The Effect of Arterialization of the Coronary Sinus in Dogs on Mortality Following Acute Coronary Occlusion

By R. W. Eckstein, M. D., George Smith, F. R. C. S., Morton Eleff, and James Demming

The mortality rates were determined in two groups of dogs following acute circumflex artery occlusion. Both groups were surgically prepared in the same manner. In a group of 20 dogs the coronary sinus was cannulated to divert the blood into the left jugular vein. Circumflex artery ligation resulted in 70 per cent mortality within one hour. In a second group of 10 dogs the coronary sinus was arterialized from the left subclavian artery and the sinus mean pressure was held at 50 mm. Hg. In this group circumflex artery ligation resulted in 100 per cent survival for one hour. Statistical analysis shows the results to be highly significant. The results strongly suggest that arterialization of the coronary sinus protects the hearts of dogs from ventricular fibrillation following coronary artery ligation.

After some years of animal research by Beck and his associates have reported remarkable success in attempts to revascularize the heart. The technical at present employs a vein graft between the aorta and the coronary sinus. Some three weeks later the coronary sinus is partially occluded near its ostium. Following these procedures they have ligated a major branch of the coronary arterial system with a remarkably low mortality when compared with the mortality from coronary ligation in normal dogs. There is no doubt that these operations protect dogs from the generally disastrous effects of a major coronary occlusion. However, the mechanism of this protection has not been critically studied and at present is only theoretic.

Although elucidation of the details of this abnormal physiologic situation is desirable in chronic dogs, we have chosen to study the effects of acute arterialization of the coronary sinus in dogs on the acute mortality rate following acute coronary ligation. This study serves to answer the questions, (1) whether there is immediate protection resulting from arterialization of the coronary sinus or whether protection occurs only after some weeks and (2) whether the protection is due to extra coronary collaterals which grow into the myocardium during the development of scar tissue in the chronic dogs. Therefore, this report deals with a comparison of acute mortality statistics following acute circumflex artery occlusion between two groups of dogs, namely, those with acute arterialization of the coronary sinus and those without.

Methods

The following method was adopted after a group of experiments were done to develop a rapid and standard technic. Mongrel dogs whose weights varied between 8.2 and 26.1 Kg, were anesthetized with morphine and pentobarbital. Under artificial respiration the left chest was opened with a cautery between the fourth and fifth ribs. The pericardium was slit and the circumflex branch of the left coronary artery was isolated at its origin. A loose ligation was placed. The left subclavian artery was treated likewise. A ligature was passed around the coronary sinus near its ostium. The animal was heparinized*. The left jugular vein was cannulated and connected to the outflow side of the double lumen coronary sinus cannula (fig. 1). This cannula was then passed through the tip of the right auricle and tied securely into the coronary sinus. The left subclavian artery was cannulated and connected to the second lumen of the coronary sinus cannula. This connection was clamped until the preparation

* The heparin was kindly supplied by Ben Venue Laboratories, Inc., Bedford, Ohio.
was complete. The aortic blood pressure was optically recorded through a cannula passed into the aorta through the left common carotid artery. Coronary sinus pressure was optically recorded from the exit lumen of the coronary sinus cannula. By means of a mercury manometer it was possible at all times to see the mean coronary sinus pressure. Electrocardiograms were taken and usually aVR was used. The entire preparation was completed in from 30 to 45 minutes. An arterial and coronary sinus blood sample was drawn from most animals and analyzed for oxygen content by the method of Van Slyke and Neill.5

Two groups of experiments were done. (A) This consisted of 10 dogs ranging in weight from 8.2 to 15.3 Kg. (average 10.1). In this group the connection between the left subclavian artery and the coronary sinus remained clamped, and the coronary sinus blood flowed into the left jugular vein without interposed resistance. After control aortic and sinus pressures and electrocardiograms were taken, the ligature about the circumflex artery was tied. Further pressures and electrocardiograms were taken and the fate of the animal was awaited. Those animals living more than 60 minutes were classed as survivals.

(B) There were 20 dogs in this group and these can be divided into two groups of 10 each, which were done alternately. (1) The dogs in this group ranged in weight from 9.5 to 26.1 Kg. (average 15.3) and were done exactly as in (A) above. (2) The second group consisted of dogs whose weights ranged from 9.1 to 25 Kg. (average 13.3) and were prepared as above. However, after control data were obtained the clamp between the left subclavian artery and the coronary sinus was removed and a screw clamp was tightened upon the outflow connection of the coronary sinus so as to maintain a mean coronary sinus pressure of 50 mm. Hg. After the blood pressure and electrocardiograms revealed no further change, the circumflex artery was ligated as before. A coronary sinus pressure of 50 mm. Hg was maintained and the death of the animal was awaited. At the close of the experiment the ligature was removed from the circumflex artery and a dilute solution of India ink was injected into it. The dyed area was cut out and weighed so as to relate the weight of the ischemic area to the total heart weight.

**RESULTS**

**Group A**

The results are shown in table 1. In this control group seven dogs died of ventricular fibrillation in an average time of 8.9 minutes. The remaining three dogs lived over 60 minutes and are classed as survivals. One of these died in 67 minutes with ventricular fibrillation and the remaining two were sacrificed after two hours. All dogs showed abnormal electrocardiograms after ligation of the circumflex artery.

**Group B-1**

In this group of alternate dogs without arterIALIZATION there were likewise seven deaths and three survivals. The deaths were all due to ventricular fibrillation in an average time of 7.9 minutes. The three surviving dogs were sacrificed: one in 70 minutes, one after 85 minutes, and one after three hours. All dogs showed abnormal electrocardiograms after circumflex artery ligation.

**Group B-2**

This entire group of 10 alternate dogs with arterIALIZATION of the coronary sinus under a pressure of 50 mm. Hg survived for 60 minutes. One of these died in 62 minutes in asystole and one died of ventricular fibrillation in three hours. In the remaining eight dogs, coronary sinus arterIALIZATION was discontinued at the end of 60 minutes with the return of sinus pressure to normal. Five of these dogs were
ARTERIALIZATION OF CORONARY SINUS FOLLOWING OCCLUSION

sacrificed in from one and one-half to two and one-half hours. However, the remaining three dogs developed ventricular fibrillation in 8, 10, changes are usually minor and consist of a reduction in the amplitude of QRS complex with a flattening to a slight inversion of the T wave

Table 1.—Showing Range and Averages of Dog Weight, Arterial Oxygen Content, Coronary Sinus A-V Oxygen Difference, Aortic Blood Pressure and Percentage of Total Heart Rendered Ischemic by Circumflex Ligation

<table>
<thead>
<tr>
<th></th>
<th>Group A Control 10 Dogs</th>
<th>Group B 1 Control 10 Dogs</th>
<th>Group B 2 10 Dogs Arterialization of Coronary Sinus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog Weights (Kg.)</td>
<td>Range: 8.2–15.3 Aver.: 10.1</td>
<td>Range: 9.5–26.1 Aver.: 15.3</td>
<td>Range: 9.1 Aver.: 13.3</td>
</tr>
<tr>
<td>Arterial Oxygen Content (Vol.%)</td>
<td>Range: 11.5–19.3 Aver.: 13.7</td>
<td>Range: 8.4–18.7 Aver.: 14.5</td>
<td>Range: 9.1 Aver.: 17.7</td>
</tr>
<tr>
<td>Percent of Total Heart Weight made Ischemic by Circumflex Ligation</td>
<td>Range: 36.0–77.0 Aver.: 40.6</td>
<td>Range: 28.0–38.0 Aver.: 35.0</td>
<td>Range: 33.0–56.0 Aver.: 44.0</td>
</tr>
<tr>
<td>Mean Aortic Pressure (mm. Hg) before Arterialization and Artery Ligation</td>
<td>Range: 47.0–137.0 Aver.: 87.8</td>
<td>Range: 48.0–138.0 Aver.: 99.4</td>
<td>Range: 74.0 Aver.: 140.0</td>
</tr>
<tr>
<td>Mean Aortic Pressure After Arterialization of Sinus</td>
<td>Range: 64.0–118.0 Aver.: 82.5</td>
<td>Range: 74.0–140.0 Aver.: 95.1</td>
<td>Range: 64.0–118.0 Aver.: 82.5</td>
</tr>
<tr>
<td>Time of Survival After Artery Ligation (minutes)</td>
<td>Range: 4.0–60.0 Aver.: 24.2</td>
<td>Range: 2.0–60.0 Aver.: 23.5</td>
<td>Range: 60.0 Aver.: 24.2</td>
</tr>
<tr>
<td>Time Until Ventricular Fibrillation Occurred (minutes)</td>
<td>Range: 3.0–18.0 Aver.: 8.9</td>
<td>Range: 2.0–37.0 Aver.: 7.9</td>
<td>Range: 30 Aver.: 100</td>
</tr>
<tr>
<td>Percent Survival for 60 Minutes</td>
<td>30</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 2. Electrocardiograms taken on lead aVR. A. control; B. 1½ minutes after coronary sinus arterialization at 50 mm. Hg; C. same but 1 minute after ligation of circumflex artery; D. control from control dog; E and F. changes produced in 30 seconds and 1 minute respectively following circumflex artery ligation without previous sinus arterialization.

and 17 minutes following discontinuation of coronary sinus arterialization. The typical electrocardiographic changes following arterialization of the sinus are shown in figure 2 B. These in aVR. Displacement of the S-T segment has not been observed. Figure 2 C shows the typical changes following circumflex artery ligation in the presence of previous sinus arterialization.
These changes consist of marked T wave inversion, S-T segment displacement and increased amplitude of the QRS complex in aVR. That these electrocardiographic abnormalities are similar to those occurring without sinus arterialization may be seen by comparing figure 2 C with figure 2 E and F, the latter two records being taken from a control dog.

A study of table 1 reveals that the one constant difference between the two groups was the mean aortic pressure decline of 12.7 mm. Hg which resulted from arterialization of the coronary sinus.

**DISCUSSION**

A statistical analysis of the mortality rates in these experiments shows the 100 per cent survival in the arterialized group of 10 dogs to be highly significant. When calculated for differences in the B group the significance value is .0015. If the total group of 20 control dogs is compared with the arterialized group the value is less than .0015. This means that the chance of 10 consecutive dogs to survive acute circumflex ligation is about 1 in 667. The rather small differences in average values shown in table 1 in regard to dog weight, arterial oxygen content, coronary sinus arteriovenous oxygen difference, aortic pressure and per cent of total heart rendered ischemic would indicate that the groups were similar. All the dogs were operated in the same manner and in the same experimental time. The circumflex arteries were all ligated at the same location, namely, at their origins. This in all cases included the left auricular artery which in many cases produced auricular arrhythmias. We believe, therefore, that these experiments critically demonstrate that in dogs acute arterialization of the coronary sinus at a pressure of 50 mm. Hg protects the hearts from ventricular fibrillation after acute circumflex artery ligation.

These experiments answer certain questions. First of all, they demonstrate convincingly that this procedure is immediately effective and therefore must depend upon existing vessels and not the growth of new vessels. Second, these studies rule out the possibility that the protection induced by this procedure results from the growth of extra coronary collaterals through scar tissue. Finally, the severe electrocardiographic abnormalities in all dogs after circumflex arterial ligation show without doubt that arterialization of the coronary sinus does not even approximate the original function of the occluded artery. The fact that the ischemic area is dark in color and is seen to bulge with systole lends support to this view. Nevertheless these hearts continue to beat and usually maintain adequate levels of blood pressure. At present we have no positive information on the possible changes in cardiac output.

This study raises immediate questions as to the mechanism of the observed protection. In the first place, does the presence of such an arteriovenous fistula so close to the heart, with the observed average fall of 12.7 mm. Hg in aortic pressure, in itself modify the mortality rate after coronary arterial ligation? Second, will simple elevation of coronary sinus pressure without the arterialization of the sinus likewise protect against ventricular fibrillation? That this is possible is strongly suggested by the studies of Gross, who was able to reduce the incidence of ventricular fibrillation and myocardial infarction following ligation of the left descendens artery by previous partial ligation of the coronary sinus. Finally it must be suggested that this procedure may even embarrass the capillary circulation in the areas of the heart supplied by the nonligated vessels, thereby reducing cardiac output work and oxygen requirement. Such a possibility suggests itself because of observations on the resistance to ventricular fibrillation which is seen in dogs with low outputs due to long periods with open chests. It is clear that these possibilities must be studied. Experiments are already in progress and will be reported in the near future.

**SUMMARY**

Acute mortality rates have been determined in 30 dogs following acute circumflex artery ligation. In 10 of these dogs the coronary sinus was arterialized at a pressure of 50 mm. Hg immediately prior to the arterial occlusion.

There was a 70 per cent mortality within one hour in the 20 control dogs without arterialization of the sinus while there were no deaths within one hour in the experimental group of
10 dogs with arterialization of the sinus. A statistical analysis shows these mortality differences to be highly significant.

It is suggested that arterialization of the coronary sinus in dogs protects them from ventricular fibrillation following circumflex arterial occlusion, but such a procedure is by no means a total substitute for the function of the occluded vessel.

Acknowledgments

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References

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