

The distribution of the cardiac veins in the New Zealand White rabbits (*Oryctolagus cuniculus*)

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Summary

In this investigation, 25 adult New Zealand White rabbits randomly selected from both sexes and studied. Coloured latex injection and corrosion cast methods were applied on the materials. This study was carried out to disclose the distribution of the cardiac veins of the New Zealand White rabbits. The veins that drain the heart were found to be the great cardiac vein, the middle cardiac vein, the right cardiac veins and the smallest cardiac veins. The great cardiac vein originated from the ventral aspect of the left cranial vena cava. The middle cardiac vein and the right circumflex vein had a common trunk (32% of cases) and opened into the left cranial vena cava. The right (small) cardiac veins emptied into the right atrium and left cranial vena cava in 4% and 96% of the cases, respectively. The septal veins were primarily responsible for the drainage of the interventricular septum. Also, a strong anastomosis was observed between the middle cardiac vein and the left marginal vein.

Key words: Rabbit, Anatomy, Cardiac veins

Introduction

The European rabbit, ancestor of the New Zealand White rabbit, was domesticated about 2000 years ago. Rabbits are used for their wool, fur, and meat. They are also important for the countries in which animal protein deficiency is seen (Inal, 1994). Moreover, New Zealand White rabbits have served as an important animal model for research in medical fields. For these reasons, it is anatomically and clinically important to bring out the differences and similarities between the New Zealand White rabbit and other animals.

The morphology of the cardiac veins has been well documented in human (Pakalska, 1974), rodentia (Walker and Homberger, 1998; Atalar *et al.*, 2004; Ciszek, 2007), rabbits' strains (Bahar *et al.*, 2007; Craigie, 1979; Yadm and Gad, 1992) and some of domestic mammals (Yadm and Gad, 1992; Piffer and Piffer, 1994; Yadm, 1993). Generally, the primary veins of the heart are the great cardiac vein, the middle cardiac vein, the right (small) cardiac veins and the

smallest cardiac veins. The great and middle cardiac veins terminate in the coronary sinus. The coronary sinus is located immediately ventral to the opening of the caudal vena cava, discharging the venous blood to the right atrium (Nickel *et al.*, 1981). Although the coronary sinus was emphasized to exist in rabbits (Craigie, 1979) and rodentia (Walker and Homberger, 1998; Atalar *et al.*, 2004), some authors stated that neither Lagomorpha (Yadm and Gad, 1992; Bahar *et al.*, 2007) nor rodent species (Bisailon, 1981) has a coronary sinus.

The great cardiac vein is the greatest vein of the heart. Generally, it opens into the coronary sinus area alone in pig (Pakalska, 1974; Nickel *et al.*, 1981). In donkey, the great cardiac vein and the middle cardiac vein form a common trunk which opens into the coronary sinus (Yadm, 1993). Middle cardiac vein is relatively short in donkey (Yadm, 1993) and beaver (Bisailon, 1981), but quite long in goat and rabbit (Yadm and Gad, 1992).

The right (small) cardiac veins draining

the right ventricle and open directly to the right atrium (Yadm and Gad, 1992) or into the coronary sinus (Craigie, 1979) in the rabbit.

The smallest cardiac veins consist of a number of minute veins which arise in the myocardium and empty into the cardiac cavity (Nickel *et al.*, 1981). The majority of these veins are presented in the right atria in dog (Esperança-Pina *et al.*, 1981) and Angora rabbits (Bahar *et al.*, 2007).

In addition to the great cardiac vein and the middle cardiac vein, the coronary sinus also gives rise to the oblique atrii sinistri vein which is characteristic of carnivores, horses (Nickel *et al.*, 1981) and human (Piffer *et al.*, 1990). This small vein draining the wall of the left atrium. In human cases, it empties into the great cardiac vein at the point where it becomes the coronary sinus (Harikrishnan *et al.*, 2005).

In the literature, few studies about cardiac veins of the breeds of rabbit are published (Yadm and Gad, 1992; Bahar *et al.*, 2007). Although New Zealand White rabbits (*Oryctolagus cuniculus*) are known as one of the oldest domesticated breeds of rabbit, there are no reports about the venous system of the heart of the New Zealand White rabbit. Therefore, this study aimed to reveal the conformation and branching of the cardiac veins in the New Zealand White rabbit macroscopically.

Materials and Methods

Preparation materials

25 adult healthy New Zealand White rabbits of both sexes, aged 1.5-2 years and weighing between 4 and 5 kg were used. All rabbits were obtained from Adana Veterinary Control and Research Institute, Adana, Turkey. The present study was performed according to the legislation of the Ethics Board of Adana Veterinary Control and Research Institute.

Animals were intravenously anaesthetized with 5 mg/kg of ketamine-HCl (Ketamidol™; RicherPharma AG, Wels, Austria) and 20 mg/kg propofol (Propofol™ amp.; Fresenius Kabi, Graz, Austria). Under anaesthesia, after heparin (Liquemine™ flk; Roche, Istanbul, Turkey) (300 IU/kg)

infusion to prevent clotting, they were killed by exsanguination from the left common carotid artery before they regained consciousness. Following a lateral thoracotomy, the heart was removed from the thoracic cavity. After plastic catheters were inserted into the caudal vena cava, the right cardiac veins and the left cardiac veins, all cardiac vessels and chambers were washed with 0.9% saline (NaCl). The Coloured latex and the Corrosion casting methods were used to describe the coronary veins.

Coloured latex

After two right cranial vena cava were clamped, Blue (Setacolor™, Cobalt blue, num. 20; PEBEO Cedex, France) coloured latex (Rubber latex™; MERCAN, Istanbul, Turkey) was injected into the caudal vena cava and the left cranial vena cava. The hearts were then immersed in 10% formalin for 3 days. After solidification of latex solution, the cardiac veins were investigated both macroscopically and using a dissection microscope (Nikon SMZ-2T; Nikon Corp., Tokyo, Japan).

Corrosion casting

Takilon (20% powder monomethylmethacrylate and 80% liquid polymethylmethacrylate) was injected into the left cranial vena cava and right cranial vena cava. The originally described corrosion cast method (Aycan and Bilge, 1984; Tadjalli and Moslemy, 2007) was applied to the materials. After takilon injection the materials were kept at room temperature for 24 h for polymerization. Then they were corrosion casted in 30% KOH at 60°C for 24-48 h and washed with tap water. Finally, the findings were recorded and photographed by Canon Powershot S2 IS. Anatomical nomenclature of the coronary vein was made in accordance with Nomina Anatomica Veterinaria (NAV) (2005) and previous reports.

Results

The coronary sinus was absent in all of the studied materials.

The great cardiac vein (*V. cordis magna*) (Figs. 1, 2, 3/1)

In all of the cases, it was the largest vein that drained the heart and opened into the left cranial vena cava which was consisted of two main parts, the left circumflex vein and the paraconal interventricular vein.

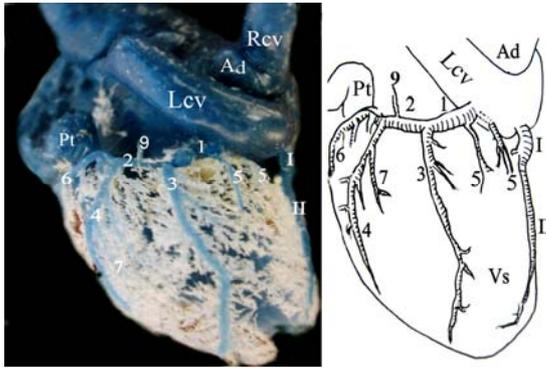


Fig. 1: Origin of the great cardiac vein, the middle cardiac vein and their branches (caudal surface), (cast). 1: The great cardiac vein, 2: The left circumflex vein, 3: The left marginal vein, 4: The paraconal interventricular vein, 5: The left distal ventricular vein, 6: The left conal vein, 7: The collateral veins, 9: The left proximal atrial vein, I: The middle cardiac vein, II: The subsinuosal interventricular vein, Pt: The pulmonary trunk, Lcv: The left cranial vena cava, Rcv: The right cranial vena cava, and Ad: The right auricle

The left circumflex vein (Figs. 1, 2, 3/2)

It was a big part of the great cardiac vein that extended through the coronary groove, covered by the left auricle. In this groove, its diameter was observed to decrease gradually from its opening toward the paraconal interventricular groove. Along its course, in addition to the small vessels from the wall of the left ventricle, the left circumflex vein also received the left proximal ventricular vein, the left marginal vein, the left proximal atrial vein and the left distal ventricular vein. Furthermore, it collected multiple branches from the left atrium (Fig. 2/9').

The left distal ventricular vein (Figs. 1, 2, 3/5)

There were two roots in 24 (96%) cases (Figs. 1, 3/5), and there also seemed to be a root in 1 (4%) of the cases (Fig. 2/5). These

branches were opened into the ventral surface of the wall of the left circumflex vein (Fig. 1/5). But, one of these two roots

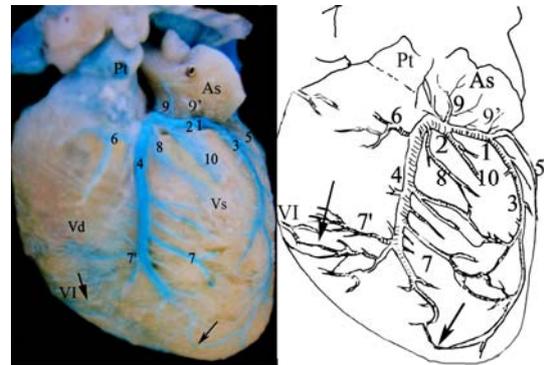


Fig. 2: The paraconal interventricular vein, the left circumflex vein and their branches (cranial surface), (Latex). 1: The great cardiac vein, 2: The left circumflex vein, 3: The left marginal vein, 4: The paraconal interventricular vein, 5: The left distal ventricular vein, 6: The left conal vein, 7-7': The collateral veins, 8: The vein joining the drainage of the left ventricle, like the angular vein in the cat, horse and donkey, 9: The left proximal atrial vein, 9': The atrial branches of the left circumflex vein, 10: The left proximal ventricular vein, VI: The right marginal vein, Pt: The pulmonary trunk, As: The left auricle, Vd: The right ventricle, Vs: The left ventricle, and black arrows: anastomose

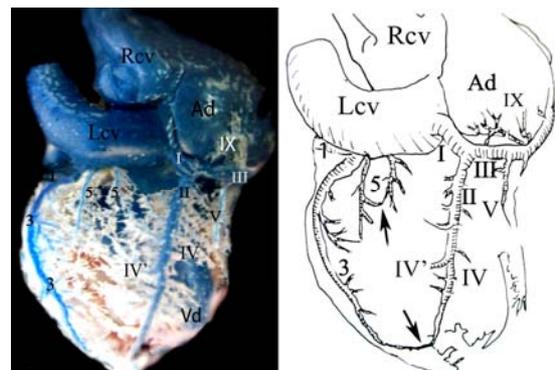


Fig. 3: Different origin of the middle cardiac vein (caudal surface) (cast). Lcv: The left cranial vena cava, Rcv: The right cranial vena cava, 1: The great cardiac vein, 3: The left marginal vein, 5: The left distal ventricular vein, I: The middle cardiac vein, II: The subsinuosal interventricular vein, III: Right circumflex vein, IV-IV': The collateral veins, V: The right distal ventricular vein, IX: The atrial branches of the right circumflex vein, Ad: The right auricle, Vd: The right ventricle, and black arrows: anastomose

emptied into the left cranial vena cava in the eleven cases (44%). Moreover, these veins were seen to open into the left cranial vena cava in a case (4%) (Fig. 3/5). After its origin, it ran towards the apex cordis, parallel to the subsinuosal interventricular groove, terminated the lower border of the proximal third of the heart.

The left marginal vein (*Ramus intermedius, V. marginis ventricularis sinistri*) (Figs. 1, 2, 3/3)

This vein opened into the left circumflex vein, and curved towards left ventricular border, extended along this border and ended near apex cordis. Along its course to apex cordis, it collected multiple branches from the wall of the left ventricle. Its terminal branches were seen to reach the subatrial papillary muscle in 17 (68%) samples. Moreover, its terminal branch collected blood from subauricular papillary muscle in 8 (32%) of the rabbits. Terminal branches of the left marginal vein were seen to anastomose with the collateral branches of the paraconal interventricular vein in 19 cases (76%) (Fig. 2/arrow). It was also observed that the terminal branches of the left marginal vein anastomosed with collateral branches of the interventricularis subsinuosal vein at distal third of the heart in 20 animals (80%).

The left proximal atrial vein (Figs. 1, 2/9)

It arose from the left circumflex vein. This branch was seen to terminate on the interatrial septum and auricula sinistra. It was also observed that the fine veins that collected the blood from the wall of the left atrium opened into the left circumflex vein (Fig. 2/9').

The left proximal ventricular vein (Fig. 1/10)

It open as the last branch into the left circumflex vein in 19 (76%) animals. It was absent in the others in which the related region was drained by the branches of the left marginal vein and the collateral branches of the paraconal interventricular vein. Moreover, a vein (Fig. 2/8) was seen to end within the angle where the paraconal

interventricular vein became the left circumflex vein in one (4%) of the cases. It was thought to be the equivalent of angular vein present in the cat, horse and donkey. It drained a part of the left ventricle between the left proximal ventricular veins and the paraconal interventricular vein.

The paraconal interventricular vein (Figs. 1, 2/4)

It was observed as a continuation of the great cardiac vein in the paraconal interventricular groove and ended near the apex cordis. Along its course, it gave off the left conal arterial vein, the septal veins and multiple fine branches to the right and left ventricle (1, 2/7, 7').

The left conal vein (Figs. 1, 2/6)

This vein arose from the cranial surface of the paraconal interventricular vein, divided into two branches after its origin, and then distributed on the conus arteriosus and proximal portion of the right ventricle. Its terminal branches were seen to anastomose with the right conal vein of the right (small) cardiac veins in 15 (60%) of the investigated hearts. Moreover, paraconal interventricular vein received few fine collateral branches from the right and left ventricles wall, cranially and caudally, respectively. In addition to the collateral veins, it also received few septal branches. These fine branches ended near the heart wall and interventricular septum.

The middle cardiac vein (*V. cordis media*) (Figs. 1, 3, 4/I)

This vein, also called the subsinuosal interventricular vein, opened into the left cranial vena cava. But, in one (4%) animal, it was observed to open into the caudal vena cava. In 8 (32%) of the investigated hearts, a common root was determined which was constituted by the middle cardiac vein and the right circumflex vein, which arose from the left cranial vena cava (Fig. 3/I). Just after its origin, the middle cardiac vein entered into the subsinuosal interventricular groove and reached to the apex cordis. Along its course, it was seen to give off 4-5 fine vessels to the right and left ventricle (Figs. 1, 3/IV, IV'). Moreover, it received the

septal branches. These branches were very fine and distributed in the interventricular septum.

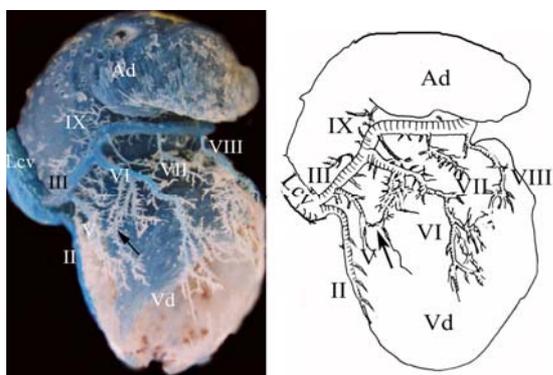


Fig. 4: Right cardiac veins (atrial surface) (cast). II: The subsinuosal interventricular vein, III: The right circumflex vein, V: The right distal ventricular vein, VI: The right marginal vein, VII: The right proximal ventricular vein, VIII: The right conal vein, IX: The atrial branches of the right circumflex vein, Lcv: The left cranial vena cava, Ad: The right auricle, Vd: The right ventricle, and black arrows: anastomose

The right (small) cardiac veins (*V. cordis parvae*) (Figs. 3, 4)

These veins consisted of the right circumflex vein, the right distal ventricular vein, the right marginal vein, the right proximal ventricular vein and the right conal vein. Moreover, it also gave off fine atrial branches (Fig. 4/IX).

The right circumflex vein (Figs. 3, 4/III)

It was seen that the right distal ventricular vein, the right marginal vein, the right proximal ventricular vein, the right conal vein and the fine atrial branches united to the right circumflex vein. This vein, in turn, lay caudally in the coronary groove, and opened into the left cranial vena cava in 24 rabbits (96%). But, the right circumflex vein was not found in one case (4%). In this heart, it was observed that these veins were directly opened into the right atrium.

The right distal ventricular vein (Figs. 3, 4/V)

It was the thinnest of the branches of the right cardiac vein. After its opening, it continued to the apex cordis obliquely and

terminated on the lower border of the distal third of the right ventricle. The right distal ventricular vein was observed to anastomose with the right marginal vein in 10 (40%) animals.

The right marginal vein (Fig. 4/VI)

It was larger than the other veins. It ran towards apex cordis on the right ventricle, parallel to right ventricular border. The main branches of the vein extended to the apex cordis. In 3 (12%) animals, it was detected that the terminal branch of this vein anastomosed with a fine branch of the right distal ventricular vein on the middle third of the heart (Fig. 4). In 10 (40%) cases, the terminal branches of right marginal vein anastomosed with collateral branches of the paraconal interventricular vein (Fig. 2).

The right proximal ventricular vein (Fig. 4/VII)

This vein originated from the right circumflex vein and terminated on the middle third of the right ventricle. In one case (4%), it was also determined that the common root was constituted by the right proximal ventricular vein and the right conal vein.

The right conal vein (Fig. 4/VIII)

It diverged from the terminal end of the right circumflex vein and extended towards conus arteriosus. Along its course, it also gave off 3-4 lateral branches and reached the lower border of the proximal third of the heart.

The smallest cardiac veins (*V. cordis minimae*)

These veins were determined only on the right half of the heart. These veins opened into the cavity of the right atrium as well as the right ventricle.

Discussion

In this study, the left cranial vena cava collected a great amount of venous blood of the heart and was also located ventral to the orifice of the caudal vena cava, as reported in rabbits (Yadm and Gad, 1992; Bahar *et al.*, 2007) and rodentia (Bisailon, 1981;

Walker and Homberger, 1998), which is not compatible with the finding of Atalar *et al.* (2004). They stated that the cardiac veins generally emptied into the caudal vena cava in the porcupine.

Coronary sinus presents in most domestic animals (Nickel *et al.*, 1981) and human (Pakalska, 1974; Maric *et al.*, 1996). However, our study also indicated that coronary sinus did not found in all cases, as observed in the breeds of rabbits (Yadm and Gad, 1992; Bahar *et al.*, 2007), beavers (Bisaillon, 1981) and donkeys (Yadm, 1993).

The great cardiac vein may open into coronary sinus (Pakalska, 1974; Nickel *et al.*, 1981; Besoluk and Tipirdamaz, 2001; Aksoy *et al.*, 2009), the right atrium (Yadm, 1993) or the caudal vena cava (Bisaillon, 1981). In this study, it opened into the left cranial vena cava as in other rabbits (Yadm and Gad, 1992; Bahar *et al.*, 2007).

The oblique atri sinistri vein (v. oblique atri sinistri) was found in horses (Nickel *et al.*, 1981), dog (Esperança-Pina *et al.*, 1981; Ghoshal *et al.*, 1975a) and human (Piffer *et al.*, 1990). But it did not exist in the our materials, as reported in ruminants (Ghoshal *et al.*, 1975c) and pigs (Ghoshal *et al.*, 1975d). We thought that the oblique atri sinistri vein is functionally the same with the vessels called left proximal atrial vein in Angora rabbits (Bahar *et al.*, 2007) and our cases.

In the investigated materials, the left marginal vein, differently from dogs (Maric *et al.*, 1996) in which it originated as two branches, started as a single root from the left circumflex vein, as it was in Angora rabbits (Bahar *et al.*, 2007). In 84% of cases, it was the strongest vein of the heart after the great cardiac vein and the middle cardiac vein and terminated at the apex cordis, the same as the finding of Dowd (1991).

One of the most interesting findings of the present study was that the vein found in 4% of cases, called the angular vein, is especially present in the cat (Nickel *et al.*, 1981), donkey (Yadm, 1993) and some sheep (Aksoy *et al.*, 2009). It was not mentioned in rabbits.

In horses, cattle (Nickel *et al.*, 1981), dogs (Esperança-Pina *et al.*, 1981), marsupial (Dowd, 1991) and donkeys

(Yadm, 1993) there were veins confirmed to be distributed to the wall of the left ventricle that are called the left proximal collateral vein and the left distal collateral vein. In the investigated materials, these veins were not found. But some fine branches of the paraconal interventricular vein was observed instead of the two branches.

The septal veins were detected to originate as multiple branches from the paraconal interventricular vein which has the same pattern as in goats (Yadm and Gad, 1992), rabbits (Yadm and Gad, 1992), dogs (Esperança-Pina *et al.*, 1981) and donkeys (Yadm, 1993).

The middle cardiac vein was found to originate from the right atrium in horses (Ghoshal *et al.*, 1975b), pigs (Pakalska, 1974; Ghoshal *et al.*, 1975c) and some dogs (Aycan and Bilge, 1984), while in our cases it was observed to open into the base of the left cranial vena cava as it was in Angora rabbit (Bahar *et al.*, 2007) and beaver (Bisaillon, 1981). Moreover, in one (4%) cases the middle cardiac vein started from the base of the caudal vena cava, which was the same pattern described by Yadm and Gad (1992) in rabbits.

The right cardiac veins have been documented to drain into the right atrium (Nickel *et al.*, 1981; Besoluk and Tipirdamaz, 2001; Aksoy *et al.*, 2009). The right cardiac veins united to compose the right circumflex vein and drained to the left cranial vena cava. This finding is supported by the findings in Angora rabbits (Bahar *et al.*, 2007), domestic animal (Nickel *et al.*, 1981) and sheep (Aksoy *et al.*, 2009). In 8 (32%) cases, the middle cardiac vein and the right circumflex vein formed a common root, opening into the left cranial vena cava. There was no such finding in the literature. In one case, the right cardiac veins were detected to open separately, as it was in goats, rabbits (Yadm and Gad, 1992), beavers (Bisaillon, 1981) and marsupial (Dowd, 1991).

In conclusion, the cardiac veins of New Zealand White rabbits basically resembled those of the human, horse, cattle, sheep and dog heart except that the great cardiac vein and middle cardiac vein opened into the left cranial vena cava rather than the coronary sinus. Although the anatomy of cardiac

veins in New Zealand White rabbits can not be completely transposed to human, the anatomical relationships between the heart and its vein system in the New Zealand White rabbits are very similar to human. So for the experiments include cardiologic procedures, utilization of New Zealand White rabbit can be suitable.

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