vein and the left distal collateral vein. In the investigated samples, there was not found the similar these veins. But, numerous fine branches of the *pars interventricularis* were observed instead of the two branches, as in birds [1,3], rabbit [12], beaver [14] and mice [15].

Along its course, *v. cardiaca circumflexa sinistra* collects multiple the *vv. atriales* and *vv. ventriculares* from the atrium sinistrum and ventriculus sinister as indicated by the literature [1-4,22], respectively. One of the most interesting findings of the present study was that a vein of *vv. ventriculares* which was stronger than the others was found in samples. We thought that this vein was the same as left marginal ventricular vein in mammalian [5,12,14,17,20,21,23], according to its course.

In fowl, the *v. cardiaca media* is a prominent venous channel, which independently enters into the atrium dextrum [1]. In our samples, it opened into the *v. cava cranialis sinistra* as reported in rabbit [12,16], beaver [14], marsupial [15]. In birds [1,3,4] the *v. cardiaca media* is the strongest vein of the cardiac veins. Moreover, Bezuidenhout [3] reported that the *v. cardiaca media* is as a double vein in ostrich. In this study, the *v. cardiaca media* was weaker than the *v. cardiaca sinistra* and a single vein. This situation is similar to finding for rabbit [12], beaver [14] and marsupial [15]. Furthermore, in birds [1,3,4], rabbit [12,16], beaver [14] and marsupial [15], along its course, it was collected fine branches from the both ventricles, as in stork

In birds, the *vv. cardiaca dextrae (ventrales)* are constituted with the *vv. atriales*, *vv. ventriculares* and *vv. conalis* [1-3]. These veins are formed to the *v. cardiaca circumflexa dextra* that drains directly into the atrium dextrum in birds [1,3]. In the present study, the *vv. cardiaca dextrae* were constituted of a few *vv. ventriculares* opened into atrium dextrum separately. Thus, the *v. cardiaca circumflexa dextra* was not formed in stork, as in some fowl [1], beavers [14], mice [15] rabbits [17], marsupial [18]. In six specimens, one of veins collecting venous blood of the ventriculus dexter was stronger than the others. This vein was similar to vessel named as the right marginal ventricular vein in mammalian [5,12,20,21,23]. This strong vein has been also reported in mice [15] and marsupial [18]

In many mammals ^[5,12,14-17,19-21,23], main cardiac veins which are the great cardiac vein, middle cardiac vein, right cardiac veins and their secondary branches are well-defined in terms of the course they follow and the place they drain and that are present in a regular and specialised way, though they may display some variations. Unlike the mammals, as reported in the resources on birds ^[1,3,4,22] as well as in our samples, the size, number, distribution and origins of these secondary branches were observed to differ from sample to sample. For this reason, the identification of the secondary branches, except for these two strong veins, were not undertaken in our samples.

The *venae cardiacae minimae* carrying venous blood from myocardium to the heart chambers opened into the atrium dextrum ^[12,16] or to all of the heart chambers in mammalian ^[5,18,20]. In our samples, these veins were found constantly in the atrium dextrum and the which is similar to the findings reported by literature ^[1,3,12,16].

The venous drainage of the interventricular septum was provided mostly by the *vv. septales* of both the *pars interventricularis* of *v. cardiaca sinistra* and the *v. cardiaca media* in birds ^[1,3]. Although the *vv. cardiacae minimae* were made a small contribution to the venous drainage of the interventricular septum by means of the few thin, the *vv. septales* were primarily responsible for septal drainage in stork, which was similar to the cases in the fowl¹ and mammalian ^[12,20].

In conclusion, the venous drainage of the heart was consisted of the *v. cardiaca sinistra*, the *v. cardiaca media*, the *vv. cardiacae dextrae* and the *vv. cardiacae minimae*. The *v. cardiaca sinistra* was the largest vessel that drained of the heart. The origin and course of *v. cardiaca sinistra* and the *v. cardiaca media* of stork basically resembled the great cardiac vein and middle cardiac vein of the mammalian, respectively. One of the most interesting finding of the present study was that the two strong veins found in all samples, called the left marginal ventricular vein and right marginal ventricular vein, especially present in the mammalian. Because *v. cardiaca circumflexa dextra* was absent, veins formed the *vv. cardiacae dextrae* opened into atrium dextrum separately. The *vv. cardiacae minimae* emptied into both the atrium dextrum and the ventriculus dexter. There was no the coronary sinus.

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