Simultaneous Comparison of Antegrade and Collateral Coronary Blood Flows

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Comparison of the antegrade and retrograde (collateral) coronary free flows showed that the retrograde flow was less than 10 per cent of the antegrade flow in 48 per cent of animals and above 20 per cent in 11 per cent of animals.

A practical method for measuring the collateral (retrograde) coronary arterial flow in animals was described by Wiggers and by Mautz and Gregg. Other techniques have been devised to measure the antegrade or normally directed coronary flow. However, heretofore it has not been possible to measure both antegrade and retrograde coronary flows simultaneously. Such simultaneous measurement would be valuable because the adequacy of the collateral circulation in a given animal cannot be judged by the absolute minute-volume of the retrograde flow alone. A much sounder estimate of the functional usefulness of the collateral circulation could be derived from a knowledge of what proportion of the antegrade flow is represented by the collateral flow. In order to obtain such a ratio, a new method has been developed capable of measuring both antegrade and collateral flows simultaneously. The retrograde flow measurement is similar to the Mautz-Gregg; the simultaneous collection of the antegrade flow has not been previously described. No simultaneous direct measurement of retrograde-antegrade flow could be possible with the available methods for recording mean coronary inflow, such as by the thermostromuhr, the rotameter, the bubble flow meter, and by the use of nitrous oxide based on the Fick principle.

METHODS

Dogs (14 to 16 Kg.) were anesthetized with intravenous Nembutal (25 mg./Kg.). Respiration was maintained by an intermittent positive pressure breathing apparatus. Blood volume was maintained by intravenous saline or dextrose solution and by return of the blood lost through the chest incision and cannulated coronary vessel. In certain instances, where there was much blood loss, replacement was by slow transfusion of another dog's blood. From 100 to 200 mg. of heparin was given intravenously to prevent coagulation in the cannulation system.

Through a small opening made in the pericardium, the anterior descending artery was dissected from its bed about 2 cm. below its origin and freed from the accompanying vein on either side. It was then ligated and cannulated above and below the ligature for the measurement of the retrograde flow, respectively. The retrograde flow measurement was similar to the Mautz-Gregg; the simultaneous collection of the antegrade flow has not been previously described. No simultaneous direct measurement of retrograde-antegrade flow could be possible with the available methods for recording mean coronary inflow, such as by the thermostromuhr, the rotameter, the bubble flow meter, and by the use of nitrous oxide based on the Fick principle.

RESULTS

Simultaneous antegrade and retrograde flows were measured in each of 105 animals (table 1). The retrograde flow varied considerably in different animals. The average retrograde flow was 3.6 ml./min. The range was from 1.9 to 8.6 ml./min. There was also great variation in the antegrade free flow. The average was 32.1 ml./min. The range was from 18 to 70 ml./min.

The retrograde flow averaged 11.5 per cent of the antegrade flow in the 105 dogs. The range was from 2.9 to 28.8 per cent. In assessing the retrograde-antegrade flow ratios, it
CORONARY BLOOD FLOWS

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<tr>
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<th>Retrograde flow (ml./min.)</th>
<th>Antegrade flow (ml./min.)</th>
<th>Retrograde-antegrade flow ratio (per cent)</th>
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</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.6</td>
<td>32.1</td>
<td>11.5</td>
</tr>
<tr>
<td>Range</td>
<td>1.9–8.6</td>
<td>18–70</td>
<td>2.9–28.8</td>
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was determined that in 92 per cent of the dogs the flow ratio was greater than 5 per cent. In 52 per cent, it was above 10 per cent. In 25 per cent, it was above 15 per cent. In 11 per cent, the ratio was above 20 per cent. There was no correlation between the antegrade and collateral blood flows. In most instances, there appeared to be a fair correlation between the volume of retrograde flow and the retrograde-antegrade flow ratio; the higher the retrograde flow, the greater the ratio. Several exceptions to this rule were observed. That measurement of the retrograde or collateral coronary flow alone, without reference to the corresponding antegrade flow, cannot provide a meaningful estimate of the adequacy of the collateral circulation was clearly demonstrable by contrasting the flow ratios of 2 particular dogs (nos. 48 and 57). In both, the collateral flow was 5 ml./min.; however, in dog 48 the antegrade flow was 70 ml./min.; in dog 57 the antegrade flow was 25 ml./min. This would indicate that the collateral flow in the former of 7.1 per cent is less adequate than that of the latter where the ratio was 20 per cent.

In general, in the experimental animal, the lower the retrograde-antegrade ratio, the less adequate is the collateral circulation and vice versa.

**Discussion**

The functional value of the collateral coronary circulation has long been debated. Many investigators believe that the anastomatic circulation, which is believed to be of almost arterial capacity, does not function until some time after a coronary artery occlusion or severe narrowing. Blumgart demonstrated that the collateral circulation is extensive in 15 per cent of humans with normal hearts and increases considerably in patients following coronary thrombosis.

Our method permits the calculation of the retrograde to antegrade flow ratio, providing a reasonable estimate of the functional value of the collateral circulation. The marked variability of this ratio in different dogs explains the lack of agreement among previous investigators concerning the functional value of the collateral circulation. In 48 per cent of our dogs, the ratio was less than 10 per cent. In these animals, it would seem that the collateral circulation was of little or no significant value until some weeks after a coronary artery occlusion. In approximately 11 per cent of our dogs, however, the ratio was over 20 per cent. It appears likely in this group that the coronary circulation was of considerable physiologic value. This may explain why myocardial infarction fails to occur in some animals following a coronary ligation.

It might be pointed out in criticism of this open method of measuring coronary flow that the results have been influenced by the absence of coronary vascular resistance which might modify coronary flow. This is a logical criticism; nevertheless, if one is concerned chiefly with the retrograde-antegrade flow ratio rather than the absolute flow, this objection is minimized. Both the antegrade and retrograde flows are measured simultaneously under the same conditions of systemic blood pressure, cardiac rate, metabolic state and vasomotor tonus.

This new method of assessing collateral circulatory function has proved helpful in evaluating the effects of the arrhythmias, variations in systemic blood pressure, experimental drugs, and surgical and other medical measures designed to improve the collateral circulation in the presence of coronary artery disease.

**Summary**

A simple method is presented for assessing the adequacy of the collateral coronary circulation, i.e., by simultaneous measurement of the retrograde and antegrade flow of the anterior descending artery. In 105 dogs, the
average retrograde flow and antegrade flow were 3.6 and 32.1 ml/min, respectively; the average retrograde-antegrade flow ratio was 11.5 per cent. This ratio ranged from 2.9 to 28.8 per cent in different animals.

In 48 per cent of the dogs studied, the retrograde-antegrade flow ratio was less than 10 per cent. This probably indicates that the collateral circulation was functionally relatively insignificant in these animals. In 11 per cent of the dogs, however, a ratio above 20 per cent was found. This figure probably indicates a functionally significant coronary flow.

The importance of the retrograde-antegrade flow ratio and the practical value of the method are discussed.

REFERENCES
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