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Work in progress report - Coronary

The sinus node artery: anatomic investigations based on injection-corrosion of 60 sheep hearts

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Abstract

The purpose of this study was to investigate the sinus node artery in the sheep heart to establish adequate baseline information for use in cardiovascular research, and to compare this information with similar data for man. The coronary arteries were exposed by using injection-corrosion casting technique in 60 sheep hearts. Polyester and diluted sulfuric acid were used. When the corrosion was completed, the specimens were photographed. The sinus node artery was single in 59 specimens, and double in one specimen. The artery originated from the right coronary artery (in 42 specimens), left coronary artery (in 16 specimens), and right aortic sinus (in 1 specimen). In the majority of specimens, sinus node artery corresponded to the right superior (anterior) atrial artery. Pericaval termination was common. Mean measurements about the sinus node artery were tabulated. According to the present study, we can state that the sinus node artery in sheep heart is similar to that of humans. Because of the importance of animal research, we suggest that experimental surgical studies of the sinus node artery should be performed on the sheep heart.
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Keywords: Sheep heart; Sinus node artery; Atrial artery; Cardiovascular research

1. Introduction

The abundant arterial supply to the sinus node must in some way be related to its function. In a teleological sense, one might speculate that pace-making is a highly critical function that needs an excellent blood supply in all circumstances. It is also possible that the metabolic requirements of pace-making cells are higher than those of the surrounding myocardium [1]. From the results of Alboni et al., pathogenesis of sick sinus syndrome (SSS) is related to disease of the sinus node artery (SNA) [2].

Sinus node dysfunction is frequent in patients who have undergone cardiosurgical procedures, which involve a manipulation of atrial walls. This is especially true in the case of the superior transseptal approach to the mitral valve where the superior posterior border of the interatrial septum is divided [3].

Because of the importance of the SNA, we investigated this artery in sheep to establish adequate baseline information for use in cardiovascular research.

2. Material and method

We used 60 normal sheep hearts obtained fresh at the slaughterhouse. The hearts placed in a solution of sodium chloride (0.09%) and sodium citrate (3.8%). To show the coronary arteries and their small branches, we used the injection-corrosion casting technique. For this method, polyester ingredient consisting of polyester (10 ml), catalyst (0.5 ml) and accelerator (0.5 ml), and diluted sulphuric acid (40%) were used. The aorta was cut 2 cm above the orifices of the coronary arteries. To determine the location of the sinus node after corrosion, a steel wire was placed between the orifice of the aorta and the base of the superior vena cava (the superior atriocaval junction). A polyethylene cannulae was tied in to the right and left coronary arteries at their origins. The polyester ingredient was placed in a bottle and

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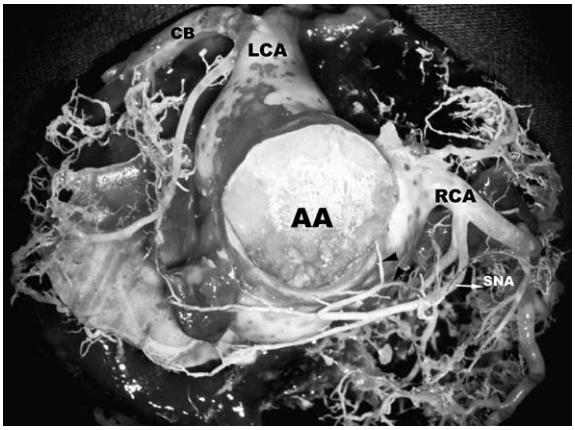


Fig. 1. The sinus node artery originating from the right coronary artery. AA, ascending aorta; SNA, sinus node artery; RCA, right coronary artery; LCA, left coronary artery; CB, circumflex branch. Black arrowheads demonstrate pericaval termination.

mixed with a glass rod for 20 s. The working life of the solution is about 7 min. This is enough time for it to pass through the arteries. The solution was injected into each coronary artery at pressure starting with 100 mmHg. But the pressure was increased over the last 2 or 3 min of the working life of the solution to a maximum of 150–200 mmHg. The hearts were hung from their base about 4–6 h for whole solidification of the polyester, and carefully put in diluted sulphuric acid for 24–48 h. When the corrosion was completed, the specimen was gently washed under cold tap water until all remnant tissue has been removed. They were then dried at room temperature, and photographed. Measurements were performed with a Vernier caliper.

3. Results

Sixty specimens were studied, and established as having the following coronary dominance: left dominance 54 specimens (90%), right dominance 1 specimen (1.7%), balanced system 5 specimens (8.3%).

3.1. Number

A single SNA was observed in 59 specimens (98.3%) and two in one specimen (1.7%) in which the SNA arose separately from the right coronary artery (RCA) and left coronary artery (LCA).

3.2. Origin

When the SNA was solitary and arose from the RCA (in 42 specimens), it corresponded to the right superior (anterior) atrial artery (Fig. 1). When the SNA was single and originated from the LCA (in 16 specimens), it corresponded to the left superior (anterior) atrial artery (Fig. 2). The left SNA branched off either from the trunk of the LCA (in 10 specimens) or circumflex branch (CB, in 6 specimens). In all 16 cases, the artery crossed the interatrial septum (Fig. 2). There were two sinus node arteries originating separately from the RCA and the CB in one specimen (Fig. 3). In one specimen, the SNA corresponding to the right superior (anterior) atrial artery arose directly from the right aortic sinus (Fig. 3).

In this study, we have not observed a SNA corresponding to the lateral or inferior (posterior) atrial artery. But in one specimen the SNA, corresponding to the right superior (anterior) atrial artery, connected to the right lateral atrial artery.

3.3. Mode of termination

The SNA originating from the right side, when solitary, terminated pericavally (in 40 specimens) and precavally (in 2 specimens). When it was double, both sinus node arteries anastomosed in front of the base of superior vena cava. The SNA originating from the trunk of the LCA terminated pericavally in nine specimens and precavally in one specimen. When the artery originated from the CB, mode

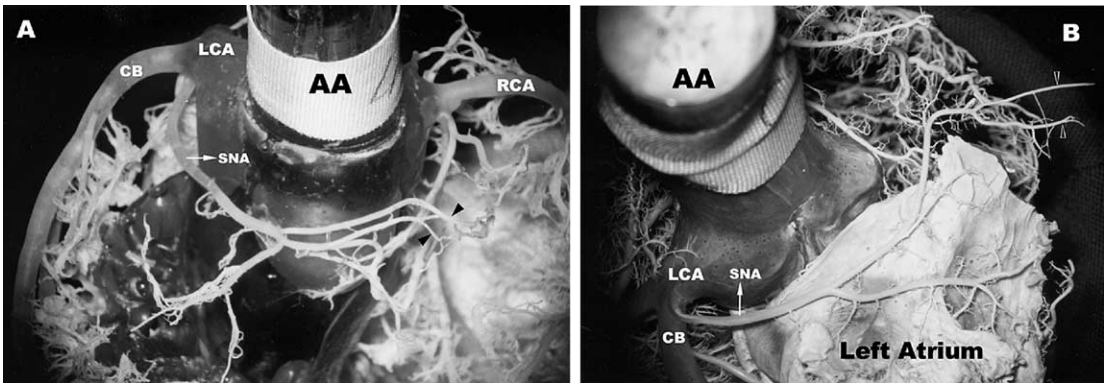


Fig. 2. The sinus node artery originating from the trunk of the LCA (A) or CB (B). AA, ascending aorta; SNA, sinus node artery; RCA, right coronary artery; LCA, left coronary artery; CB, circumflex branch. Black arrowheads demonstrate pericaval termination.

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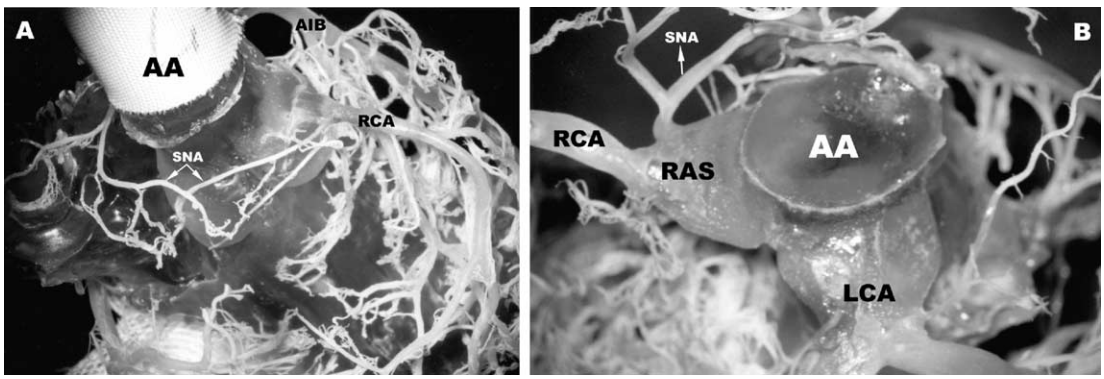


Fig. 3. In one of two cases, the sinus node artery originated from the both coronary arteries (A), and in another one, it originated directly from the right aortic sinus (B). AA, ascending aorta; SNA, sinus node artery; RCA, right coronary artery; AIB, anterior interventricular branch; RAS, right aortic sinus; LCA, left coronary artery.

Table 1
Mean measurements of the sinus node artery

	Origin of the sinus node artery					
	RCA		LCA		CB	
D (mm)	3.25 ± 1.72		2.26 ± 0.99		5.06 ± 1.44	
R (mm)	1.13 ± 0.27		1.17 ± 0.20		1.15 ± 0.14	
	Right	Left	Right	Left	Right	Left
$R_{pericaval}$ (mm)	0.57 ± 0.07	0.54 ± 0.09	0.53 ± 0.15	0.54 ± 0.16	0.56 ± 0.05	0.48 ± 0.03
$R_{precaval}$ (mm)	0.50 ± 0.00		0.55 ± 0.00		0.63 ± 0.11	

RCA, right coronary artery; LCA, left coronary artery; CB, circumflex branch; D, mean distance between origin of the sinus node artery and the ostium of the coronary artery; R, mean diameter of the sinus node artery; $R_{pericaval}$, mean diameters of the right and left terminal branches of the sinus node artery terminating pericavally; $R_{precaval}$, mean diameter of the terminal branch of the sinus node artery terminating precavally.

of termination was pericaval in four specimens and precaval in two specimens. In one specimen, the SNA, arising from the right aortic sinus, terminated pericavally. We have not encountered retrocaval termination.

3.4. Measurements

Mean measurements (mean ± SD) are demonstrated in Table 1. Distance between the origin of the SNA and the ostium of the coronary arteries was variable. Average distances were 3.25 ± 1.72 mm (from the right coronary ostium), 2.26 ± 0.99 mm (from the left coronary ostium) and 5.06 ± 1.44 mm (from the origin of CB). Mean calibers of the SNA at the origin were 1.13 ± 0.27 mm (RCA), 1.17 ± 0.20 mm (LCA), and 1.15 ± 0.14 mm (CB). Mean diameter of the right terminal branch was larger than the left terminal branch in RCA and CB originated specimens. In the LCA originated specimens, the left terminal branch was larger than the right terminal branch.

4. Discussion

The nature of the blood supply to the sinus node influences the clinical expression of sinus node ischemia and related diseases. The relation between SSS and coronary artery disease is controversial. Most reports of SSS include a large percentage of patients with coronary artery disease. Results of Alboni et al. showed for the first time in the clinical setting a role for the SNA disease in the pathogenesis of SSS in a selected group of their patients [2]. In two previous studies, the electrophysiologic measures of sinus node were correlated with the severity of SNA disease, but in subjects with normal sinus rate and only in the basal state [4,5]. Engel et al. failed to demonstrate a correlation between the prolongation of corrected sinus node recovery time and the presence or the extent of atherosclerotic lesions proximal to the origin of the SNA [4]. In contrast, Jordan et al. demonstrated that sinoatrial conduction time is correlated with the site of atherosclerotic involvement of the SNA [5].

In addition, it is important to underline that during certain surgical procedures, the SNA might be damaged. The major complications in early postoperative days are sinus arrest, atrial fibrillation, flutter, and junctional rhythm. The rhythm disturbances in the early post-operative period are considered as reflecting the damage to the SNA [6].

The good exposure of the mitral valve and its subvalvular apparatus play a key role in the success of mitral valve

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surgery. In some patients with a small left atrium or deep chest, visualization of the mitral valve is difficult. To surmount the problem several alternative surgical techniques have been described such as the superior approach and various transseptal approaches. Morphologic data show that the superior posterior border of the interatrial septum is crossed before the SNA reached the sinus node. Therefore, damage to the sinus node blood supply becomes very probable during the superior transseptal approach to the mitral valve. Because of the importance of the SNA, mentioned above, many authors have investigated this artery in human or animals [7–9]. In this study, we aimed to investigate this artery in the sheep to establish adequate baseline information for use in cardiovascular research, and to compare this information with similar data for man.

In the majority of cases, the SNA was reported single in humans [8,10]. Vieweg [11] and Sow [9] reported a high incidence of duplication of the SNA (11 and 11.11%) whereas most authors reported frequencies varying from 1.4 to 7% [7,12,13]. In sheep, we observed that SNA was double in only one specimen (1.7%).

The predominance of right coronary origin confirms a generally accepted fact though the frequencies vary from author to author. Many of them reported that SNA originated from the RCA in about 60% of cases and from the CB in about 40% of cases [2,7,14]. None of them has mentioned a SNA arising directly from the trunk of the LCA although Bokeriya [8] and James [12] reported the SNA arose from the trunk of the LCA in 25.95 and 2.22%, respectively. In sheep, we observed that the SNA originated from the trunk of the LCA in 17% of specimens.

Many published reports showed that the SNA corresponded to the right or left superior (anterior) atrial arteries in humans [10,12,14]. The present study demonstrated that the SNA corresponded to either right or left superior (anterior) atrial artery (71.7 and 26.6%, respectively). Mean distance between the ostium of the coronary artery and origin of the SNA in sheep was shorter than in humans. Sow [9] reported that the distance described above was 16.79 ± 8.61 mm (in right-sided origin), or 17.50 ± 7.75 mm (in left sided origin) in human heart. In our specimens, the distance was measured 3.25 ± 1.72 or 5.06 ± 1.44 mm, respectively. Verhaeghe [1] reported that the diameter of the SNA in human heart was 1.10 mm (in right-sided origin) or 1.15 mm (in left-sided origin). In our study, those measurements were 1.13 mm in the right side or 1.17 mm in the left side. According to our results mentioned above, we can state that the diameter and correspondence of the SNA were surprisingly similar to humans. Nevertheless, dominance and mean distance between the ostium of the coronary artery and origin of the SNA were rather different.

The anatomic features of the SNA are very important in cardiac surgery. Some regions at which there exist major risks of damaging or dividing the SNA are as follows: the base of the superior vena cava at the superior atriocaval junction, the anterior and lateral walls of the right or left atria, particularly opposite the proximal segments of the RCA and CB, the roof of the atria, the interatrial septum [9]. Detailed knowledge of the arterial supply of the sinus node will benefit clinical knowledge and surgical procedures and methods of cardiological examination and treatment. Proper precautions may be taken to preserve the main arterial supply to the sinus node during surgery.

In conclusion, our results showed that some features of the SNA were similar to man. Because of these similarities, we suggest that experimental cardiovascular surgical studies, particularly for superior transseptal approach to the mitral valve, should be performed on the sheep heart.

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Appendix A. ICVTS on-line discussion

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Date: 04-Jan-2004

Message: Thank you for the very interesting and illustrative study you did. I have few comments, Firstly, your results showed a left coronary dominance in 90%, balanced system in 8.3% and right dominance in 1.7%. I find this completely different with what I know and the results of Babalola et al., where the right system is dominant in 75%, left system is dominant in 15% and a balanced system in 10% [1].

I want to know if this is due to the performance of the study in sheep.

As regards to the origin of the sinus nodal artery, I like a lot your results but for illustrative purposes if we added the classification of Kovac's, GS 2004 who stated that in 66%, it originates from the right coronary artery (RCA); in 62% from the proximal (types A, B, and C); and in 4% from the distal portion (type D), in 34% the origin is from the left coronary artery (LCA) (type E) [2]. As regards the superior septal approach and its impact on the degree of transection of the sinus nodal artery, this classification is valuable as a prognostic indicator during the superior septal approach. This exposure gives a superb view, but the SNA is transected in 96% of the cases (types A, B, C, and E), remaining intact in only 4% (Type D). The reason why not all cases with transected SNAs develop dysrhythmias post-operatively may be due to the numerous anastomoses between surrounding atrial arteries and the arteriolar network of the sinus node. On the other hand, the SNA does not terminate in the sinus node in most cases but usually crosses it to give off nutrient branches and, coursing further, supplies larger areas of the right atrial wall. Thus proximal division of the SNA does not completely cut off blood supply from the distal stump; some flow may be available as a retrograde flow coming from distal anatomoses, which are increasing over time. Further development of these collaterals may be the explanation for the relatively quick sinus node arteries bearing any relationship to the incidence of different early postoperative dysrrhythmias or to late arrhythmic changes after several years following early recovery. Finally, arrhythmologists may wonder whether some "spontaneously" occurring rhythm disturbance, like sick sinus syndrome, or lone atrial fibrillation is related to any of these types [2].

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