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RESEARCH ARTICLE

A macroanatomic investigation of the coronary arteries and myocardial bridges in Awassi sheep

Gürsoy Aksoy[1]*, Zekeriya Özüdoğru[2], Derviş Özdemir[3]

[1]Department of Anatomy, Faculty of Veterinary Medicine, Kafkas University, 36100, Kars, Turkey
[2]Department of Anatomy, Faculty of Veterinary Medicine, Aksaray University, 68100, Aksaray, Turkey
[3]Department of Anatomy, Faculty of Veterinary Medicine,
Atatürk University, 25100, Erzurum, Turkey
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*gursoyaksoy@gmail.com

İvesi koyununda koroner arterler ve kalp kas köprüleri üzerinde makroanatomik bir araştırma

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Öz

Amaç: Çalışmada, koroner arterlerin seyrini ve kalp kas köprülerinin lokalizasyonlarını ortaya koymak amaçlandı.

Gereç ve Yöntem: Her iki cinsiyetten 10 ergin İvesi koyunu kullanıldı. Materyallere renkli lateks enjeksiyon metodu uygulandı.

Bulgular: Subepicardial yağ dokusunun parakonal ve subsinuosal interventrikular olukların yaklaşık ortalarına kadar uzandığı belirlendi. Sağ ve sol koroner arterlerin kısmen intramyokardial seyrettiği görüldü. Dört koyun kalbinde sağ koroner arterin hemen sağ tarafında aorta'dan üçüncü bir koroner arterin orijinlendiği tespit edildi. R. proximalis atrii sinistri'nin 9 kalpte doğrudan a. coronaria sinistra'dan başlangıç aldığı görüldü. R. interventricularis paraconalis'in 2 kalpte sulcus interventricularis subsinuosus'un ortalarına kadar ilerlediği saptandı. R. distalis ventriculi sinistri'nin 1 materyalde şekillenmediği gözlendi. Myokardial köprülerin 8 kalpte parakonal interventrikular olukta, 2 kalpte hem parakonal interventrikular hem de subsinuosal interventrikular olukta lokalize olduğu belirlendi. Bu köprülerin 1 kalpte koroner olukta da sekillendiği tespit edildi. Myokardial köprülerin sağ koroner arter ve dalları üzerinde oluşmadığı görüldü.

Öneri: Bazı araştırıcılar, insan kalbinin koyun kalbine benzerliğini ileri sürmüşler ve koyun kalbinin insan kardiyovaskuler cerrahisinde bir model olarak kullanılabileceğini ifade etmişlerdir. Bu nedenle yapılan çalışma, konu üzerinde literatür bulunmayan hem İvesi koyununda kalbin tanınması hem de koyun kalbinin insan kardiyovaskuler cerrahisinde model olarak kullanılıp kullanılamayacağı konusunda bir fikir verebilir.

Anahtar kelimeler: Anatomi, kalp kas köprüsü, koronor arter, koyun.

Abstract

Aim: The purpose of the study was to reveal the course of coronary arteries and localization of myocardial bridges.

Materials and Methods: It was used 10 mature Awassi sheep of both sex. The color latex injection method was applied to the materials.

Results: The subepicardial adipose tissue was found to extend up to approximately the middle of the paraconal interventricular and subsinuosal interventricular grooves. Coronary arteries had partially an intramyocardial course. A third coronary artery sprang almost from the aorta on the right side of right coronary artery in 4 of the hearts. The left proximal atrial branch directly originated from the left coronary artery in 9 hearts. The paraconal interventricular branch coursed up to the middle of the subsinuosal interventricular groove in 2 hearts. The left distal ventricular branch was not formed in 1 heart. The myocardial bridges were observed at the beginning of the paraconal interventricular groove and on, both the paraconal interventricular and subsinuosal interventricular grooves in 8 and 2 hearts, respectively. In 1 heart, the myocardial bridge was also seen on the coronary groove. There was no myocardial bridge on the right coronary artery and its branches.

Conclusion: Some researchers have suggested the human heart's resemblance to the sheep heart and sheep heart can be used as a model in human cardiovascular surgeon. Therefore, the presented study can give an idea of both the identification of the heart in the Awassi sheep and whether sheep heart can be used as a model in human medicine.

Keywords: Anatomy, coronary artery, myocardial bridge, sheep.

Introduction

Awassi sheep, which originated from Mesopotamian region, are raised in Israel, North Africa and the Southeastern Anatolian region of Turkey. Their head, neck and feet are brown or black, and their bodies are covered with white-colored, rough-mixed wool. The males usually have horns, while the females are hornless. Their tails are oily and round, and they are 45-50 kg in weight (Akçapınar 2000).

The subepicardial fat tissue is located in the coronary, paraconal and subsinuosal interventricular grooves (Hadziselimovic et al 1974, Ghoshal 1975). The arteries responsible for the arterial vascularization of the heart are the left coronary artery and the right coronary artery (Hegazi 1958, Hadziselimovic et al 1974, Ghoshal 1975, Nickel et al 1981, Pasquini et al 2003). These arteries are situated either subepicardially (Bahar et al 2007) or intramyocardially (Hadziselimovic et al 1974). The left coronary artery reaching the coronary groove ramifies the paraconal interventricular branch and the left circumflex branch (May 1960, Bhargava and Beaver 1970, Collin 1975, Getty 1975, Akbulut et al 2014). Furthermore, the left coronary artery gives the branches vascularizing the left atrium and left ventricle (Bhargava and Beaver 1970, Getty 1975). The right coronary artery continues as right circumflex branch when it reaches the coronary groove. It separates into the main branches to right atrium and right ventricle. The left coronary artery is stronger than the right coronary artery in sheep and cattle (Hegazi 1958, Ghoshal 1975). In ruminant and dog, the left circumflex branch is referred to as the interventricular subsinuosal branch when it enters the interventricular subsinuosal groove (Getty 1975). The interventricular subsinuosal branch is composed of the left coronary artery or the right coronary artery in cats (Getty 1975, Aksoy and Karadağ 2002), and the right coronary artery in horses and pigs (Getty 1975). Studies have reported that myocardial bridges defined as a short segment of the superficial muscular band that runs across the coronary arteries (Yamaguchi et al 1996, Ozbag and Kervancioglu 2004). The myocardial bridge is situated on the paraconal interventricular branch in sheep and goat (Hadziselimovic et al 1974, Tıpırdamaz 1987), in Eastern Anatolian Red cattle (Karadağ and Soygüder 1989), dog (Tıpırdamaz et al 1996), roe deer (Frackowiak et al 2007) and Zavot cattle (Akbulut et al 2014). There are the myocardial bridges in dogs, sheep, goats and humans on the left coronary artery and the right coronary artery (Kervancıoğlu et al 2002). The myocardial bridge is located intermittently both the paraconal interventricular branch and the subsinuosal interventricular branch (Dursun et al 1992).

The heart of a sheep is considered as a model in cardiovascular surgery due to its close resemblance to the human heart (Shofti et al 2004), and today, it is used in various cardiovascular surgical interventions (Solem et al 2000). They can cause death due to various heart diseases and sudden cardiac insufficiency (Dursun 1992, Yamaguchi et al 1996, Agirbasli et al 1997, Ishii et al 1998, Amitani et al 2000). At the same time, there is hardly any study in the heart of this sheep. For these reasons, the aim of this study has been to reveal the macroanatomical features of coronary arteries and the locations of myocardial bridges in Awassi sheep.

Materials and Methods

In the study, the hearts of 10 adult Awassi sheep from both sex were used. Latex injection method (Aycan and Bilge 1984) was applied on the hearts. Materials were supplied from the sheep cut for consumption in the slaughterhouse of Erzurum province. Vessels were washed with 0.9% physiological saline. Color latex (ZPK-582-G, Educational & Scientific Products Ltd., West Sussex, UK) was injected via the aorta ascendens. Latex-applied hearts were left at room temperature for 72 hours in 10% formaldehyde solution for polymerization. Finally, the hearts were dissected and they were photographed. The Nomina Anatomica Veterinaria (2012) was used for terminology.

Results

The paraconal interventricular, subsinuosal interventricular and coronary grooves were observed to be covered with fat tissue. The fat tissue located in the paraconal and subsinuosal interventricular grooves extended to approximately the middle of these grooves. In 8 hearts, the myocardial bridges were situated in the paraconal interventricular groove (Figures 3a and 7a), while in 2 hearts the myocardial bridges were located in both the paraconal interventricular (Figure 9b) and the subsinuosal interventricular (Figures 2a and 4b) grooves. The myocardial bridges were set at the beginning of these grooves. In 1 specimen, the myocardial bridge was formed on the coronary groove on the left side (Figure 4a). But the myocardial bridge was absent on the right coronary artery and its branches. Both the left coronary artery and the right coronary artery were partially intramyocardial after their origins. The origin of the left coronary artery was more voluminous than the origin of the right coronary artery. It was concluded that this condition was due to the myocardial bridge on the first part of the paraconal interventricular branch.

The heart was supplied by the left coronary artery (Figures 1B, 3C, 7A and 9A) and the right coronary artery (Figure 1C). However, a third coronary artery (Figure 1D) originated immediately from the aorta on the right side of the right coronary artery in 4 hearts.

The left coronary artery divided into the left circumflex (Figures 2A, 4A, 6A, 8A, 3E, 7C and 9C) and the paraconal interventricular (Figures 2E, 6E, 3D, 5G, 7B and 9B) branches

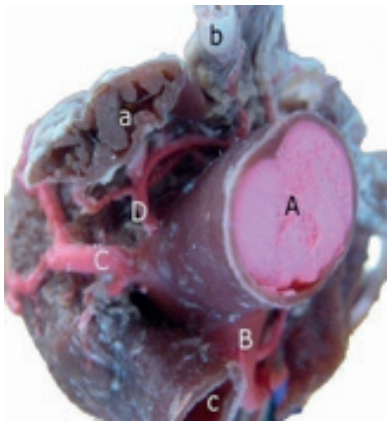

Figure 1. A third coronary artery stemming from the aorta.
A. Aorta, B. Left coronary artery, C. Right coronary artery, D. A third coronary artery, a. Right atrium, b. Left atrium, c. Pulmonary trunk

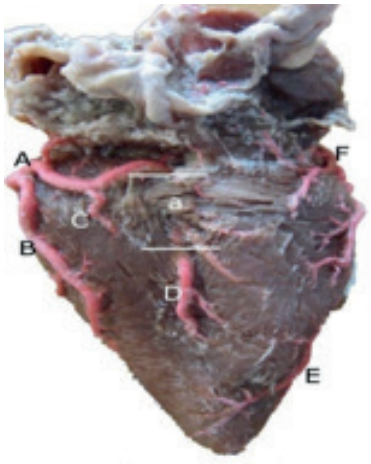

Figure 2. The myocardial bridge on the subsinuosal interventricular groove.
A. Left circumflex branch, B. Left marginal ventricular branch, C. Left distal ventricular branch, D. Subsinuosal interventricular branch, E. Paraconal interventricular branch, F. Right circumflex branch, a. Myocardial bridge on the subsinuosal interventricular groove

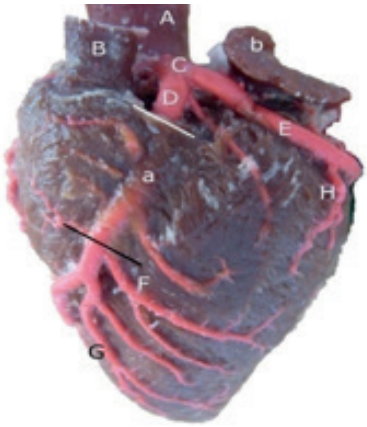

Figure 3. The left coronary artery and its branches, and the myocardial bridge on the paraconal interventricular groove.
A. Aorta, B. Pulmonary trunk, C. Left coronary artery, D. Paraconal interventricular branch, E. Left circumflex branch, F. Left proximal collateral branch, G. Left distal collateral branch, H. Left marginal ventricular branch, a. Myocardial bridge on the paraconal interventricular groove, b. Left atrium

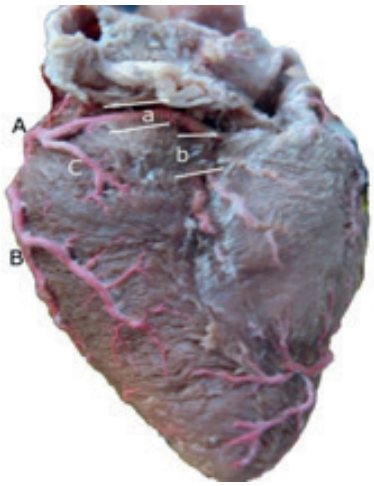

Figure 4. The myocardial bridges located at the atrial surface.
A. Left circumflex branch, B. Left marginal ventricular branch, C. Left distal ventricular branch, a. Myocardial bridge on the coronary groove, b. Myocardial bridge on the subsinuosal interventricular groove

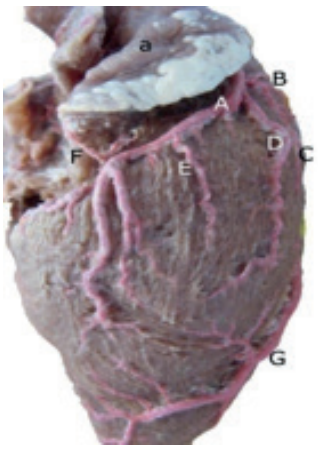

Figure 5. The branches of the right coronary artery.
A. Right circumflex branch, B. Pulmonary trunk, C. Right conal branch, D. Right proximal ventricular branch, E. Right marginal ventricular branch, F. Right distal atrial branch, G. Paraconal interventricular branch, a. right atrium

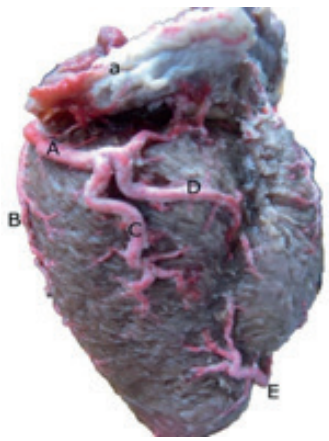

Figure 6. The left circumflex branch and subsinuosal interventricular branch.
A. Left circumflex branch, B. Left marginal ventricular branch, C. Left distal ventricular branch, D. Subsinuosal interventricular branch, E. Paraconal interventricular branch, a. Left atrium

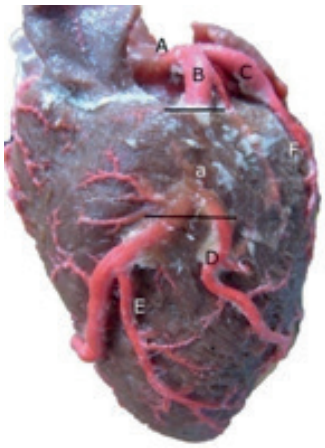

Figure 7. The left coronary artery and its branches, and the myocardial bridge on the paraconal interventricular groove.
A. Left coronary artery, B. Paraconal interventricular branch, C. Left circumflex branch, D. Left proximal collateral branch, E. Left distal collateral branch, F. Left proximal ventricular branch, a. Myocardial bridge on the paraconal interventricular groove

Figure 8. The branches emerging from the left circumflex branch.
A. Left circumflex branch, B. Left proximal ventricular branch, C. Left marginal ventricular branch, D. Left distal ventricular branch, a. Left atrium

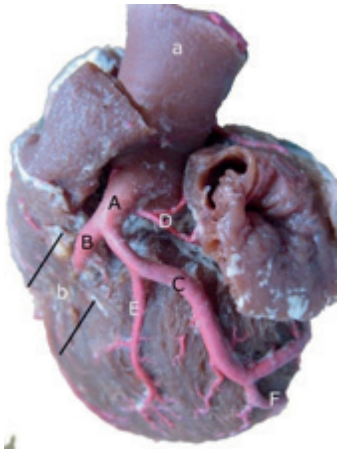

Figure 9. The origin of the left proximal atrial branch.
A. Left coronary artery, B. Paraconal interventricular branch, C. Left circumflex branch, D. Left proximal atrial branch, E. Left proximal ventricular branch, F. Left marginal ventricular branch, a. Aorta, b. Myocardial bridge on paraconal interventricular groove

when it reached the coronary groove. The left proximal atrial branch originated from the left coronary artery in 9 hearts (Figure 9D). Among the ventricular branches, the left marginal ventricular branch was the most voluminous (Figures 2B, 4B, 6B, 3H and 9F); however, this mentioned branch was weak in 1 heart (Figure 8C). There was no left distal ventricular branch in 1 specimen. After the left circumflex branch gave off the atrial and ventricular branches, it entered the subsinuosal interventricular groove and continued as the subsinuosal interventricular branch (Figures 2D and 6D) ending without reaching the apex of the heart.

The left proximal collateral branch originated from under the myocardial bridge in 5 hearts (Figure 7D) and, also immediately after the end of the myocardial bridge in 5 hearts (Figure 3F). The left conal branch emerged from under the myocardial bridge in all specimens. The paraconal interventricular branch coursed up to the apex of the heart. On the other hand, in 2 hearts the paraconal interventricular branch passed over the apex of the heart and ran until the middle of the subsinuosal interventricular groove (Figure 6E).

Stemming from the aorta, the right coronary artery moved on to the coronary groove. This vessel gave off the branches to the right atrium and right ventricle. The right coronary artery which is weaker than the left coronary artery was called as the right circumflex branch (Figure 5A) in the coronary groove, and it terminated without reaching the subsinuosal interventricular groove. A third coronary artery (Figure 1D) arose from the aorta on the immediate right side of the right coronary artery in 4 hearts. This artery coursed over the right atrium and ended at the base of the cranial vena cava.

Discussion

The coronary arteries have been reported to be located subepicardially in roe deer (Frackowiak et al 2007) and buffalo (Gupta and Bansal 2012). In the present study, the right and left coronary arteries, unlike those in roe deer and buffalo, were partially intramyocardial after their origins.
In the various studies that have been performed on this subject using different species of animal the myocardial bridge has been shown to be on the paraconal interventricular branch in Eastern Anatolian Red cattle (Karadağ and Soygüder 1989), in Zavot cattle (in 8 out of the 10 studied) (Akbulut et al 2014), in sheep and goat (Hadziselimovic et al 1974, Tıpırdamaz 1987), in roe deer (in 9 out of the 21 studied) (Frackowiak et al 2007), and in dog (Tıpırdamaz et al 1996). In this study, the myocardial bridge was showed on the paraconal interventricular branch in 8 hearts in agreement with the literature.

Kervancıoğlu et al (2002) reported that 90.4% of myocardial

bridges were found in dogs, 67.6% in sheep, 66.6% in goats, 76.9% in humans on the left coronary artery; 32.3% in sheep, 33.3% in goats, 23.1% in humans on the right coronary artery. In the study conducted by Akbulut et al (2014), myocardial bridges were observed on the subsinuosal interventricular branch, paraconal interventricular branch and right coronary artery in Zavot-breed cattle. Our findings showed that 80% of the myocardial bridges were on the paraconal interventricular branch, 20% on the subsinuosal interventricular branch, and 10% on the left circumflex branch, but the myocardial bridge was not found on the right coronary artery. The formation of the myocardial bridges on the left coronary artery is consistent with the results derived from the studies by Kervancıoğlu et al (2002) and Akbulut et al (2014). However, the absence of myocardial bridge on the right coronary artery conflicts with the findings from the reference.

Dursun et al (1992) noted that in one sheep, one goat and one dog, the myocardial bridge was intermittently both the paraconal interventricular branch and the subsinuosal interventricular branch. In our study, the myocardial bridge was not intermittently both the paraconal interventricular branch and subsinuosal interventricular branch.

Investigations have demonstrated that the vascularization of the heart was provided by the right and left coronary arteries (Nickel et al 1981, Aksoy and Karadağ 2002, Doğruer and Özmen 2012, Akbulut et al 2014). Observations in the present study support these findings. In our study, the left coronary artery was dominant as in the calves (Bhargava and Beaver 1970, Karadağ and Soygüder 1989), goats (Chakravarthy and Sastry 1979, Lipovetsky et al 1983, Tıpırdamaz 1987, Yang et al 1989), dogs (Dursun 1979, Tıpırdamaz et al 1996), sheep (Tıpırdamaz 1987, Doğruer and Özmen 2012), deer (Frackowiak et al 2007) and humans (Acer et al 2009). In buffalo, however, the right coronary artery has been stated to be strong (Tecirlioğlu et al 1977, Karami et al 2008). Our findings, therefore, are not in agreement with those from the studies.

In one study (Doğruer and Özmen 2012), the left proximal atrial branch was reported to originate from the left coronary artery in 9, the left circumflex branch in 4, and the angle between the left coronary artery and the left circumflex branch in 1 of 14 Kıvırcık sheep. It has also been reported that the left proximal atrial branch can be separated from the left coronary artery in buffalo (Tecirlioğlu et al 1977). Moreover, several studies (Bisaillon 1981, Tıpırdamaz 1987, Karadağ and Soygüder 1989, Tıpırdamaz et al 1996) have noted that this vessel sprang from the left circumflex branch. Similar to certain studies from the literature (Tecirlioğlu et al 1977, Doğruer and Özmen 2012), in our study, it was found that the left proximal atrial branch arose either from the left coronary artery or the left circumflex branch.

The left marginal ventricular branch was determined to have the largest volume of ventricular branches in our study. This finding is consistent with the report on rabbits of Aksoy and Karadağ (2002) but in disagreement with the finding on cattle of Karadağ and Soygüder (1989).
As the studies (Karadağ and Soygüder 1989, Vladova 2005, Doğruer and Özmen 2012) indicate, the continuation of the left circumflex branch has been seen to form the subsinuosal interventricular branch in present study.

The paraconal interventricular branch has been stated to reach the atrial surface in cattle (Bhargava and Beaver 1970, Karadağ and Soygüder 1989). However, it has been reported that this branch reached the atrial surface in 4 of the 14 Kıvırcık sheep (Doğruer and Özmen 2012). It has been expressed that the vessel ended at the apex of the heart in cats (Aksoy and Karadağ 2002), and 48.7% of indigenous Iranian cats while it ended without reaching the apex of the heart in 6.5% of cats, and crossed the apex of the heart in 44.8% of the remaining (Monfared et al 2013). According to Tıpırdamaz et al (1996) the above-mentioned branch coursed on the auricular surface of the heart in dogs. Our work revealed that the paraconal interventricular branch ran on the auricular surface, just as Kıvırcık sheep (Doğruer and Özmen 2012), cats (Aksoy and Karadağ 2002), native Iranian cats (Monfared et al 2013) and dogs (Tıpırdamaz et al 1996), and reached atrial surface in 2 of Awassi sheep, which is also in agreement with the literature (Tecirlioğlu et al 1977, Karadağ and Soygüder 1989, Doğruer and Özmen 2012, Monfared et al 2013).

In our study, 4 of the investigated hearts were found to have a third coronary artery arising from the aorta on the right side of the right coronary artery. This vessel advanced over the right atrium, and ended where the cranial vena cava opened into the right atrium. To date, no such finding has been reported in the literature in sheep.

Conclusion

The origins and courses of coronary arteries and the myocardial bridges on coronary arteries were determined in Awassi sheep. The fat tissue was seen in the coronary, paraconal and subsinuosal interventricular grooves. Both the coronary arteries were partially intramyocardial. There was a third coronary artery in the 4 of 10 sheep hearts. The left proximal atrial branch directly sprang from the left coronary artery in 9 hearts. The left distal ventricular branch was not present in 1 heart. The myocardial bridges were seen on the left coronary artery. But there was no myocardial bridge on the right coronary artery. To the best of our knowledge, there are currently no references on the coronary arteries and myocardial bridges in Awassi sheep. Furthermore, it has been suggested the sheep heart's resemblance to the human heart and the sheep heart's can be used as a model

in human cardiovascular surgeon. It is therefore believed that this research will contribute to the body of literature on anatomical studies related to this subject.

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