Laboratory Investigation

New Findings on the Origin of the Blood Supply to the Atrioventricular Node

Clinical and Surgical Significance

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The anatomy of the heart's conduction system and of its blood supply have been research topics for many years. However, several proposals have never been demonstrated. In this paper, we describe 2 vascular conduits that have never before been objectively shown to supply the conduction system. Twenty human hearts from subjects aged between 15 and 65 years—with and without coronary disease—were dissected after anterograde and retrograde injection with latex butaclor E-650 by means of a technique developed by the authors. In 40% of these hearts, Kugel's artery was found to supply the atrioventricular node. The right descending superior artery supplied the atrioventricular node in 70% of the hearts dissected. These findings may be of major significance both in clinical cardiology and in cardiovascular surgery. ***(Tex Heart Inst J 1998; 25:113-7)***

Study of the blood supply to the atrioventricular (AV) node is perhaps one of the most difficult tasks that an anatomist can face. The AV node artery and the 1st septal artery, a branch of the left anterior descending (LAD) artery, were at first thought to be the only ones that supplied the AV node. The former originates from the right coronary artery (RCA) and the latter from the left coronary artery (LCA) (Fig. 1). However, clinical and surgical data suggested that alternative sources of perfusion had not yet been described.[1-7] Atrial vessels were always thought to be the answer, yet classical dissection techniques proved useless in efforts to follow these vessels to the node, and this deterred many anatomists from the attempt.

By means of a new injection and dissection technique introduced by the authors, 2 new conduits have been found and are now described—with particular attention to their significance in cardiovascular surgery.

Materials and Methods

For the present study, 20 hearts were removed from the cadavers of subjects with and without coronary artery disease, who had ranged in age from 15 through 65 at time of death. These hearts were injected with latex butaclor E-650 in an anterograde and retrograde manner, by means of the following procedure (Fig. 2). First, both coronary trunks were tied at their origin. Then, the RCA was dissected at a point 1 to 2 cm from the margo acutis, above the inferior wall of the right ventricle. With a small incision, 2 cannulae were then introduced into the RCA, in opposite directions. The same steps were followed in the LAD artery, at a point 2 cm away from the 2nd diagonal branch—provided that the diameter of the vessel was suitable for the procedure. Otherwise, the artery had to be cannulated at the next lowest possible level.

After cannulation, both arteries were injected simultaneously, at a pressure of 80 mmHg, for 30 seconds. The injection was never done at the origin of the coronary trunks, because the cannulae would occlude the atrial vessels, and injection would not be successful. Finally, the heart was submerged in a buffer solution of 10% formaldehyde for 96 hours. By the end of that period, the latex was hardened and dissection could be started.

We began dissection with the heart's conduction system, taking care to track all its vascular structures, including those visible only at magnification (x20 or

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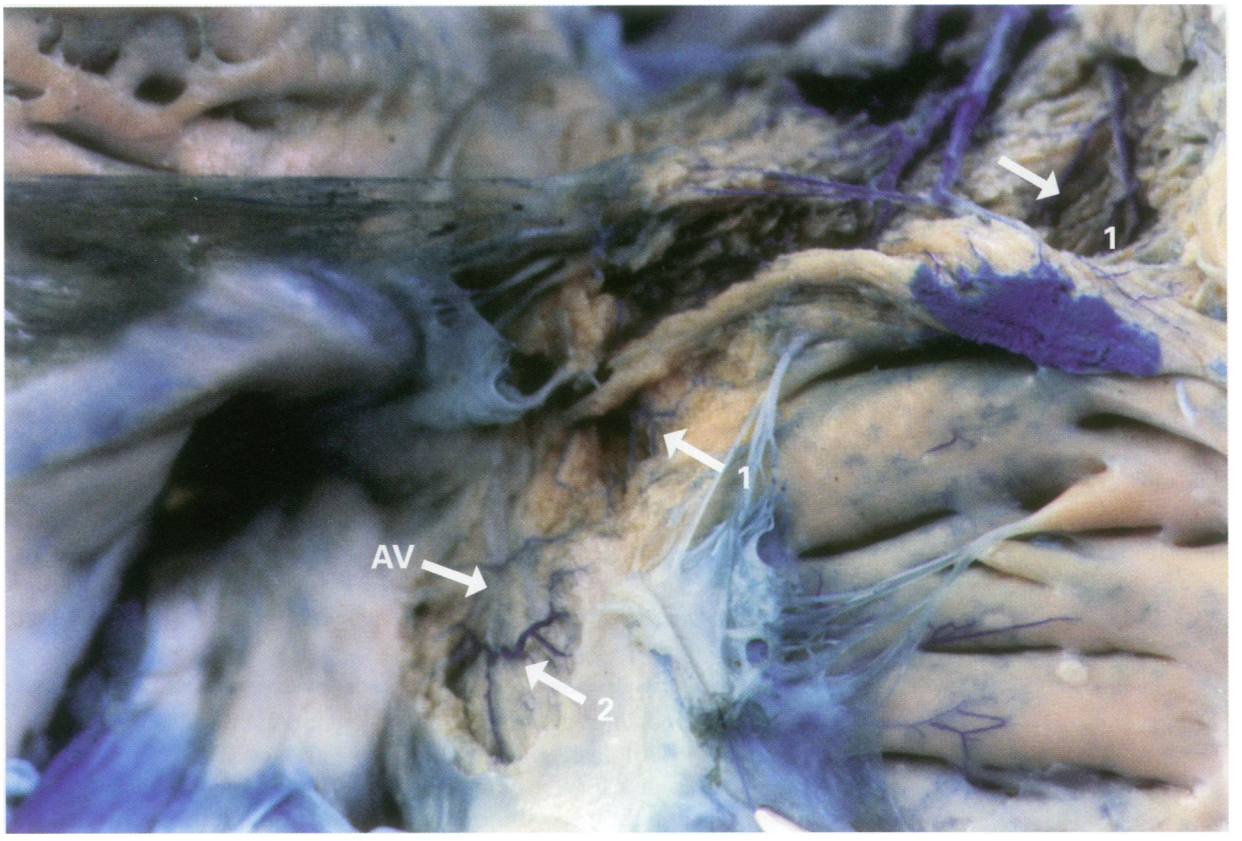


Fig. 1 *The classical concept of the blood supply to the atrioventricular node.*

1= 1st septal artery; 2 = atrioventricular node artery; AV = atrioventricular node

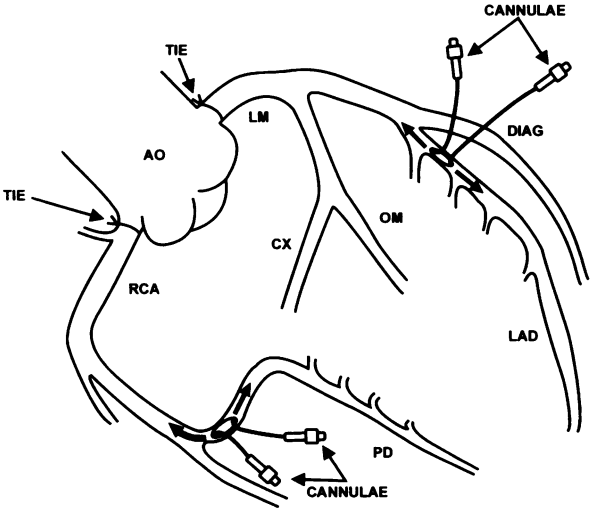


Fig. 2 *The retrograde injection technique.*

AO = aorta; CX = circumflex artery; DIAG = diagonal artery; LAD = left anterior descending artery; LM = left main artery; OM = obtuse marginal artery; PD = posterior descending artery; RCA = right coronary artery

lower). Then we followed each vessel from the AV node to its origin. In all instances, we dissected the perforating branches.

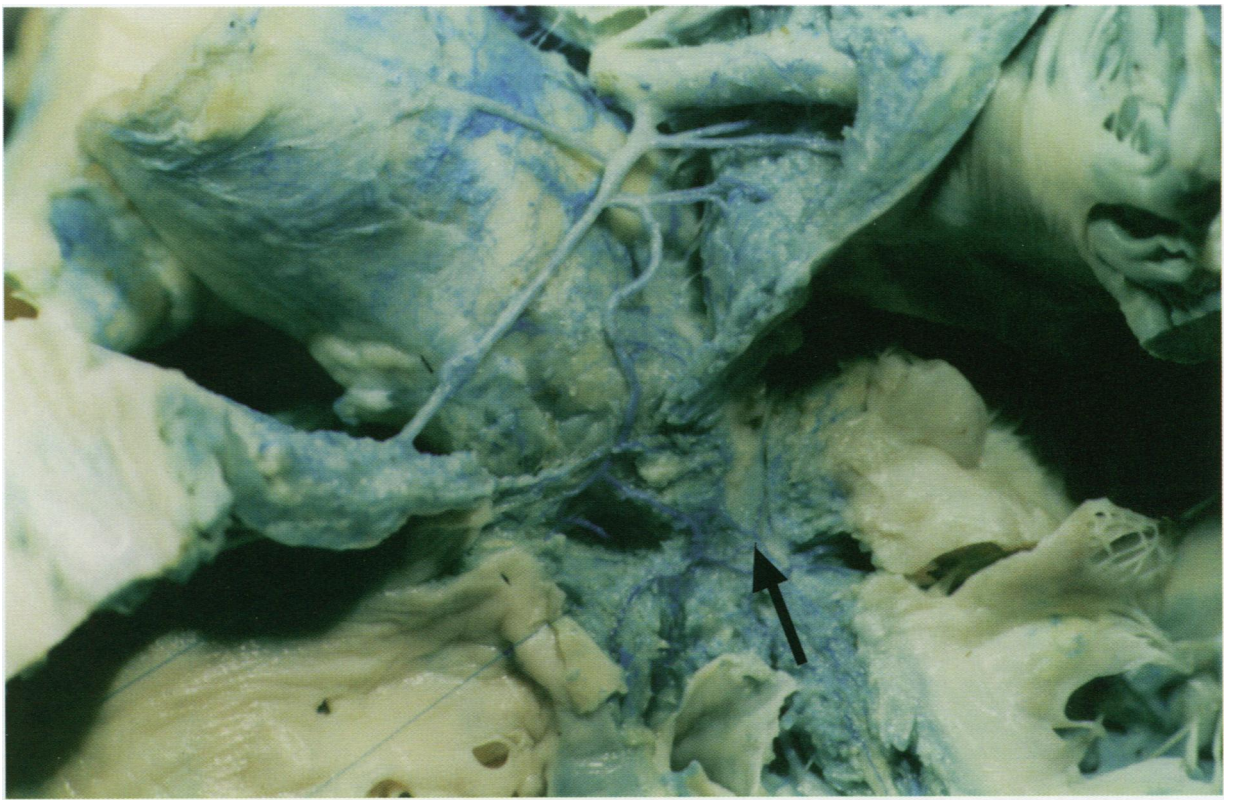
Results

We found that the right superior descending artery supplied blood to the atrioventricular node in 14 of 20 hearts dissected (70%); and we found that Kugel's artery supplied blood to the atrioventricular node in 8 of the 20 hearts (40%).

Discussion

From the time of Einthoven's invention of electrocardiography, many studies have tried to establish a close relationship between the vascular anatomy and the conduction system. Anatomic, histologic, and radiologic research have all helped to clarify the sources of the AV node's blood supply.

Although tracing the course of the AV node artery and the 1st septal artery can explain most of the AV blocks caused by ischemic injury of the anterior and inferior walls, 2 observations remained unexplained. First, there was the question of why occlusion of the circumflex artery caused AV block. Then there was the question of why, in an acute myocardial infarction of the inferior wall,[8] the percentage of AV block was higher when the RCA was occluded at its origin than at one of its branches (particularly at



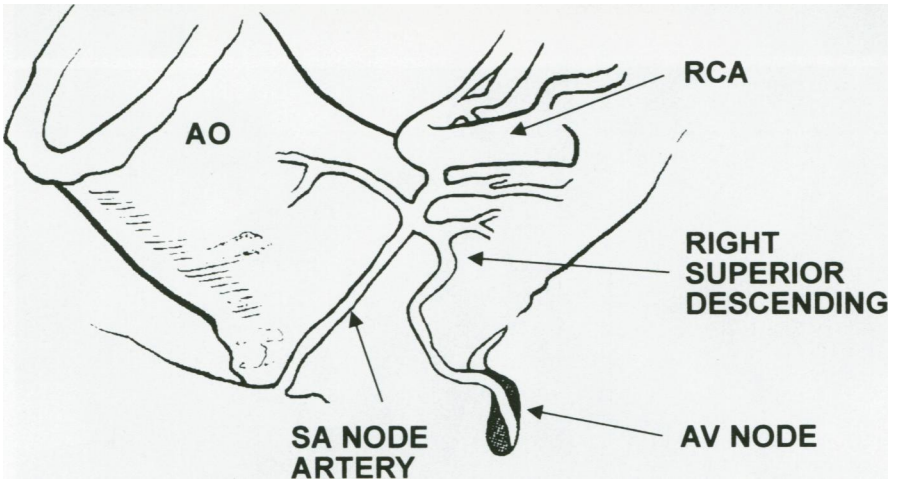


Fig. 3 *The right superior descending artery has an important role in supplying the atrioventricular node (arrow).*

AO = aorta; AV = atrioventricular; RCA = right coronary artery; SA = sinoatrial

the level of the crux cordis). Following the course of Kugel's artery and the right superior descending artery explains these phenomena clearly, for it demonstrates the system of periaortic anastomoses that nourishes the conduction system.

The traditional method of anatomical dissection is to identify the main branches of the coronary arteries and to track them to the target. This method is useless, however, in tracking the insubstantial vessels near the AV node. It was for this reason that we began dissection with the heart's conduction system and tracked the intranodal vascular structures in a retrograde manner. We are confident that this technique enabled us to find most of the arteries supplying the AV node.

Right Superior Descending Artery. This atrial vessel[9,10] has its origin within the 1st centimeter of the RCA (Fig. 3). From its origin, the right superior descending artery (RSD) branches to the crista supraventricularis, close to the right aortic coronary sinus. Then, the trunk of the vessel penetrates the right atrium and runs along the anterior border of the fossa ovalis. From there, it goes through the central fibrous body and supplies the bundle of His and the area within the triangle of Koch, including the AV node.

Kugel's Artery (arteria anastomotica auricularis magna). In 1927, Kugel[11] described this vessel as the arteria anastomotica auricularis magna and said that it had 3 points of origin and anastomotic patterns. Nevertheless, he made no statements regarding the

Fig. 4 *Kugel's artery.* ***A****) Anastomosis between right and left coronary trunks.* ***B****) Atrial branch supplying the atrioventricular node (arrow).*

AV node. It was James[12] in 1968 who 1st proposed that Kugel's artery could be a source of perfusion for the conduction system. However, the truth of his assertion was never demonstrated until now.

Kugel's artery, which produces a large periaortic anastomosis between the right and left coronary trunks, has several perforating branches, some of which lead directly to the AV node (Fig. 4). Its proximity to the aortic root is of great importance in many surgical procedures.

Surgical Significance

Because these arteries originate at the beginning of the coronary trunks, they have great significance in any surgical procedure involving the aortic root. For example, when replacing the ascending aorta and its valve during a Bentall[13] procedure, the surgeon dissects both coronary arteries at their origins, to build the pedicles that later will attach to the graft. Both when dissecting the trunks and when pulling the pedicles, the surgeon risks cutting Kugel's artery and the right superior descending artery. Similar risks are run when performing Yacoub's aortic replacement or Ross's[14] autotransplantation of the pulmonary valve. In the Ross operation, the 1st septal artery is exposed and sometimes damaged, thereby provoking the already familiar conduction disturbances.

The origin of the supply of blood to the conduction system is highly relevant to clinical and surgical procedures. Therefore, we encourage a thorough review of cardiac mapping, with an eye to revision.

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Editorial Commentary

This clear demonstration of the arterial blood supply to the atrioventricular node has practical clinical significance to both the cardiologist and surgeon. While taking an elective in cardiovascular surgery at the Texas Heart Institute, Alejandro Nieponice, a medical student from Argentina, demonstrated to me the findings he had made with his coworker and faculty sponsor, Dr. Gustavo Abuin. I immediately recognized the importance of these findings and encouraged publication.

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