An Experimental Study to Increase Blood Supply to An Ischemic Myocardium

Part I. Anatomy of Blood Vessels in Canine Heart

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It is well known that the blood vessel of the canine heart is different from that of the human beings. Aside from the fairly resembling pattern of the distribution of superficial blood vessel of the mammalian heart1), the anatomy concerning the distribution of deep vessel has not been studied in details. The author has been particularly interested with the anatomy of the septal artery which has a great relationship with the survival rate with ligation of the coronary arteries of the heart.

EXPERIMENTAL

Method

50 canine hearts were used. After the dog with normal heart was killed with ether inhalation, the heart with the ascending aorta and the brachio-cephalic branch was removed from the body, and thoroughly rinsed with water. A French catheter No. 5 was inserted into the left carotid artery, and the aortic arch and the right carotid artery were both ligated. The coronary arteries were perfused with water for 30 minutes through the inserted catheter with a syringe. Most of the arterial branches were cleared of blood in this manner. Then, another catheter was inserted through the ostium of the coronary sinus and the blood was removed by squeezing of the heart and perfusion. The specimens were immersed in a water bath in a refrigerator 4°C. for 24 hours and the above procedure was repeated. Various measures were used to visualize the vessels in the heart which has almost become white by perfusion. 1) 20 cc. of barium sulphate mixed in water in a ratio of 1:5, or 70% Diodrast was injected into the coronary arteries and the ostium of the coronary sinus. X ray pictures and normal photographs were taken in the anterior-posterior direction with its ordinary position in the body and flattened out position.
after incision along the posterior line between the apex and sulcus dividing the ascending aorta and the pulmonary artery. 2) Solution colored with aniline (red) and indigo carmine (blue) was injected into the right and left coronary arteries, respectively, and the distribution of the superficial vessels was delineated. The hearts were also cut in the horizontal plane in several pieces to see the communications between the right and left coronary arteries. 3) After Chinese ink (pigment made of carbon particles) was injected in the arterial and venous system, histologic sections were made to study the fine communications in the deep muscles. 4) In order to study the relationship of the coronary arteries and the veins in situ, various kinds of models were made. At first, celloidin or paraffin was injected into the vessels and found to be inadequate to pursue the fine branches due to their fragility, and it was replaced with the following technique. When methacrylic resin was used, the elasticity, firmness and fluidity were found to be excellent. Briefly explaining the method, ethyl ester of methacrylic acid and its methyl ester are measured separately in a ratio of 1:4–5. The specimen is submerged in a water bath which is kept around 4°C. Ethyl ester and methyl ester are mixed together thoroughly just before the injection and the mixture is pumped into the coronary systems through the catheter with a syringe. In order to facilitate the interpretation of the relationship of the arterial and venous side, red, yellow and blue oil paints were mixed into the above mixture in about 1%.

Proper attention was taken to prevent water mixing with the mixture. The specimen which was treated in such a way was kept in 20% alkali for 24 hours and later washed with running water to clear the digested myocardium for an hour. Digestion of the heart muscle was often difficult to obtain within a short period of time. It usually took about 4 weeks to complete the procedure by repeating the digestion and washing. It was easy to read the direction, course, division and numbers of the vessels than the aforementioned 3 methods.

Results

The general outline of the coronary arterial system

Two main branches were identified, i.e., the right and the left coronary arteries. The former arised from the right anterior cusp of the aortic valve and coursed along the auriculoventricular sulcus between the right atrium and right ventricle. Usually 4 or 6 large branches to the auricular appendage was found besides fine capillaries. One-third of the posterior septum was supplied with arteries from the peripheral branch of the right coronary artery.

The left coronary artery arised from the left anterior cusp of the aortic
valve and divided into the anterior descending branch and circumflex branch after running two or three mm. distally.

(a) *Anterior descending branch*: The bifurcation which usually exists on the postero-lateral side of the pulmonary artery is covered with the left auricular appendage. It courses along the interventricular groove. Usually, 3 to five to the left ventricle and much smaller branches to the right ventricle are found. There is, however, three or four fairly large branch to the left ventricle. They mostly descend over the anterior portion of the left ventricle which has a caliber of two thirds of the main branch. The distribution of this branch supplies one-third of the anterior portion of the left ventricle, anterior region of the septum, and one fifth of the right ventricle. The rest of the left ventricle is supplied by the circumflex branch.

(b) *Circumflex branch*: It courses along the left auriculoventricular groove to the midline of posterior ventricle. Branches half size of the main branch are found 3 to four in number which descend on the left ventricle. The terminal portion of the circumflex branch is named as the posterior descending branch and unites with the anterior descending branch which is supplying the apex. Branches to the left auricular appendage arise directly from the circumflex branch in seven to 10 small twigs which are hard to designate as a sizable branch. Circumflex branch also supplies about one-seventh of the posterior portion of the septum.

(c) *Septal branch*: It arises mostly from the origin of the anterior descending branch and, in a few percentage, from the origin of the circumflex branch and the main stem of the left coronary artery. Though the origin of the septal branch from the anterior descending branch is variable, most of the cases are found arising within 2-3 mm. posterior or posterolateral to the origin of the main branch. It penetrates the septum perpendicular to the surface of the left heart with two to three fairly large branches distributed evenly on the sagittal plane. Mainly the septum is provided with blood from the septal branch with small blood supply on its marginal portion from the right coronary artery and the circumflex and anterior descending branches. (Figs. 1 and 2).

*The general pattern of the coronary venous system*

Injections of the right coronary venous system were not met with success. Main outlet for the venous return to the right heart was not known except evenly distributed veins accompanying the right coronary arterial system was found on the surface.

The venous return of the left ventricle was mostly from the coronary sinus. Five or seven fairly large size branches were noticed. Those which were consistent were the posterior ventricular branch, the lateral ventricular branches and the anterior great cardiac branch naming the branches closer to its outlet. The venous network was more finer than the arteri-
al side. The veins usually accompanied the arteries.

**Special circulation in the myocardium**

Extremely fine anastomoses were found between the arterial and venous system (Fig. 3). Direct communication between the venous system of the myocardium with the ventricular cavity was noticed in the left ventricle. These direct communications were found in the anterior descending branch and the circumflex branch. (Fig. 4).

Fine communications between the branches of the right and left
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Fig. 3. Photograph of model by acrylic resin. Abundant fine anastomoses between arteries and venules are seen.

Fig. 4. Photograph showing Thebesian vessels. Top: anterior descending branch and great cardiac vein. Bottom: left ventricular cavity.

coronary arteries and its subdivisions were demonstrated. Chinese ink injected into the coronary artery under pressure of 100 mg. Hg. were not only seen in the capillaries in the deep muscle, but between the space of the muscle fibers (Fig. 5).

DISCUSSION

The general pattern of the coronary system of the dog heart has been presented by others\(^2\)\(^3\), and was confirmed. Present study was to investigate the distribution of the left coronary artery to clarify some of the inconsistent results reported by several investigators on the effect of ex-
perimental coronary ligation. Most reporters have tied the anterior descending branch to evaluate the surgical procedures designed to increase collaterals to ischemic myocardium. They, however, only gave obscure statement on the position of ligation of the coronary arteries. For instance, the ligature is said to be "at the origin of the anterior descending branch", "the middle portion of the anterior descending branch", and "2 mm. from the origin of the left coronary artery" etc. If septal branch is included in the tie, careful analysis should be made in case of interpretation of the survival rate, electrocardiographic changes, etc. The septum is mainly irrigated by the septal branch which arises from the anterior descending branch within a perimeter of 2 mm. Therefore, inclusion of septal branch in the ligature is conceivable. This point should be made more clear.

The size and form of the blood vessels were not given. It is already agreed that the technique of injection greatly changes their conditions in a removed heart. Vein wall are particularly distensible. In spite of pressure of injection was kept around 100 mm. Hg., measurements were quite different from one specimen to another.

Concerning the distribution of the vessels in the myocardium, the description by Grant, Batson et al. was confirmed. Coronary venous system penetrating the myocardium ended in Thebesian vessels with outlets in the ventricular cavity. Diagramatically, the veins on the surface of the heart were connected to a capillary mesh which lied in the middle of the myocardium and this was bridged with the so called sinoluminal vessels with the ventricular cavity. Direct communication with the arterial system and the ventricle, however, could not be demonstrated.
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SUMMARY

The blood vessels in 50 fresh canine hearts which were removed from the body were studied. Various injection methods were used to outline its distribution. Models using methacrylate were found to be the best to obtain the relationship of the vessels. Importance of the anatomy in case of studying the effect of ligation of the vessels were emphasized.

References

3) Grant, & Regnier, Heart, 1926, 13, 285.
4) Grant, Heart, 1929-31, 15, 103.