Application to Coronary Arteries of the Basic Principles Governing the Development of Collateral Arterial Channels

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Numerous techniques have been studied in the past for the operative treatment of coronary arterial disease.1,2 The approach selected for the current project consists of an attempt to cause collateral arterial channels to develop from a transplanted donor artery to a distal coronary artery.

The problem was attacked by analyzing experiments reported in the literature (also studied by John3 and Winblad4) on the factors which determine when collateral arteries will develop and when they will not. During this study, a "common denominator" was found which seemed to be present in all situations in which collateral arteries developed.5 This "common denominator" consists of the presence of three conditions: (1) a suitable donor artery; (2) a hypotensive recipient artery; and (3) a pre-existing vascular communication between these two arteries.

A hypothesis was formulated which states that collateral arteries can be expected to develop if, and only if, the "common denominator" situation is present.

Many series of experiments were performed on a total of 350 dogs to test experimentally the application of this hypothesis to coronary arterial disease. Detailed presentation of these experiments will require many long papers or a monograph. The major findings are summarized herein.

Studies on the Donor Artery

The flow of significant quantities of blood to the coronary arterial system through collaterals from a pedicle was shown to occur only when a pedicle was used which contained a donor artery large enough to deliver significant quantities of blood and still maintain a high pressure at the point of delivery. It was found advisable to include soft tissue and a large vein in the pedicle to provide a small runoff bed from the artery. Otherwise, the artery was a blind pouch from the time of operation until the development of the first collateral. A high incidence of occlusion of the artery was found when the vein was ligated proximally.6

Many of the potential sites for collateral development seemed worthwhile, because the experiments showed that multiple moderate-sized collateral arteries should be expected rather than a single large one. Collaterals arose from recanalization of the end of pre-existing branches of the donor artery, rather than sprouting directly through the wall of the parent vessel.

Implantation near a moderate- or large-sized coronary artery was found to be advisable, in order to keep the potential collateral as short as possible. The speed and extent of development of collateral arteries seem to depend upon the pressure gradient per unit length of collateral.

The best results were obtained when the pedicle was sutured directly to a cleanly incised area of myocardium. Irritating substances, intended to stimulate vascular inflammation, were found to cause, primarily, an unhealthy granulomatous reaction with rather poor vascularization.

Studies on the Hypotensive Recipient Artery

The production of experimental chronic coronary hypotension was very difficult. It was found necessary to reduce the cross-sectional area of the proximal anterior descending artery of the dog to about half of normal before a reduction in flow occurred. It was

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also necessary to reduce the area even more severely, with reduction of the flow to about half of normal, before a decrease in the distal pressure occurred, because of a consistent chronic increase in the resistance of the distal coronary artery. The pressure had to be reduced chronically before collateral channels were stimulated. Too much reduction in the pressure caused a high mortality rate or myocardial infarction with relatively little need for collateral.6

The problem was eventually solved. The technique used included initial reduction of the cross-sectional area of the proximal coronary artery to between about 5 per cent and 15 per cent of normal. The constriction remained stable for one to two weeks, then gradually tightened automatically so that the artery was completely occluded one to two weeks later.

The device has been successfully applied on the anterior descending, circumflex, and right coronary arteries. It was unsuccessful on the left main coronary artery. This failure was probably caused by reduction of the flow in such a large area of the ventricle that the dog died of congestive failure before the development of sufficient hypotension to stimulate collateral formation.

Studies on the Pre-existing Vascular Communication

Most collaterals in the body which have been studied in the past could have developed from an initial vascular communication which had been present since birth. However, the only initial vessel available between a pedicle and a coronary artery is a newly developed capillary in granulation tissue across a suture line. Experiments were therefore performed on the hindleg of the dog to find out whether such a capillary could successfully develop into a satisfactory collateral artery.7 The results showed that these capillaries could, under favorable conditions, develop into multiple collateral arteries with lumen diameters up to 0.75 or 1.0 mm.

Experimental Methods

A pedicle containing the mammary artery, mammary vein, a portion of the sternocostalis muscle, and surrounding connective tissue was developed. It is believed to satisfactorily meet the requirements outlined herein. The pedicle was sutured in a flat tunnel beneath the surface of the left ventricle of dogs, passing under a large coronary artery. Irritating substances were not used.

An Ameroid device was developed for constric-
tion of the arteries in the manner described. It was applied to the proximal anterior descending, or to the anterior descending and circumflex arteries. The devices were either inserted at the same time as the pedicle or were applied at a later operation. The pressures in the distal coronary arteries were monitored during operation to permit proper adjustment of the devices.

Evaluation of Results

Many methods have been used for evaluation of "myocardial revascularization" in the past, and were considered for use in this project. Only two were selected.

Corrosion casts were made after autopsy of each dog and gave good anatomical demonstration of the arterial lumens. Frame-by-frame analyses of coronary cinearteriograms, taken with the hearts beating normally, were used extensively. This method is believed to provide a definite objective demonstration of the size and location of arteries, and of the direction and velocity of movement through collateral channels. No other method seems to offer as much information with relatively little disturbance of the circulation of the animal.

The results showed that collateral arteries to the involved coronary artery consistently developed when the constrictive devices were properly used. These collaterals consistently came from the pedicles that included the features described as desirable. They sometimes also came from other coronary arteries, if there were any normal ones nearby. Figure 1 shows filling of the anterior descending coronary artery distal to the occlusion, through collaterals from the pedicle. Figure 2 shows that the remainder of the left coronary arterial tree was filled from the sinus of Valsalva.

Summary

The experiments performed on 350 dogs showed that when certain technical points were observed, a pedicle containing the mammary artery, mammary vein, and surrounding soft tissue consistently contributed large col-
lateral channels which were capable of carrying the entire arterial blood supply to a large portion of the left ventricle of the heart of a dog with experimental chronic coronary arterial hypotension. Original plastic devices were used to produce controlled, gradual, coronary constrictions and occlusions.

Direction and velocity of movement and size of the donor arteries, the collateral channels, and the recipient coronary arteries were determined from frame-by-frame analysis of cinearteriograms.

Acknowledgment


References

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