Visualization of the Coronary Arteries during Life

By JAMES A. HELMSWORTH, M.D., JOHNSON McGUIRE, M.D., BENJAMIN FELSON, M.D., and RALPH C. SCOTT, M.D.

By retrograde catheterization of the carotid or the brachial arteries, small polyethylene or woven catheters have been inserted into the ascending aorta in 10 individuals. Diodrast or Neo-Iopax solution was forcibly injected and serial roentgenograms were rapidly taken. The coronary arteries or branches were demonstrated in 5 of the subjects. Similar studies were made in 5 dogs with normal hearts, and also in 10 dogs in whom a coronary artery had previously been obstructed. In certain of the normal animals not only the larger, but also smaller branches were clearly shown and the absence of filling in obstructed vessels was demonstrated.

ROENTGEN visualization of the coronary arteries in the living patient would contribute greatly to the diagnosis of coronary artery disease. It also should be helpful in studying the results of experimentally induced coronary obstruction in animals. With these objectives in mind, a technic of coronary arteriography which has proved successful in animals and in man is presented.

In an earlier communication a method of visualization of the coronary arteries was described. A radiopaque medium was injected through a catheter inserted via the brachial artery into the ascending aorta and the coronary arteries were demonstrated roentgenographically. These studies have been continued and, to date, successful visualization of the coronary arteries in 13 dogs and 5 human beings has been obtained. The purpose of the present report is to describe the technic and hazards of coronary arteriography and to record additional experiences in this field.

Rousthó, in 1933, filled the coronary arteries in living rabbits by inserting a catheter into the ascending aorta via the common carotid artery and injecting Thorotrust. Grossman, employing a similar method, visualized the coronary arteries with Diodrast in 5 dogs. Recently, Pearl and his co-workers reported coronary visualization with Diodrast in dogs, using a special nylon catheter. Barclay and co-workers visualized the coronary circulation in a viable sheep fetus by retrograde injection through the femoral artery. Hoyos and Del Campo obtained coronary artery filling with Diodrast in man by needle puncture of the ascending aorta through the anterior chest wall. Gordon, Brahms, and Sussman noted incidental filling of the coronary arteries in 10 of 1200 angiograms. In 1948, Jönsson, using the method of catheter aortography which he attributed to Radner, successfully visualized the coronary arteries in 5 human subjects.

TECHNIC

Preliminary experiments were carried out on 15 dogs. The anesthetic agent was intravenous sodium pentobarbital. A segment of the right common carotid artery was mobilized and a serrefine clamp was placed on the distal extremity of the mobilized segment. A looped sling of fine silk was then placed about the proximal extremity. Through a small transverse incision in the artery, a polyethylene or a woven cardiac catheter was advanced into the ascending aorta. At frequent intervals physiologic saline was slowly flushed through the catheter in an effort to prevent thrombosis.

Under fluoroscopic control the catheter was advanced to approximately 1 cm. above the aortic valve. Contrast substance was injected to the tip of the radiolucent polyethylene catheter in order to identify its position. Early in the study single Bucky roentgenograms were made immediately following the rapid (0.2 to 0.8 second) injection of varying amounts (7 to 15 cc.) of 70 per cent Diodrast or 75 per cent Neo-Iopax. As many as 16 injections were given to one animal. Later, serial roentgenograms were made.
at one-half second intervals during and following the injection using the Fairchild Roll Film Cassette. With this apparatus fewer injections were necessary. In the later experiments electrocardiographic tracings were taken before, during, and after the injection of the contrast agent. At the completion of each study the carotid artery was ligated and a simple wound closure made.

Ten animals were specially prepared by ligation and division of a branch of the left, right, or circumflex coronary artery. The ends of the severed vessel were marked with silver clips to permit their identification on roentgenograms. Coronary arteriography was then performed, usually within six hours after the occlusion. Four animals were used for coronary arteriography. The heart was removed and injected intact, using a modification of the Schlesinger technic.10

After these preliminary animal experiments, coronary arteriography was carried out on patients. Premedication consisted of morphine and sodium pentobarbital in dosages depending upon the weight of the patient. Food and water were withheld for six hours before the study. No anticoagulant was administered. An ocular test for sensitivity to the contrast agent was made. Experience demonstrated that the right brachial, the right common carotid, and either of the superficial femoral arteries were suited for the passage of the catheter into the ascending aorta. Under local anesthesia the artery was exposed through a small incision and a 4 cm. segment was mobilized by dividing and ligating only the smallest branches. After the adventitia was removed a looped sling of silk was placed around the extremities of the segment. A transverse opening was made in the vessel and tension on the slings prevented blood loss. As the catheter was inserted the proximal sling was released. The catheter was advanced under fluoroscopic control until its tip was in the proximity of the aortic valves. Continuous slow injection of saline-heparin solution (75 mg. heparin per liter of normal saline) was maintained. A final test for sensitivity was made by injecting 1 cc of contrast medium through the catheter. From 10 to 20 cc. of 70 per cent Diodrast or 75 per cent Neo-Topen were injected rapidly (0.8 to 2.0 seconds). In the earlier studies a single Bucky exposure was made at the end of each injection. Later, employing the Fairchild Cassette, exposures were made at one-half second intervals during and after the injection. Both common carotid arteries were digitally compressed during the contrast injection in an effort to limit the amount of contrast agent entering the cerebral circulation. Several injections were made in each patient. Electrocardiograms were taken before, during, and after the injection in 2 cases. At the completion of the procedure the catheter was withdrawn and the vessel carefully examined. In several cases a soft thrombus was extruded before normal flow occurred from above and below the arteriotomy. The opening in the artery was closed with an evertting stitch of 5-0 silk on an atraumatic needle.

Results in Dogs

Coronary artery visualization was attempted in 15 dogs. In 13, successful filling (fig. 1) was obtained on one or more occasions. Repeated injections were carried out in several animals before successful coronary arteriograms were obtained. In the other 2 animals the coronary tree could not be visualized because it was impossible to pass the catheter tip into the ascending aorta.

A branch of one of the coronary arteries had been ligated in 10 of the 15 dogs studied. The site of obstruction was identified in 6 animals by visualization of the artery to the point of ligation with no filling beyond (figs. 1). In 4 animals filling was inadequate for demonstration of the occlusion. Electrocardiographic tracings were made in 9 of these 10 animals, and arrhythmias developed in 8. The arrhythmias consisted of second degree atioventricular block, sinus arrest with nodal escape, premature ventricular contractions, paroxysmal ventricular tachycardia, and ventricular fibrillation. Changes in the T waves were observed in 5 of these animals following the injection of contrast medium. These changes consisted of increase in depth of a negative T wave, decrease in height of an upright T wave, or change of the T waves from positive to negative. These alterations were usually transient.

There were 15 attempts to visualize the coronary tree in these 9 animals. In 9 of the 11 successful injections and in 3 of the 4 unsuccessful ones arrhythmias were observed. There were T wave changes in 4 of the 11 successful injections and in 3 of the unsuccessful ones. It was therefore apparent that electrocardiographic changes developed in the absence of coronary opacification.

Electrocardiograms were made in only 1 of the 5 normal dogs and no arrhythmia was seen although transient T wave changes were noted. Twenty cc. of physiologic saline were rapidly injected through the catheter in 4 of the ani-

---

* Manufactured by Fairchild Camera and Instrument Corporation, Jamaica, New York.
mals and no electrocardiographic changes were observed.

Five deaths occurred in the entire group of 15 animals. These fatalities were encountered in animals in which recent coronary ligation had been performed. Three developed frequent premature ventricular contractions following the coronary artery ligation and died of ventricular fibrillation shortly after the injection. In the other patient, although no contrast medium was demonstrated in the coronary tree, there was transient increase in the height of the T waves immediately following the injection.

**DISCUSSION**

It has been possible to demonstrate one or more major vessels as well as a number of the smaller branches of the coronary tree in both dogs and patients. In certain instances the left coronary artery was better filled and in others the right. It is believed that the factor determining which vessel will fill best with a given injection is the location of the tip of the catheter in relation to the orifice of the vessel. Visualization of the coronary tree in the dogs was invariably clearer than in the human beings. Technically, the quality of the films was better in the animals because of their smaller mass. Furthermore, a larger quantity of contrast medium was injected proportionately in the animals than in the humans.

![Fig. 1. Dog 594. Coronary arteriogram, right posterior oblique view. Note the filling of all the major coronary arteries and many of the smaller branches.](image)

The other 2 died several hours after the procedure, the cause of death being undetermined.

**RESULTS IN MAN**

Coronary visualization was attempted in 10 patients with successful filling in 5. In 3 cases the demonstration of the coronary arteries was good (figs. 4 and 5), while in the remaining 2 cases the filling was less complete.

Electrocardiographic observations were made during attempts at coronary visualization in 2 patients. Successful filling in 1 patient was associated with a brief period of sinus slowing.
Fig. 2. Dog 777. (a) Coronary arteriogram, right posterior oblique view. (b) Postmortem injected specimen in same position. R, right coronary artery. L, left anterior descending artery. C, circumflex artery. The site of occlusion is marked by the proximal metallic clip.

Fig. 3. Dog 786. Coronary arteriogram, right posterior oblique view. The site of occlusion of a branch of the circumflex artery is indicated in the roentgenogram and tracing by the metallic clip. The round metallic object at the level of the aortic arch was a buckshot.
Fig. 4. Patient R. W. Diagnosis: mediastinal tumor. Coronary arteriogram, right posterior oblique view. Note filling of the anterior descending and circumflex arteries.

Fig. 5. Patient B. K. Left posterior oblique view. Note that the anterior descending and circumflex arteries did not fill. Autopsy showed marked arteriosclerotic narrowing of these vessels. The right coronary artery was essentially normal.
The possibility that coronary arteriography may prove of value in the detection of coronary artery disease is suggested by the demonstration of the site of occlusion in the animals prepared by coronary ligation. This is further suggested by the failure of the left coronary artery to fill in patient B.K. (fig. 5), related, in our opinion, to the extensive arteriosclerotic narrowing found in this vessel at autopsy.

The most important consideration in coronary arteriography is its effect upon the patient. Jönsson\(^4\) noted no reactions in 5 patients in whom the coronary arteries were filled. In our group of 10 patients there was 1 fatality which has been previously reported.\(^1\) This occurred in an 88 year old moribund woman who died suddenly after the sixth injection of 10 cc. of 70 per cent Diodrast. This was one of the early cases and since that time no significant reactions have been encountered. In Grossman’s experiments\(^2\) 4 out of 5 dogs succumbed to the procedure. In our 15 animals there were 5 deaths which were attributed to the arteriography. Each death occurred in an animal who had been subjected to thoracotomy with coronary ligation a few hours earlier.

The 2 patients who had electrocardiograms taken during the procedure developed no arrhythmias. All the dogs that developed arrhythmias had had coronary ligation. It is to be noted that no electrocardiographic abnormalities were found in normal dogs during the procedure as performed by Pearl and his coworkers.\(^1\)

The contrast substances used in this study were 75 per cent Neo-Iopax and 70 per cent Diodrast. No sensitivity reactions were encountered. Because of the reactions of blood vessels to these concentrated media, it is felt that neither of them is ideal for coronary arteriography. The dangers of the method would be reduced if a safer contrast medium were found. It seems likely that the arrhythmias following the injection of Diodrast or Neo-Iopax are due to vasospasm, anoxia or direct irritation of the myocardium.

The polyethylene catheter has been very useful because of the thinness of its wall, which permits a larger bore to be inserted into the artery. It has the disadvantage of being radiolucent. It was noted that arterial spasm occurred unless a catheter was used which moved freely and without friction in the artery. Thrombosis of the incised artery did not occur in any patient.

Prior to the use of the Fairchild Roll Film Cassette one Bucky film was made at the end of each injection and multiple injections were often necessary to obtain visualization of the coronary arteries. Since using the Fairchild Cassette fewer injections have been required since films made at one-half second intervals for a period of four seconds are more likely to depict the brief period of coronary opacification.

**Summary**

1. The coronary arteries in man and dogs have been visualized roentgenographically by catheterization of the ascending aorta and injection of radiopaque media.

2. The site of experimentally produced coronary occlusion in dogs has been demonstrated.

3. The hazards of the procedure are emphasized and it is recommended that, for the present, coronary arteriography should be limited to experimental investigation.

4. The method should prove of value in studying experimentally induced coronary artery disease in animals. With improved contrast agents it may prove helpful in the diagnosis of coronary artery disease in man.

**REFERENCES**


6. **Heyos, J. M., and Del Campo, C. G.:** Angiography of the thoracic aorta and coronary.
vessels, with direct injection of an opaque solution into the aorta. Radiology 50: 211, 1948.


Visualization of the Coronary Arteries during Life
JAMES A. HELMSWORTH, JOHNSON MCGUIRE, BENJAMIN FELSON and RALPH C. SCOTT

Circulation. 1951;3:282-288
doi: 10.1161/01.CIR.3.2.282
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1951 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/3/2/282

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/