The Atrial Coronary Arteries in Man

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An anatomic study of the atrial coronary arteries in 43 fresh normal human hearts is described. The implications of the findings are discussed for clinical problems facing the cardiologist and the cardiovascular surgeon.

The arterial supply of the atria has received little attention, and the anatomic descriptions available are conflicting. Textbooks of anatomy dismiss the arterial supply of the atria with a sentence stating that they receive arterial branches from the coronary artery of their respective sides.

Interest in atrial circulation increased slightly with discovery of the sinoatrial and atrioventricular nodes. The most significant studies in human hearts were those of Keith and Flack, Spalteholz, Crainiciu, and Gross. Several excellent studies of the blood supply to the canine cardiac atria have been reported in recent years; however, these observations fail to clarify the situation for man.

A knowledge of circulation in the atria is of importance, especially with respect to the normal cardiac pacemaker and atrial portion of the conduction system. The arterial circulation may influence the function of these structures, particularly as related to cardiac arrhythmias. Furthermore, recent interest in cardiac surgery makes detailed knowledge of the atrial anatomy of greater importance. To clarify some of the conflicting descriptions of the atrial coronary arteries 43 human hearts were studied.

Methods

All methods for studying the coronary arteries have shortcomings. Principally, 3 methods have been employed, any of which may be combined with classic dissection. The first consists of injection of the coronary vessels with colored opaque solutions, followed by dehydration of the specimen in alcohol and subsequent clearing with various oils. This procedure preserves the entire heart and permits a study of the relationships of the coronary vessels to the other structures. Unfortunately only the superficial coronary vessels are adequately displayed and the interatrial or interventricular septa are not shown.

The second method consists of injecting radiopaque substances into the coronary arteries and then obtaining planar and stereoscopic roentgenograms to reveal the arterial distribution. This was the method employed by Gross and Schlesinger and his colleagues. This type of examination provides a permanent record of vascular distribution while preserving the heart specimen for other studies such as the pathology. Examination of the intact heart by this method is confused by the crossing of depicted vessels, whereas preparations flattened ("unrolled") to avoid such overlapping distort the spatial orientation of cardiac structures.

The third method consists of injecting with a noncorroding substance and then digesting away the tissues. Many substances have been used for injection, the chief ones being celluloid, low-melting-point metals, and certain plastics. This method provides an exact spatially oriented replica of the coronary vascular system, with distribution of the right and left coronary arteries being demonstrated separately by means of differently colored injection material. Additional casting of the great vessels and the cardiac chambers can assist in displaying the relationship of the vascular and nonvascular structures. To make possible associated histologic examinations, Baroldi, Mantero, and Seomazzoni immersed their heart specimens in a 10 per cent formol bath after the plastic injection and obtained their sections of myocardium for microscopic study prior to corrosion.

After considering the various methods, we chose to use the injection and corrosion technic in our observations. Vinylite resin dissolved in acetone was used for injection and concentrated hydrochloric acid for corrosion, according to the method of Stern, Ranzenhofer and Liebow.

The hearts of 32 males and 11 females, ages 12 to 81 years, were examined. The age distribution was similar in each decade except that only one was in the eighth and one in the ninth decade. These subjects died of noncardiac diseases or accidents.

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Fig. 1. Ramus ostii cavae superioris arising from the right coronary artery and terminating by encircling the base of the superior vena cava.

Results

Arterial Supply of the Sinoatrial Node.
The largest artery to the human cardiac atria supplies the region near the superior vena cava and sinoatrial node. Gross\(^6\) named it the ramus ostii cavae superioris, regardless of its origin, while Spalteholz\(^4\) arbitrarily designated the atrial arteries as anterior, intermediate, and posterior, depending upon their origin. Crainicianu\(^5\) referred to this vessel as the Keith-Flack artery. Gross's term for this artery is specific and its use is recommended for the present.

In this series of 43 hearts, the ramus ostii cavae superioris was well demonstrated in 39 hearts, poorly in one heart and not at all in 3. The failure to demonstrate the vessel in the 4 latter hearts was almost certainly technical in origin.

Although the ramus ostii cavae superioris varies considerably in its origin, its ultimate distribution appeared to be as constant as any other major artery of the body. It always terminated in the region of the orifice of the superior vena cava, and almost always did so by encircling that region.\(^3\), \(^5\), \(^6\), \(^10\)

Of the 39 hearts in which the ramus ostii cavae superioris was well demonstrated, it arose from the right coronary artery in 24 (61 per cent) and from the left in 15 (39 per cent). Gross found it to arise from the right coronary artery in 60 per cent and from the left in 40 per cent of his series of hearts.\(^6\) Both in Gross's study and ours this vessel was never found to arise from both coronary arteries in the same heart. Communications with other atrial vessels did exist, however.

This atrial artery always arose from the first few centimeters of the right or left coronary artery, so that by Spalteholz's nomenclature it would be either the right or left anterior atrial artery. When it originated from the right coronary artery (figs. 1-3) it coursed cephalad and posteriorly along the body of the right atrium, behind the aorta, to reach the anterior interatrial groove. It ascended in this groove, distributed branches to both atrial walls, and terminated by encircling the orifice of the superior vena cava. The circle was complete or very nearly so, with some large branches descending from it toward the inferior vena cava, along the region of the tail or terminus of the sinoatrial node.

Grossly visible anastomoses that have been demonstrated are as follows: (1) With the terminal branches of the intermediate right atrial artery; and (2) with a small artery from the left circumflex coronary artery that coursed behind the two great vessels, and corresponds to one variation (26 per cent) of Kugel's arteria anastomotica auricularis magna.\(^20\) Failure to demonstrate other communications should not be construed to imply that they do not exist.

When the ramus ostii cavae superioris arose from the left side (figs. 3-5) it most frequently originated from the left circumflex artery near its beginning but it also originated from the main left coronary trunk. From an origin on the left side it coursed cephalad along the body of the left atrium, behind the aorta, to reach the anterior interatrial groove. Its course and distribution were then similar.
to that described for the atrial artery that originated from the right coronary, terminating in a circle about the base of the superior vena cava. Grossly visible anastomoses that have been demonstrated for this artery are: (1) Over the body of the left atrium with the left intermediate atrial artery; and (2) in the interatrial septum with the posterior left and right atrial arteries, which corresponds to the major variation (66 per cent) of Kugel's arteria anastomotica auricularis magna.26

In 2 hearts the ramus ostii cavae superioris that arose from the left side had a course quite different from the typical one described above. Instead of going directly to the interatrial septum, the vessel traveled in the opposite direction (fig. 6), toward the margo obtusus, parallel but slightly above the atrioventricular sulcus. At the margo obtusus (where the left intermediate atrial artery usually arises) the vessel divided at right angles into 2 large branches. The one of these continued in essentially the course described above and distributed to the lateral and posterior walls of the left atrium. The other larger branches ascended over the top of the left atrium between the pulmonary veins, crossed the middle of the interatrial septal groove, and terminated in a circle about the base of the superior vena cava. Gross found the ramus ostii cavae superioris to originate occasionally as the left intermediate atrial artery. In the present study this type of origin was not found. It is possible that Gross was actually describing this unusual distribution, as his method could have resulted in misinterpretation of the origin of a large vessel seen near the margo obtusus.

**Arterial Supply of the Atrioventricular Node.** Though not as large as the ramus ostii cavae superioris, a constant artery (sometimes more than one) was found supplying the atioventricular node region (figs. 7 and 8). It originated from the artery crossing the crus of the posterior wall of the heart, which was the right coronary artery in 35 hearts (83 per cent), the left coronary artery in 3 (7 per cent), and from both in 4 (10 per cent). The blood supply of this area was not satisfactorily demonstrated in one heart. Other investigators have also found a specific artery originating from the right coronary artery to supply the atioventricular node.3, 5, 6, 21 Gross applied the name of ramus septi fibrosi to this vessel.

This artery coursed anteriorly from its origin near the crus of the heart, traveling deep to the coronary sinus and rising cephalad to
Fig. 4. Left. The ramus ostii cavae superioris as it arises from the left circumflex artery. Two cannulas are visible at the left coronary ostium because the left circumflex and left anterior descendent arteries arose separately from the aorta in this heart.

Fig. 5. Right. Schematic drawing of the ramus ostii cavae superioris arising from the left circumflex artery. Note the long branch (left atrial circumflex artery) following the base of the left atrium, having arisen from the ramus ostii cavae superioris; in some hearts this branch arises from the left circumflex artery directly. Also shown is the arteria anastomotica auricularis magna (Kugel), which may arise from a left ramus cavae superioris or directly from the left circumflex artery; it anastomoses posteriorly with the right or left coronary artery.

The base of the interatrial septum. It was usually straight and 2 to 3 cm. in length. The terminal branching was remarkable in that it always divided at an angle of 90° or greater from the main atrioventricular nodal artery. This right angle branching is also found in the perforating arteries that branch from the main vessels at the epicardial surface of the left ventricle, and again in the subendocardium.

It was interesting to find that whether the artery to the atrioventricular node originated from either the right or left coronary artery, these main vessels made a sharp U-shaped turn under the posterior descending vein, with the atrioventricular nodal artery arising from the apex of the U (figs. 3, 8, and 9).

This U-shaped turn is possibly of considerable embryologic significance when examined in the light of Keith and Flack's study on the phylogeny of the atrioventricular node. They noted that in lower animals, as well as in a 32-mm. human embryo, the node was situated on the epicardial surface, and that only when that portion of the myocardium invaginated to form the interatrial septum did the node become located inside the heart. Such an invagination could account for the peculiar course of the main coronary arteries at the point where they supply a branch to the atrioventricular node, as well as for the terminal right angle branching of this vessel.

Grossly demonstrated anastomoses of the atrioventricular nodal artery were as follows: (1) With perforating branches from the ante-
rior interatrial septum, which arose from the left circumflex artery, the left anterior descending artery, or the main right coronary artery (Kugel's arteria anastomotica auricularis magna); and (2) with right or left posterior atrial arteries which penetrated laterally into the posterior interatrial septum.

Other Arteries of the Atria. No other atrial arteries were found as commonly as these to the two nodes, nor were there other atrial arteries of size comparable to the ramus ostii cavae superioris. There are, however, several other arteries that are commonly seen. Because they are small, failure to demonstrate them consistently cannot be considered indicative of their absence. Because of this possible failure to demonstrate them in many of the 43 hearts, it would be misleading to indicate their percentile incidence.

Although Spalteholz's regional classification of atrial arteries and nomenclature is simple and appealing, this terminology may suggest that all hearts have anterior, intermediate, and posterior atrial arteries for the left and right atria. Our findings suggest that this is not always true, and would support the use of a different type of nomenclature.

Of these small and numerous atrial arteries, 2 groups were less variable than the others. The first of these was the group in the region of the margo acutus, similar to the location of Spalteholz's intermediate right atrial artery. There was usually at least one fairly large artery in this area. It ascended over the superior region of the right atrium to supply that portion of myocardium. It often anastomosed with branches from the artery that circled the base of the superior vena cava (figs. 2, 3, and 10).

The second group supplied the lateral wall of the left atrium, the site of Spalteholz's left intermediate atrial artery. When a vessel was large enough to demonstrate easily in this area, it often did not arise near the margo obtusus, but rather from the trunk of the ramus ostii cavae superioris shortly after it originated from the left circumflex coronary artery. Its course was then parallel to the left circumflex artery, but higher, along the base of the left atrium (fig. 5). It distributed branches to the atrial wall all along its course and terminated in the posterior portion of the left atrium. This vessel will be referred to as the left atrial circumflex artery. In 2 hearts, as described previously, it was actually the ramus ostii cavae superioris, supplying the sinoatrial node by first coursing over the superior surface of the left atrium.

The other small atrial arteries were only regional twigs. They may have important potentialities as collateral vessels. This is particularly true of those that perforate the anterior portion of the interatrial septum. Small twigs in the region of the posterior atrial arteries described by Spalteholz may communicate with the main artery to the atroventricular node. Tiny arteries were observed to encircle the left and right atrial appendages, but were more numerous around the left.

Veins and Venous Channels of the Atria. As the atrial chambers were cast, vessels were found to be filled directly from the lumen of
Fig. 7. The artery to the region of the atrioventricular node. Note its straight course in an upward direction, and its right angle terminal branching. Just above the coronary sinus is the arteria anastomotica auricularis magna, coursing in the base of the region of the interatrial septum; it arose from the left circumflex artery near the bifurcation of the main left coronary artery.

Fig. 8. Schematic illustration of the U turn of the right coronary artery beneath the coronary sinus deep to the posterior descending vein. The artery to the atrioventricular node with its terminal angle branches is shown.

These chambers. These were presumably thebesian channels, and were much more frequent in the right atrium than the left, and more numerous on the right side of the interatrial septum.

The thebesian channels in the anterior and lateral portions of the right atrium were often so numerous as to coalesce and to cast as trabeculae of plastic. The small atrial arteries in these regions often course beneath these trabeculations, temporarily disappearing from view in their course (fig. 10).

The venous channels in the interatrial septum located at the base of the superior vena cava were especially striking in that they assumed considerable size and frequently were associated with the arterial circle of the ramus ostii cavae superioris (fig. 11).
FIG. 9. The right coronary artery making its unique U turn deep to the posterior descending vein.

FIG. 10. The right intermediate atrial branch, showing how it is covered over in part of its course by plastic which casts the thebesian channels of the right atrium. The terminal branches of this atrial artery communicate with the arterial circle at the base of the superior vena cava.

DISCUSSION

The nature of the blood supply to the human sinoatrial node indicates in part why the clinical expressions of sinoatrial nodal ischemia are so variable. For example, whether or not sinoatrial node block develops depends, at least, upon the following 4 factors: (1) The coronary artery from which the ramus ostii cavae superioris originates, (2) whether or not an occlusion is distal or proximal to the origin of the ramus ostii cavae superioris, (3) the effectiveness of the collateral circulation to the sinoatrial node, including thebesian channels, and (4) the circulatory demands of the sinoatrial node area at the time.

Since the artery to the sinoatrial node arises much more frequently from the right coronary artery, shifting pacemaker, atrial fibrillation, sinoatrial node block and other manifestations of sinoatrial nodal ischemia should be anticipated more frequently with right coronary disease, all other factors being equal.

Incomplete atroventricular block, Wenckebach phenomenon, and other disturbances due to malfunction of the atroventricular node or upper bundle of His may be expressions of disease of the atrial arteries with resultant impairment of their circulation. Disturbances in function of the atroventricular node and bundle of His are to be expected much less frequently with occlusion of the left coronary artery, since it supplied the atroventricular node in only 10 per cent of hearts studied. The effectiveness of the collateral circulation would of course influence the degree of ischemia suffered.

Isolated lesions of the artery to either of the 2 atrial nodes have received extremely little attention from pathologists; in fact, this is true of the atrial myocardium. Segments of ventricular myocardium are routinely removed at the autopsy table for histologic examination, whereas it is unusual to study segments of atrial tissue. Nevertheless, disease
arteries whenever possible, and adequate consideration made when they must be ligated or otherwise occluded.

Incisions, clamping, or ligation that transgresses the anterior interatrial septal groove can only on rare occasion avoid disturbing the main circulation to the sinoatrial node. Similarly, the posterior half of the base of the interatrial septum contains the artery that nourishes the atrioventricular node; therefore, procedures involving this region may produce disturbances in atrioventricular conduction.

The peculiar U turn into the base of the posterior interatrial septum by the main right coronary artery exposes this large vessel to surgical procedures involving the interatrial septum. Traumatic occlusion of this artery would not only induce ischemia of the atrioventricular node but could also produce infarction of the entire posterior wall of the left ventricle.

It is obvious, therefore, that a detailed knowledge of the atrial circulation and its anatomy are of considerable importance, not only from the surgical point of view, but also for a better physiologic understanding of the atria and their function.

**Summary**

The atrial coronary arteries were studied in 43 fresh normal human hearts. The largest atrial artery in man was that supplying the region of the sinoatrial node. It arose from the left coronary artery in 39 per cent and the right coronary artery in 61 per cent of the hearts. Its general course from either artery was to the anterior interatrial septum and thence to an encircling termination at the base of the superior vena cava.

A specific artery supplied the region of the atrioventricular node. It arose from the right coronary artery at the posterior junction of the interatrial and interventricular septa in 83 per cent of these hearts. The parent artery at this location made an interesting U turn beneath the posterior descending vein. This turn may be of considerable embryologic significance.

Many other atrial coronary arteries were noted but were small and variable. One of
their principal functions may be that of potential sources of collateral circulation.

The clinical significance of a knowledge of the atrial circulation is evident and was discussed.

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SUMMARIO IN INTERLINGUA
Le arterias coronari atrial eseva studiate in 43 normal cordes human in stato fres. Le plus grande arteria atrial eseva illo que alimenta le region del nodo sino-atrial. Illo partiva ad le sinistre arteria coronari in 39 pro cento del cordes e ab le dextere arteria coronari in 61 pro cento. Su curso general, in le un e le altere caso, duceva ab le arteria de su origine verso le parte anterior del septo interatrial et postea verso un termination incursante al base del vena cave superior.

Un arteria specific alimentava le region del nodo atrio-ventricular. Illo partiva ab le dextere arteria coronari al junction posterior del septos interatrial et interventricular in 83 pro cento del casos. In iste sito le arteria matre desebeva un interessante curva in forma de U infra le descendentis vena posterior. Il es possibile que iste curva possede un considerabile signification embryologic.

Numerose altere arterias coronari atrial eseva notate, sed illos eseva parve e variabile. Un de lor principal functiones es possibilement lor capacitae potential de establis un circulation collateral.


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