Anatomy of the Ventricular Coronary Arteries in the Dog

By EMIL BLAIR, M.D.

The dog is used a great deal in physiological and surgical research on the heart. In view of this, it is surprising that information with regard to the anatomy of the coronary system is somewhat incomplete and inconsistent. This may account for the variations reported in mortality rate from acute ligations. A right descending coronary artery is described by Bradley which is not confirmed by other investigators. Pianetto describes the left coronary artery as being much more important in the dog, resulting in a left preponderance of arterial supply to the myocardium. The origin of the septal artery is in dispute; furthermore, its description is not complete. The present study was undertaken to delineate the coronary arterial supply to the myocardium, to evaluate vascular preponderance, and to provide a workable nomenclature of the coronary arterial distribution of the dog.

Methods

Studies were performed on 60 canine hearts. Following sacrifice of the animal with a large dose of pentobarbital sodium, the heart was removed and washed in saline. Direct dissections, limited to the myocardium, were carried out on the principal branches and subdivisions. The principal divisions of the coronary vessels were visualized with Urokon. In a number of hearts, the individual arteries were injected with different colors of vinyl plastic material. After fixation the vessels were dissected free of the plastic so that the precise areas of the myocardium supplied could be discerned. Other hearts, after injection, were placed in sodium or potassium hydroxide for digestion of the soft tissue.

For purposes of description, the heart is considered to have an anterior and a posterior aspect, a base, and an apex. The right and left ventricles are divided anteriorly by the anterior longitudinal groove and posteriorly by the posterior longitudinal groove. The aortic cusps are designated according to their positions as right anterior, left anterior, and posterior.

The distribution of the septal artery was observed by (1) direct dissection, (2) angiogram, (3) vinyl plastic injection, and (4) lampblack injection followed by direct dissection. For study, the specimen was prepared in the following manner: the left common coronary artery was entered through the aorta and incised for that distance required to visualize the origin of the septal artery. The right ventricular wall and, subsequently, the left ventricular wall were removed from the septum. This left the septum together with the lateral margins, the apex, the base, and the anterior and posterior longitudinal grooves, in which there remained the left descending artery and the posterior branch of the left circumflex artery, respectively. For purposes of description, the septum has an anterior and a posterior margin, a base, and an apex. The right ventricular side contains papillary muscles in addition to trabeculae carneae; the left ventricular side contains only trabeculae carneae, the left papillary muscles being located on the corresponding ventricular wall. The papillary muscles on the right side vary greatly in number. However, in the majority of instances anterior, medial, and posterior groups were found, and there was frequently an anterior superior papillary muscle located near the base anteriorly.

Results

Left Coronary Artery

Common Coronary Artery

A left common coronary artery was found in 55 of 60 dogs (92 per cent). The artery had its origin in a depression above the anterior aortic cusp. In 95 per cent there was one orifice, and in 5 per cent there were two. In the latter instances, the left circumflex artery originated separately from the left descending artery, and there was, therefore, no common coronary artery. The left common coronary artery was very short, averaging 2 to 3 mm. in the majority of the animals, as indicated in table 1. Its major subdivisions
were: descending artery, circumflex artery, and septal artery. The pattern of the divisions is demonstrated in figure 1. In the majority of instances (55 per cent), all three of the major divisions began at the same area. The most common variation from this was the origination of the septal artery somewhat below the left circumflex artery. This is in agreement with Garmella et al., 6 but at variance with Donald and Essex. 4 In one instance, the septal artery arose from the right circumflex, and in three others from the left circumflex. The origin of the septal artery usually was directly in the path of the left descending artery. It was absent in two instances. Figures 2 and 3 illustrate the topographical distribution of the left coronary artery as observed in a majority of the animals.

Left Descending Artery
In table 2 are listed the frequency distributions of the four branches of the left descending artery: (a) anterior ventricular, (b) right ventricular of the anterior surface, (c) left pulmonary conus, and (d) terminal. The left descending artery ran immediately adjacent to the pulmonary artery, hugging the latter artery very closely. It was covered by a pad of fat of varying thickness, and a superficial band of myocardium crossed over it in a few instances. The anterior ventricular branches broke off at varying intervals, usually beginning at the junction of the upper and middle thirds of the anterior surface of the left ventricle. The arteries spread out laterally across the left ventricle and inferiorly toward the apex. Most frequently, there were three major anterior ventricular branches, as shown in table 2. The right ventricular arteries came off the left descending artery at varying intervals, crossed the anterior longitudinal groove, and supplied a band of the right ventricle. This band was approximately 10 to 15 mm. in width, narrowing toward the apex. There were usually two to four right ventricular branches. In addition, 65 per cent of the hearts showed a distinct pulmonary conus artery supplying the left lateral margin of the pulmonary conus and anastomosing freely with the corresponding branch from the right coronary artery. Deep perforators supplied the anterior margin of the septum near the base. A terminal branch was present in 95 per cent of the animals. The left descending artery, with its terminal branch, occupied the anterior longitudinal groove.

Left Circumflex Artery
This was the largest of all the divisions. It supplied the greatest portion of the myocardium, including a significant portion of the posterior aspect of the right ventricle. The left circumflex artery lay in the left coronary arterial groove at the base of the heart and was covered by a thick pad of prearterial fat. Shortly after its origination, it ran beneath the left atrium. This artery gave off four myocardial branches: anterior, medial, posterior, and right ventricular. The anterior branch, present in 87 per cent of the hearts, usually began approximately 4 to 6 mm. after the origin of the left circumflex. As many as three anterior branches were found, but the majority of the animals had only one of significant size (table 2). When this branch was present, the anterior ventricular branches of the left descending artery generally started at a somewhat lower level. The anterior branch spread out laterally and inferiorly across the
upper third of the anterior surface of the myocardium. The medial branch was one of the larger subdivisions of the circumflex. As many as three medial branches were present in some animals, but 68 per cent had only one large branch. This artery came off at a rather acute angle from the left circumflex in the region of the lateral margin of the left ventricle and crossed inferiorly toward the apex.

The posterior branch of the left circumflex originated at the posterior longitudinal groove on the posterior aspect of the heart. In 55 per cent of the animals, there was one principal posterior branch, and in 40 per cent there were two. The posterior branch ended in an anastomosis with the terminal branch of the left descending artery. Perforators supplied the posterior margin of the septum near the base. During its course down the posterior longitudinal groove, the posterior branch gave off a number of right ventricular branches, usually two. The left circumflex artery usually terminated in two right ventricular branches which crossed over the posterior longitudinal groove at the base into the right ventricle. Through either its direct right ventricular branches or those from its posterior division, the left circumflex artery supplied approximately one-fourth to one-third of the posterior aspect of the right ventricle.

Arterial Supply to the Apex

The apex of the heart was supplied exclusively by divisions of the left coronary artery. Table 3 lists the frequency with which divisions of the left coronary artery contributed to the apex. The anterior ventricular branches of the left descending artery were the most frequent contributors to the apex. Next in importance was the medial branch of the left
Table 2

*Per Cent Distribution of Divisions of Left Coronary Artery*

<table>
<thead>
<tr>
<th>Artery</th>
<th>Number of branches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Left descending</td>
<td></td>
</tr>
<tr>
<td>Left anterior ventricular</td>
<td></td>
</tr>
<tr>
<td>Right anterior ventricular</td>
<td>3</td>
</tr>
<tr>
<td>Left pulmonary conus</td>
<td>35</td>
</tr>
<tr>
<td>Terminal</td>
<td>5</td>
</tr>
<tr>
<td>Left circumflex</td>
<td></td>
</tr>
<tr>
<td>Anterior*</td>
<td>13</td>
</tr>
<tr>
<td>Medial</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td></td>
</tr>
<tr>
<td>Right posterior ventricular</td>
<td>3</td>
</tr>
<tr>
<td>Septal</td>
<td></td>
</tr>
</tbody>
</table>

*Present in 59 of 60 animals.
(Per cent of animals with 4+ branches.
Figures based on 36 specimens.

circumflex artery. The apex was usually supplied by more than one of these branches. The most frequent combination observed was that of an anterior ventricular branch and the medial branch. The next most common supply was by the anterior ventricular branch alone.

Anastomoses

The coronary vessels anastomosed with each other quite frequently on the surface of the heart. Of the major anastomoses of the left coronary artery, given in table 4, the most frequent was that between the terminal branch of the left descending artery and the posterior branch of the left circumflex artery. These branches lay in the anterior and posterior longitudinal grooves, respectively, and anastomosed adjacent to the apex. The next most common anastomosis, between an anterior ventricular branch and the medial branch of the left circumflex artery, usually took place just above or at the apex of the heart.

Septal Artery

Satisfactory studies were completed in 36 specimens. The site of origin of the septal artery is indicated in figure 1. Most frequently, the septal artery came off adjacent to the origin of the left circumflex and in the direct path of the left descending coronary artery. Immediately after its origin, the septal artery turned acutely toward the septum, which is medial, and traversed the base of the heart for a short distance, just underneath the aortic valve ring. It then turned toward the right ventricular side of the septum, coursing underneath the septal leaflet of the tricuspid valve for a short distance, and plunged inferiorly toward the apex, becoming superficial on the right ventricular side. Here, approximately at the junction of the upper and middle thirds of the septum, the septal artery could frequently be visualized and dissected free. Beyond this point, the artery continued somewhat more deeply toward the apex, ending in a terminal branch which bifurcated and ramified into the trabeculae carneae at the apex. The distribution of the principal branches is shown in figure 4.

The length of the septal artery was highly variable, due to the variations in size and weight of the hearts studied. The distance from the orifice to the anterior branch was between 16 and 25 mm. (65 per cent), from the orifice to the medial branch between 26 and 35 mm. (72 per cent), from the orifice to the posterior branch, approximately the same as with the medial branch (54 per cent).

As many as five branches came off the septal artery (table 2). Most often there were three (58 per cent). The next highest inci-
Figure 5

Variations in the septal artery. Views are from the right side, with the anterior border on the right and the base superior. (A) This is the most common distribution. (B) There is no posterior branch. The terminal branch bifurcates and the inferior limb supplies the posterior papillary muscles. (C) and (D) There is a prominent posterior superior branch going to the membranous septum. Note retrograde filling of the left descending and posterior branch of the left circumflex through large arterial channels.
dence was two branches (28 per cent). The frequencies of occurrence of the principal branches were as follows: anterior, 94 per cent; medial, 67 per cent; posterior, 97 per cent. The anterior and posterior branches, therefore, were fairly constant, with some variation in the medial branch.

The anterior branch was usually single (83 per cent), although in 11 per cent of the animals there were two branches. The anterior branch diverged from the septal artery as the latter passed through the deep substance of the septum in the proximal (anterior) third. This branch arose inferiorly and passed toward the lower third of the anterior margin of the septum, in the direction of the anterior longitudinal groove. It supplied the anterior papillary muscle (or muscles) and from this point gave off numerous ramifications to the trabeculae carnea in the form of rosette-type networks.

The medial branch was absent in 32 per cent of the animals. Usually there was one branch (53 per cent), and in 14 per cent, there were two. The medial branch arose during the superficial course of the septal artery and supplied the medial papillary muscles and the adjacent trabeculae carnea. When this branch was absent, the medial papillary muscles and trabeculae carnea were supplied by a division from the anterior branch.

The posterior branch was present as a single artery in 97 per cent of the animals, actually constituting the terminus of the septal artery. After a short distance, it bifurcated in 70 per cent of the hearts. The branch supplied the posterior papillary muscle (or muscles) and trabeculae carnea in the adjacent region.

In addition to these principal branches, numerous small branches were given off at right angles to the septal artery along its entire course. These were extremely small and ended in capillary networks in the trabeculae carnea. Occasionally, a distinct posterior superior branch or anterior superior branch or both were given off. The latter supplied an anterior superior papillary muscle which was occasionally present. The posterior superior branch supplied the membranous portion of the septum. When these distinct branches were absent, these areas were supplied by small arterial networks arising from the principal trunk.

The septal artery supplied approximately 75 per cent of the septum (fig. 4). The remaining 25 per cent consisted of areas along the anterior and posterior margins, usually near the base. The anterior margin was supplied by deep perforators from the left descending coronary artery, which anastomosed freely with the anterior branch of the septal artery. The posterior margin was supplied by perforators from the posterior branch of the left circumflex, which anastomosed freely with the terminal branch of the septal artery and with the posterior superior branch when
Table 6

<table>
<thead>
<tr>
<th>Artery</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left common</td>
<td>Origin for descending, circumflex, and septal arteries</td>
</tr>
<tr>
<td>Descending</td>
<td>Anterior surface of left ventricle, apex</td>
</tr>
<tr>
<td>Anterior ventricular</td>
<td>Anterior margin of septum</td>
</tr>
<tr>
<td>Perforators</td>
<td>Inferior border of anterior surface of left ventricle; apex</td>
</tr>
<tr>
<td>Terminal</td>
<td>Margin of right ventricular adjacent to the anterior longitudinal groove</td>
</tr>
<tr>
<td>Right ventricular</td>
<td>Left margin of the pulmonary conus</td>
</tr>
<tr>
<td>Pulmonary conus</td>
<td></td>
</tr>
<tr>
<td>Circumflex</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>Upper one-third of anterior surface of left ventricle</td>
</tr>
<tr>
<td>Medial</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td></td>
</tr>
<tr>
<td>Perforators</td>
<td></td>
</tr>
<tr>
<td>Right ventricular</td>
<td></td>
</tr>
<tr>
<td>Septal</td>
<td></td>
</tr>
<tr>
<td>Right circumflex</td>
<td>Pulmonary conus, except the left margin</td>
</tr>
<tr>
<td>Pulmonary conus</td>
<td>Right ventricle, except for margins adjacent to the longitudinal grooves</td>
</tr>
<tr>
<td>Ventricular</td>
<td></td>
</tr>
</tbody>
</table>

it was present. Figure 5 demonstrates the anastomoses and some common variations in the septal artery distribution. In no instance was any supply detected from the right coronary system. The conduction system did not have any specific branch, but was supplied by the profuse network arising from the branches mentioned above, or directly from the principal trunk.

**Right Coronary Artery**

The orifice of the right coronary artery was located in a depression above the right anterior aortic cusp. Of the 60 animals, 54 (90 per cent) had one orifice (table 5A). In the other six there were two orifices. In addition to the principal right branch, there was a separate origination going to the right atrium in one instance, a septal artery in one instance, and a right ventricular perforator in four. Contrary to published accounts, the right coronary artery consists only of a right circumflex. There is no right descending coronary artery as seen in the human. The right descending artery in the human occupies the posterior longitudinal groove. In the dog, this groove is occupied by the posterior branch of the left circumflex artery.

The right circumflex artery has two principal subdivisions insofar as the myocardium is concerned: right ventricular and pulmonary conus (table 5B). The pulmonary conus branch was present in 95 per cent of the animals. This was a prominent artery, arising 3 to 5 mm. after origin of the right circumflex, which dipped inferiorly just past its origin for a short distance. It then ascended over the body of the pulmonary conus, medially toward the anterior ventricular groove, spreading out over the conus and frequently sending a separate branch to the pulmonary artery itself. The right ventricular branches were present in all of the animals and varied from 4 to 10 in number. These arteries came
Contribution of the left coronary arterial system to the right ventricle.

off at varying intervals along the course of the right circumflex and descended inferiorly across the body of the right ventricle, as demonstrated in figure 2. The right circumflex artery ended in a small branch, short of the posterior longitudinal groove.

The pulmonary conus artery and the right ventricular branches of the right circumflex anastomosed freely with their counterparts from the left coronary artery. Only rarely did a branch from the right circumflex artery extend to either longitudinal groove.

The right circumflex coronary artery, therefore, does not supply the entire right ventricle. Between one-fourth and one-third of the margins of the right ventricle immediately adjacent to the anterior and posterior longitudinal grooves are supplied by branches from the left descending and the posterior branch of the left circumflex arteries, respectively (fig. 6).

Discussion

The heart of a dog is left coronary preponderant, in agreement with the observations of Pianetto. The largest and most important artery is the left circumflex. This artery gives off divisions that supply at least half, and sometimes more, of the left ventricle and approximately one-third of the posterior surface of the right ventricle.

In coronary ligations, the differences in mortality may have been due to inadvertent inclusion of the septal artery, in which case death rate would be high. Varying types of acute or chronic occlusive procedures on the left descending artery, below the origination of the septal branch, might be expected to yield a high incidence of survival as compared with occlusion of the left circumflex artery. When survival is desired, experimentally induced occlusion of a major coronary vessel would logically best be confined to the left descending artery, as suggested by the described myocardial arterial supply. Oclusive procedures in which a greater magnitude of interference with blood supply to the myocardium is desired would probably be more successful if initiated in the left circumflex artery, shortly after its origin. Haeger reports an unusually high mortality rate from ligation of the right coronary artery (15 of 16 animals). This is somewhat surprising in view of the incomplete supply of blood afforded by the right coronary. The considerably lower figures reported by Porter (2 of 11) and by Donald and Essex (5 of 21) would appear to be more likely. However, any consideration of mortality rates as governed by the acute, simple deprivation of a certain segment of blood flow must be tempered by the influence of other factors, such as anesthesia and somatic reflex phenomena, as enumerated by Garmella et al.

The nomenclature of the canine coronary anatomy is patterned after that of the human vasculature. Since the two species are extremely different, some confusion exists, especially with regard to the description of the posterior aspect of the dog's heart. Furthermore, the name "left anterior descending" is really redundant, since the "left" and "anterior" denote exactly the same anatomical position. It is believed that "left descending" is quite adequate for the description. Table 6 presents a simple nomenclature of the ventricular coronary artery distribution in the dog as outlined in this report.

Summary

The ventricular coronary arterial system of the dog displays preponderance of the left
VENTRICAL ARTERIES

in 100 per cent of the animals studied. The single most important source of blood supply is the left circumflex artery, which supplies not only most of the left ventricle, but also significant portions of the right ventricle. Details of the septal branch are described. Morphological implications concerning death or survival in experimental coronary occlusive procedures are discussed. A simple nomenclature is offered.

References
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Circ Res. 1961;9:333-341
doi: 10.1161/01.RES.9.2.333

Circulation Research is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7330. Online ISSN: 1524-4571

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