Experimental Reversal of Capillary Blood Flow

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A number of recent investigations in vascular surgery have been based on the hypothesis that reversal of blood flow in capillaries is possible. Experimental and clinical attempts have been made to reverse the direction of the flow across the capillary bed by the anastomosis of arteries and veins. The present authors have shown by the microscopic observation of capillaries in acute experiments on cats, dogs and rabbits that a reversal of blood flow in mesenteric capillaries will occur following the connection of an artery to a vein provided the collateral arteries and veins are obstructed. Furthermore, it was shown that blood flowing in a reverse direction through capillaries loses oxygen.

The oxygen consumption of the part were determined.

Methods

Cats were used in most of the experiments and additional studies were performed on dogs and rabbits. Anesthesia was produced by the intraperitoneal injection of Nembutal. Several regions of the body were studied in preliminary experiments but we shall report only those which were made on the mesenteric blood vessels since they yielded the most conclusive results. A short low midline incision was made and the terminal ileum was delivered, thus exposing the mesenteric blood vessels of this area. The blood vessels of the ileocecal region were followed back to the root of the mesentery and large branches of both the mesenteric artery and vein were prepared for cannulation. The femoral artery and vein were similarly prepared. The method is illustrated in figure 1.

The cannulas consisted of polyethylene tubing of suitable caliber. The largest tubing that would fit the blood vessel was used in each case, the outside diameter varying from 2 to 4 mm. The cannulas were prepared by beveling the tips with a sharp scalpel, after which they were treated with DriSilicone. Short couplers of larger tubing, which fitted snugly over the cannulas, were used to connect them together. As can be seen in the illustration in figure 1, ligatures of braided silk were placed around the bowel and its remaining mesentery at the extreme ends of the segment of bowel under study, in order that the collateral blood supply could be eliminated when desired. Shortly before the cannulas were introduced, the animals were heparinized.

The quartz rod technic was used for the illumination of the blood vessels of the mesentery and a 500 Watt light source was employed. A constant gentle flow of Ringer's solution at 39 C. kept the tissues moist and warm. Motion of the tissues under study was prevented by the use of a small plastic

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One of us (R. H.) was a Fellow of the National Research Council of Canada, 1949-50.
The capillaries were observed using a binocular microscope, and from time to time were photographed on Kodachrome film employing a Kodak special movie camera. The rate of blood flow of the bowel segment was determined by temporarily disconnecting the venous cannula and timing the flow of blood. The oxygen content of the arterial and venous blood was determined by the method of Van Slyke and the rate of blood flow and the arterio-venous oxygen difference were used in computing the oxygen consumption. Pressures in the mesenteric lary and was drained away from the arterial end of the bed. Thus the capillary bed of an area was studied with the flow directed in the normal direction or in the reverse direction, and the direction of flow was altered as desired.

**Results**

Thirty-one experiments were performed on 19 cats, 3 dogs, and 3 rabbits. Excellent forward capillary blood flow was observed in

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**Fig. 1.** Showing the experimental procedure. Part of the small intestine has been delivered through an abdominal incision. A mesenteric artery and vein have been isolated. These vessels are connected by cannulas to the femoral artery and vein. Braided silk ligatures occlude the intestines and collateral blood vessels. The capillaries of the mesentery are studied microscopically.

...artery and vein were determined by means of small sidearms on the cannulas and a Sanborn Electro-manometer.

With the cannulas in place as shown in figure 1, studies were made with the blood flow in the normal direction, that is, from femoral artery to mesenteric artery through the capillaries and returning through the mesenteric and femoral veins. Following this, a retrograde perfusion was produced by attaching the arterial inflow cannula to the mesenteric vein, and the outflow cannula to the mesenteric artery. Under this latter condition, the arterial blood was directed at arterial pressure into the venous end of the capil-
The longest period that reversal of blood flow was observed was 57 minutes.

The rate of flow and the oxygen consumption of the segment of intestine were determined in ten experiments. The average flow was 4.42 cc. per minute with forward flow, and 3.07 cc. per minute with reverse flow. The oxygen consumption was 0.3 cc. per minute with forward flow and 0.17 cc. per minute with reverse. These figures are given in table 1. Even gross ob-

<table>
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<th>Excellent Microscopic Capillary Blood Flow</th>
<th>Normal perfusion</th>
<th>Reverse perfusion</th>
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<td></td>
<td>27 exps.</td>
<td>17 exps.</td>
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<tr>
<td>Average Rate of Blood Flow cc./min</td>
<td>4.42</td>
<td>3.07</td>
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<tr>
<td>Average Tissue Oxygen Consumption cc./min</td>
<td>0.3</td>
<td>0.17</td>
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Two other types of experiments will be commented upon briefly. An attempt was made to produce a chronic reversal of flow in a segment of bowel of heparinized animals but either death occurred or thrombosis at the site of the inflow cannula took place. In other animals, the terminal aorta and the inferior vena cava were severed, the proximal end of the aorta was anastomosed to the distal end of the vein and the distal end of the aorta to the proximal end of the artery but death occurred within 24 hours. We are not certain as to the cause of death.

Fig. 2. Showing the effect of collateral pathways on perfusion pressure. A. Pressure in mesenteric artery with flow in normal direction, collaterals open. B. Pressure of inflowing blood in mesenteric vein with retrograde flow, collaterals open, followed by elevation in inflow pressure that occurs when collaterals are tied.

The effects of opening and closing the collateral pathways on the perfusion pressure are shown in figure 2.

**Discussion**

The present experiments show that at least temporary retrograde flow in the capillary bed can be produced by transposing the arterial inflow and the venous outflow. However, the studies indicate that this retrograde flow occurs only if the collateral arterial pathways are closed. This finding may be due in part to the resistance to inflow imposed by the cannula. The presence of a plexus of collateral veins provides a shunt mechanism through which the blood in a mesenteric vein at an artificial arterial pressure can escape directly into the general venous return, thereby avoiding the capillary bed. The studies reported in figure 2 support this statement. At any rate, this finding in studies on the intestinal tract suggests that the presence of uninterrupted collateral arteries and veins in the heart, brain, or extremity would exert the same inhibitory influence upon the reversal of capillary blood flow. Moreover, if reversal is to occur in these organs, the blood must leave by way of the organs’ arteries.
The tissue oxygen consumption fell from an average of 0.3 cc. per minute during normal perfusion to an average of 0.17 cc. during retrograde perfusion. However, in three experiments there was no decline. The figures should not be compared too critically for it should be remembered that a mesenteric artery and its adjacent vein do not necessarily connect with identical areas of the capillary bed. The figures do show that the tissues will take up oxygen from blood flowing through its capillaries in a reverse direction.

**SUMMARY**

It has been shown in acute experiments on cats, dogs and rabbits that a reversal of blood flow in mesenteric capillaries will occur following the connection of an artery to a vein providing the collateral arteries and veins are obstructed. The blood must be permitted to leave the area by means of the mesenteric arteries. Blood flowing in a reverse direction through capillaries loses oxygen.

**REFERENCES**


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