Retrograde Perfusion of the Coronary System*

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INTRODUCTION

During the last 15 years, retrograde perfusion of the coronary vessels has been applied in surgery of the heart to prolong the time of reversible cardiac standstill.\(^4\) However, the results remained mediocre and most authors abandoned this method to support the myocardium during operation.

In order to find a plausible explanation for these conflicting results, perfusion experiments were carried out, in vitro, using bovine (40), porcine (20) and canine (20) hearts.

METHODS

All the hearts used in the experiments were isolated from the circulation immediately after death. The coronary vessels were washed out—both in antegrade and retrograde direction—with a heparinized isotonic saline solution. This was done to prevent clots, if formed, from interfering with the experimental results. Once isolated, the heart was weighed and suspended by the aorta from a special stand (Fig. 1).

Cannulae were introduced and fixed into the left and right coronary orifices. A specially designed cannula, which incarcerates itself in the opening between the right auricle and the coronary sinus, fixed with a purse-string suture, avoided leakage in the coronary sinus during perfusion (Fig. 2).

Needles, with a diameter of 2 mm., were placed at the lowest point in the left and right ventricular cavities, to collect the intracavitary fluid. The perfusion fluid used was physiologic saline, at a temperature of 37°C. In all experiments, the fluids collected from cannulae and needles were received in graded cylinders, while the fluid injected was kept in a reservoir in which the level could be measured.

In pigs and calves, the great azygos vein had to be clamped since it drains directly into the coronary sinus. This is contrary to dogs and men where the great azygos vein opens up into the superior vena cava.

Microscopic postmortem examination of the retrograde perfused hearts was carried out. All hearts were weighed before and after retrograde perfusion.

Perfusion

In all experiments, the coronary vessels were perfused under pressures of 20, 30,
Cannula in situ in the coronary sinus

![Image of cannula](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21398/)

40, 50 and 60 mm.Hg, each during five-minute periods. After every period, the flow was determined at the entry and exit of cannulae and needles. Knowing the retrograde flow through the orifices of the left and right coronary artery and the flow to the ventricular cavities, the distribution of retrograde perfusion could be measured.

**Calculations**

The quantities of fluid which appeared in various parts of the heart, were measured relative to the total quantity of the fluid administered, and converted to percentages. For each animal species we present not the average percentage, but the upper and lower limits to give the clearest possible idea of the spread (Table 1). Average values for all five-minute perfusion periods at various pressures were accepted as starting-points in Graph 1.

**Results**

**A. Bovine Hearts.** Retrograde perfusion of bovine hearts made it possible to demonstrate the relation between perfusion pressure and retrograde flow. Up to a pressure of 50 mm.Hg, the flow increased with an increase in pressure. Any increase in pressure above this value was not associated with an appreciable increase in flow (Graph 1).

In these experiments, the larger portion of the fluid injected passed directly from the coronary sinus to the cardiac cavities, via the Thebesian veins (Table 1, Graph 2). When the perfusion pressure was increased, drainage via the right heart increased at the expense of the outflow of fluid via the orifices of the coronary arteries and Thebesian veins of the left auricle and ventricle. At perfusion pressures of 40, 50 and 60 mm.Hg in some experiments there was no outflow at all from the right coronary ostium.

**B. Porcine Hearts.** The results obtained in this series of experiments were very similar to those of the preceding series. The same relation was found between the perfusion pressure and the retrograde flow at given pressures (Graph 1). The distribu-

**Graph 1**

Correlation between the retrograde flow and pressure, in the bovine, porcine and canine heart.

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**C. Canine Hearts.** Generally a similar relation between perfusion pressure and...
retrograde flow, was found in dogs (Graph 1). The distribution of the perfusion fluid is again similar to that in the bovine and porcine hearts (Table 1, Graph 2). There was always drainage via the right coronary artery in dogs.

In all these experiments, about 70 per cent of the perfusion fluid irrigated the right auricle and ventricle, while only 18 per cent reached the left auricle and ventricle. The remaining 12 per cent flowed through the orifices of the coronary arteries, particularly through the left. Regardless of the duration of the perfusion, the weight increase of the perfused hearts never exceeded 20 per cent of the initial weight. In the microscopic preparations of the hearts, after perfusion had taken place, no clots could be demonstrated in the coronary vessels. In the majority of specimens of the three animal species examined, there was a linear relation between the weight and the retrograde flow at given pressures.

**DISCUSSION**

These three series of experiments permit us to make the following deductions:

(a) The relation between weight and retrograde flow is not similar from one species to the other. In spite of the fact that the average weight of the porcine heart is 70 grams larger than that of the bovine heart, the average retrograde flow is higher in calves (Graph 1). It seems likely that

<table>
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<th>Type</th>
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**TABLE 1—DISTRIBUTION OF PERFUSION FLUID (PER CENT OF TOTAL SALINE ADMINISTERED TO THE CORONARY SINUS) IN THE BOVINE, PORCINE AND CANINE HEART, AT VARIOUS PRESSURES**
these differences are based on anatomic conditions inherent to each species. In this respect, it should be realized that we are dealing with new-born calves and grown-up pigs.

(b) In pig, calf and dog hearts, there is a linear relation between perfusion pressure and retrograde flow up until 50-60 mm.Hg.

(c) In all experiments, the larger part of the perfusion fluid directly entered the right auricle and ventricle, passing in decreasing quantities to the left auricle and ventricle, the orifice of the left coronary artery and finally the orifice of the right coronary artery.

The explanation of this distribution of perfusion fluid is a shunting of the larger part of this fluid from the coronary sinus to the cavities of the heart, by way of the Thebesian veins. The observations that the Thebesian veins opening up into the right auricle and ventricle are much more numerous than these opening up into the left heart, correspond with our results.14

When comparing the increase in weight of antegrade and retrograde perfused hearts, evidence is collected to support this explanation. During postmortem antegrade perfusion of the human heart with a non-oncotic perfusion fluid, an increase in weight of 40 per cent or more was found, caused by interstitial edema. During antegrade perfusion of the isolated living rat heart, comparable figures were reported.15 Antegrade postmortem perfusion of dog hearts even yielded figures up to 80 per cent. However, during retrograde perfusion, the weight increase never exceeded 20 per cent, the osmolarity of the perfusion fluids used being the same in all experiments.

This observation is in accordance with a direct shunting of a large amount of the perfusion fluid, via Thebesian veins, to the cavities of the heart during retrograde perfusion. That very little and sometimes no fluid appeared in the right coronary ostium may be explained by the finding of Gregg, that sometimes the right coronary artery is drained by the anterior cardiac veins, of which these opening up into the right auricle cannot be included in the retrograde perfusion.16

Two factors appear to account for the ineffectiveness of retrograde perfusion to support the beating heart deprived of its coronary blood supply.

(a) In all experiments, maximal retrograde flow, at a pressure of 50 mm.Hg never reached more than 10 per cent of the flow during antegrade perfusion, at normal pressures.

(b) The areas perfused by the retrograde flow are mainly located in the right ventricle, whereas this method is devised for surgery in conditions in which a hypertrophic left ventricle can be expected (valvular aortic lesions).
REFERENCES


MYXOSARCOMA COMPLICATING CYSTIC HAMARTOMA OF LUNG

A case of rapidly developing myxosarcoma of the lung in a two-year-old girl is described. The condition appeared first as a left-sided pneumothorax; when the lung expanded, a large tension cyst presented which had to be removed by thoracotomy. The history of the removed cyst was compatible with cystic hamartoma and it is postulated that the myxosarcoma developed from remnants of this tumor. A second thoracotomy was performed four months later and a myxosarcoma was found to have infiltrated the whole lung, mediastinum and diaphragm; its removal was not feasible. The child died 30 days after operation.


POST MORTEM BRONCHOGRAPHY IN STUDY OF BRONCHITIS AND EMPHYSEMA

Airborne lead particles were used to produce post-mortem bronchograms. The method has the special merit of outlining the bronchial tree to respiratory bronchleole level where the presence of alveoli projecting from the walls results in a distinctive change of outline. The in vivo appearance of "peripheral pooling" has been duplicated in the post-mortem bronchograms of a case of centrilobular emphysema. Bronchograms of normal lungs have shown far fewer branchings of the bronchial tree leading to respiratory bronchleole level in the central tissue of the lungs than has previously been recognized. There may be as few as six branches from the main bronchus to the first respiratory bronchleole.