The Effect of Acute Occlusion of the Coronary Sinus on the Coronary Circulation

By Alvin A. Bakst, M.D., Harry Goldberg, M.D., and Charles P. Bailey, M.D.

The changes in the coronary circulation, which are precipitated by the acute occlusion of the coronary sinus, have been investigated. In normal animals, retrograde blood emerging from the peripheral segment of a ligated and transected circumflex coronary artery is small in quantity, and arterial in nature, signifying an insignificant interarterial collateral flow. After the coronary sinus is arterialized, the retrograde circumflex arterial blood increases in quantity and is venous in nature. We now studied the effect on the coronary circulation of elevating the pressure of the coronary sinus by ligation, without arterIALIZATION. Under this condition, coronary sinus pressure rises, and retrograde circumflex flow is of normal quantity, but is also venous in nature. The source of this blood from the capillary bed and its directions of flow are discussed.

Our previous studies on the retrograde blood flow, and the oxygen content of this blood, obtained from the distal end of the ligated and transected circumflex coronary artery in dogs, revealed the normal collateral circulation to be insignificant, which directly confirmed previous work reported by Wiggers and Green. This retrograde flow averaged 1.7 cc. per minute, and the blood was highly oxygenated indicating its origin from neighboring arteries. It therefore represented a measure of intercoronary collateral anastomotic flow. These findings were significantly altered in dogs in which the coronary sinus had been arterialized for four to eight weeks. In these animals, the retrograde circumflex arterial flow increased markedly, averaged 12.2 cc. per minute, and was venous in nature. Since the pressure within the coronary sinus was elevated to systemic levels, and its blood was highly oxygenated, the venous nature of the retrograde circumflex arterial flow pointed towards a retroperfusion of the myocardial capillary bed.

These observations stimulated our curiosity as to the changes which would occur in the coronary circulation should the coronary sinus pressure be elevated by ligation, without arterIALIZATION.

Methods

Mongrel dogs, whose weights varied between 14 and 18 Kg, were used. They were anesthetized with intravenous sodium pentobarbital, after which artificial respiration was maintained, using intermittent positive pressure supplied through an endotracheal tube with an inflated rubber cuff. The left chest was entered through the fourth intercostal space, and the lung was retracted. Ten cc. of procaine hydrochloride (2 per cent) was injected into the pericardial sac, which was then opened widely. The left coronary artery was dissected to and slightly beyond its bifurcation into the left anterior descending and circumflex coronary arteries. Ligatures were placed around these two major branches. The coronary sinus was ligated immediately proximal to its entrance into the right atrium. After a lapse of 10 minutes a needle tipped polythene catheter, attached to a water manometer, was inserted into the coronary sinus, for obtaining coronary sinus pressure, and blood sample for determination of oxygen content. The circumflex coronary artery was dissected to and slightly beyond its bifurcation into the left anterior descending and circumflex coronary arteries. Ligatures were placed around these two major branches. The coronary sinus was ligated immediately proximal to its entrance into the right atrium. After a lapse of 10 minutes a needle tipped polythene catheter, attached to a water manometer, was inserted into the coronary sinus, for obtaining coronary sinus pressure, and blood sample for determination of oxygen content. The circumflex coronary artery was clamped immediately distal to the origin of the septal branch, in an effort to study its effect on the oxygen content and saturation. The minute volume of retrograde circumflex arterial blood flow was then recorded. Oxygen content of all blood samples was determined according to the method of Van Slyke and Neill.

The left anterior descending artery was then clamped immediately distal to the origin of the septal branch, in an effort to study its effect on the
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TABLE 1.—Retrograde Blood Flow, and Oxygen Content of Blood from the Peripheral Segment of the Transected Left Circumflex Coronary Artery following Acute Ligation of the Coronary Sinus

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Retrograde blood flow from the peripheral segment of the circumflex artery. However, in all animals, ventricular fibrillation ensued before flow studies, and blood samples for determination of oxygen content could be obtained.

Since the oxygen content of the specimen of coronary sinus blood taken before the circumflex coronary artery was cannulated was identical to that taken afterwards, only the simultaneous specimen is reported.

Originally, we attempted to establish control retrograde circumflex arterial flow values in the same dog, prior to the ligation of the coronary sinus. These flow values were within the range of the expected normal. However, during the 10-minute interval which we allowed to elapse prior to the collection of the physiologic data, either fibrillation ensued, or the heart beat became significantly weaker, and retrograde flows fell to minute volumes. Consequently, we deemed it imperative to perform immediate coronary sinus ligation and compare these values to those of the previously established normal control.

RESULTS

Retrograde Blood Flow from the Distal Segment of the Divided Circumflex Branch of the Left Coronary Artery. The results are shown in Table 1. The retrograde bleeding ranged from 0.6 cc. to 4.0 cc. with an average of 1.6 cc. per minute.

Oxygen Content of the Retrograde Circumflex Blood Obtained from the Distal Cut End of the Circumflex Coronary Artery. The results are shown in Table 1. The oxygen content of this retrograde blood was distinctly venous in nature, ranging in value between that of the pulmonary artery and the coronary sinus. It ranged from 2.0 to 10.9 volumes per cent, with an average of 6.0 volumes per cent. Concomitant samples of pulmonary arterial blood ranged from 6.4 to 12.1 volumes per cent, with an average of 9.6 volumes per cent.

Mean Coronary Sinus Pressure and Blood Oxygen Content. The mean coronary sinus pressure ranged from 48 to 58 cm. of water, with an average of 52 cm. of water.

The oxygen content of coronary sinus blood ranged from 0.5 to 2.7 volumes per cent, with an average of 3.0 volumes per cent.

The Effect of Ligation of the Left Anterior Descending Coronary Artery on the Retrograde Flow from the Distal Cut End of the Ligated Circumflex Artery. An attempt was made to measure the effect of occlusion of the anterior descending coronary artery on retrograde circumflex arterial blood flow, and oxygen content of this blood. However, in every animal, ventricular fibrillation regularly ensued within twenty to thirty seconds following the clamping of the vessel. In none of the animals did the ventricles beat for an adequate period of time to permit our retrograde flow studies.

DISCUSSION

In 1938, using a radiopaque lead-agar mass injected into a coronary artery, Schlesinger described the existence of anastomotic interarterial vessels in the normal heart. Prinzzmetal and his associates, by perfusing the left coronary artery with a suspension of glass beads of varying sizes, proved the existence of interarterial anastomotic channels, as well as direct arteriovenous anastomoses between the circumflex artery and the coronary sinus.

With this knowledge, we may proceed to...
analyze the results of our experiments. The retrograde blood from the distal segment of the circumflex coronary artery was of normal quantity and was definitely venous in nature. Close inspection of the data of the individual animals reveals that in all dogs save number 4, the retrograde coronary artery blood oxygen content ranged approximately midway between that of the coronary sinus, and the pulmonary artery. This desaturated blood might have arisen from the capillary bed, or from the coronary sinus via direct arteriovenous anastomoses. The fact that the oxygen content of the backflow blood was higher than that of coronary sinus blood probably indicated the admixture of a small quantity of oxygenated blood arising from interarterial collaterals. The unsaturation of this retrograde circumflex arterial flow served to confirm similar studies on retrograde flows from the left anterior descending artery by Gregg and Dewald. However, these investigators reported a significantly greater retrograde bleeding than we have found in our investigations. The presence of venous blood flowing in retrograde fashion from the distal segment of a transected coronary artery does not, per se, establish the existence of retroperfusion of the capillary bed. Gregg and Dewald noted that following coronary sinus ligation, the backflow blood was unsaturated, and contained less oxygen than venous blood. Inasmuch as it was abolished by their occlusion they concluded that it was derived from other unligated coronary arteries. They postulated that blood traversed the capillary bed and entered the venous system, where it was trapped, and was then rerouted from the venous system through a second set of capillaries, in retrograde fashion, to the coronary artery. We do not believe that the blood is rerouted through a second capillary bed, since, if this were true, its oxygen content would be lower than that of coronary sinus blood, and this is not true. We do believe, however, that the retrograde blood flowing from the peripheral segment of the transected circumflex coronary artery does arise from the capillary bed. Normally, following the ligation and transection of a coronary artery, the peripheral coronary arterial pressure averages 15 cm. of water as compared with a normal mean coronary sinus pressure of 6 cm. of water. Blood arising from the nonoccluded arteries enters the capillary bed and flows from the high to the low-pressure area. Since the transected peripheral circumflex arterial pressure is higher than that of the coronary sinus, the blood within the capillary bed flows in the direction of the low-pressure area, which is the coronary sinus. After the coronary sinus is occluded, its mean pressure rises to about 54 cm. of water, as compared with a concomitant rise of the peripheral coronary arterial pressure to about 40 cm. of water. Blood continues to reach the capillary bed from the unligated coronary arteries. Under these conditions, however, the peripheral segment of the ligated coronary artery represents the low-pressure point, and the capillary blood flows in its direction. This demonstrates the possibility of retrograde flow from the capillary bed to the coronary arteries. It is unnecessary to invoke a second passage of the blood through the capillary bed to explain the emergence of unsaturated blood from the distal segment of a transected coronary artery. Gregg, however, does state that potent venous drainage channels exist, so that, should the peripheral coronary artery be ligated but not opened to atmospheric pressure, no adequate collateral circuits exist to route the venous blood through the capillary bed of the occluded coronary artery.

**Summary and Conclusions**

Retrograde blood flow and oxygen content of the blood, obtained from the peripheral segment of the transected circumflex coronary artery, have been determined in dogs in which coronary sinus pressure had been elevated by acute ligation without arterialization. Following coronary sinus ligation, the mean pressure of the coronary sinus rose to from 48 to 58 cm. of water. Coronary sinus blood oxygen content, following occlusion, was unchanged from normal. The backflow from the distal segment of the circumflex coronary artery averaged 1.6 cc.
per minute, which was not different from that found in the normal animal.

The oxygen content of this retrograde blood was strikingly venous in nature, averaging 6.0 volumes per cent. This blood may arise from the myocardial capillary bed or from the coronary sinus via direct arteriovenous conduits.

Following arterialization of the coronary sinus, unsaturated retrograde circumflex arterial blood can only arise from the myocardial capillary bed.

Complete ligation of the coronary sinus was followed by a significant reduction in the left coronary artery inflow.

REFERENCES


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