AN EXPERIMENTAL STUDY OF DIATHERMY.

III. THE TEMPERATURE OF THE CIRCULATING BLOOD.

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We have convinced ourselves by experiment that the normal lung can be heated only slightly above the systemic temperature by the application of high frequency currents to a dog's thorax (1). Interference with the circulation of blood to the lung, however, either by clamping one of the main branches of the pulmonary artery, or by ligation of all the root vessels, provides the conditions necessary for local deep heating (2). The implication that the circulating blood serves to carry away the heat produced in the lung seems obvious. Such an interpretation is in harmony with the physiology of heat distribution and temperature regulation (3). It is probable that together with its many other equilibrating functions the blood is a fairly ideal medium for distribution and maintenance of a uniform temperature.

Methods.

The methods which we have previously used for deep temperature measurements were easily modified for the purpose of recording intravascular temperatures. In place of the thermocouple needle we used similar copper-constantan couples housed in No. 14 gauge rolled steel tubing 10 cm. long. The junction was soldered to the end of the tubing, the solder forming a smooth, blunt tip. Capillary rubber tubing with a 3 mm. outside diameter was used to protect the wires. This was sufficiently small to permit its passage through the femoral vein or artery into the vena cava and aorta, or through the jugular and carotid, into the right and left heart. The steel and rubber tubing were smeared with a petroleum jelly of high melting point to inhibit blood clotting about them.

The methods for applying diathermy were those previously described.
The Temperature of Arterial and Venous Blood.

Experiment D 24.—A male mongrel hound weighing 21.7 kilos was anesthetized by the intravenous injection of barbital-sodium. The right femoral artery and left femoral vein were exposed and opened sufficiently to admit the passage of two thermocouples into their lumina. These thermocouples were then pushed up into aorta and vena cava. At the conclusion of the experiment the aortic thermocouple was found in the abdominal aorta just under the diaphragm; the other in the vena cava at the opening of the superior hepatic vein. The dog’s rectal temperature was recorded by a mercury thermometer calibrated in 0.10°C., which could be read accurately to about 0.02°C. A comparison of rectal thermometer readings and temperatures in the right femoral artery and aorta showed an average agreement within 0.02°C. in five readings taken at approximately 5 minute intervals for ½ hour. This agreement held even though the thermocouple position was altered and advanced up the artery from a point 10 cm. above its entrance into the vessel to a point 30 cm. above its entrance into the vessel. The latter position was the one found at autopsy, namely, in the abdominal aorta immediately under the diaphragm. It should be stated that when the animal began to lose heat and the rectal temperature fell, the agreement was not so close as that just mentioned.

Measurements of venous blood temperatures made simultaneously showed a decided difference from both arterial and rectal temperatures. At the time of the first three observations the venous temperature was 0.25–0.33°C. below the arterial. With the further advance of the thermocouple upward into the vena cava this difference became less until a point was reached 30 cm. above the entrance of the thermocouple into the vein, which corresponded to the level of the hepatic veins, where the venous temperature was higher than both arterial and rectal temperatures by slightly more than 0.10°C.

In the chambers of the heart the normal relationship, in the anesthetized dog at least, is for the temperature in the left ventricle to be slightly below the temperature in the right auricle. This difference amounts to less than 0.2°C. and usually more than 0.05°C., and may be supposed to be due to heat loss in the blood as it traverses the lungs. The difference between temperature readings obtained by passing thermocouples down the right jugular vein and left carotid artery into the heart in three dogs is shown in Table I. As will be understood from what has just been stated, the venous temperature will depend not only on the location of the thermocouple but on the relative amount of blood from the abdominal viscera flowing into the right auricle.
In another experiment (D 40) in which great care was taken to prevent cooling of the animal, the rectal temperature rose by nearly 0.1°C during the period of observation. In this dog the temperature of the blood was lower than that registered by a thermocouple in the rectum. The venous and arterial blood temperature, however, exhibited the relationships just described. As the venous thermocouple was advanced along the femoral vein and up into the vena cava the recorded temperature continued to mount until it exceeded the arterial blood temperature by 0.04°C. Both intravascular thermocouples were then occupying positions 47.5 cm. above the points of entrance in the femoral vessels, one of them lying in the vena cava, the other in the aorta at a level half-way between the dome of the diaphragm and the heart. These relative temperatures are graphically shown in Fig. 1. The upward inclination of the temperature curve for the arterial thermocouple was the result of the gradual rise in body temperature as illustrated by the similar curve for the rectal temperature. It should not be confused with the striking rise in venous temperature which occurs as the thermocouple is advanced upward into the vena cava.

**The Temperature of the Arterial and Venous Blood during Diathermy.**

The passage of the diathermy current between electrodes placed laterally on the dog's thorax results not only in an elevation of rectal temperature and lung temperature, as has been shown, but in an equivalent rise in the temperature of the circulating blood. The

### TABLE I.

<table>
<thead>
<tr>
<th>Experiment No.</th>
<th>Reading on thermocouple passed down right jugular vein °C.</th>
<th>Reading on thermocouple passed down left carotid artery °C.</th>
<th>Difference °C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 25</td>
<td>36.37</td>
<td>36.29</td>
<td>−0.08</td>
</tr>
<tr>
<td></td>
<td>36.35</td>
<td>36.33</td>
<td>−0.02</td>
</tr>
<tr>
<td>D 26</td>
<td>34.91</td>
<td>34.87</td>
<td>−0.04</td>
</tr>
<tr>
<td></td>
<td>34.81</td>
<td>34.75</td>
<td>−0.06</td>
</tr>
<tr>
<td></td>
<td>34.75</td>
<td>34.69</td>
<td>−0.06</td>
</tr>
<tr>
<td>D 29</td>
<td>37.07</td>
<td>36.88</td>
<td>−0.19</td>
</tr>
<tr>
<td></td>
<td>37.06</td>
<td>36.87</td>
<td>−0.19</td>
</tr>
<tr>
<td></td>
<td>37.11</td>
<td>36.93</td>
<td>−0.18</td>
</tr>
</tbody>
</table>
arterial blood in the left heart or aorta, normally slightly cooler than
the venous blood, rises to a greater degree than does the venous. The
usual relationship is, therefore, reversed. For example, in Ex-
periment D 25 the temperature in the left ventricle before dia-
thermy was 36.29°C., in the right auricle, 36.37°C. After the onset
of current flow this relationship was reversed, the temperature in the
left heart now exceeding that in the right by 0.14–0.28°C. The
difference, though not great, persisted as long as the current flow
continued and disappeared as soon as the current was shut off, the

![Diagram](https://example.com/diagram.png)

**Fig. 1.** Curve showing temperatures at various levels in aorta and vena cava
with simultaneous rectal temperatures.

venous being now 0.07°C. above arterial. In another experiment
(D 26) the left carotid blood was 0.06°C. cooler than the right jugular
before the passage of 1500 milliamperes between the electrodes. After
½ hour's diathermy, the arterial blood temperature exceeded the
venous by 0.2°C.

Changes of a similar order of magnitude appeared in Experiment
D 40. These are graphically plotted in Fig. 2, and in Table II will
be found a comparison of the temperatures of arterial and venous
blood before and during the passage of the diathermy current in four
separate experiments.
TABLE II.
Comparison of Arterial and Venous Blood Temperatures before and during Diathermy.

<table>
<thead>
<tr>
<th>Experiment No.</th>
<th>Temperature before diathermy</th>
<th>Temperature during diathermy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arterial °C.</td>
<td>Venous °C.</td>
</tr>
<tr>
<td>D 25</td>
<td>36.29</td>
<td>36.37</td>
</tr>
<tr>
<td>D 26</td>
<td>34.69</td>
<td>34.75</td>
</tr>
<tr>
<td>D 29</td>
<td>36.88</td>
<td>37.06</td>
</tr>
<tr>
<td>D 40</td>
<td>38.22</td>
<td>38.29</td>
</tr>
</tbody>
</table>

Fig. 2. Curve showing temperature of right and left heart blood before and during diathermy.
DISCUSSION.

The facts presented in this paper may be regarded as further evidence of the effective cooling of the lung during diathermy by the blood circulating through it. It can be estimated roughly, assuming a minute volume of blood flow through the lungs of 2.50 liters, and a rise of 0.2°C in arterial blood temperature above venous, that approximately half of a large calorie of heat is being removed from the lungs per minute. This is evidently sufficient to prevent any marked degree of local heating.

SUMMARY AND CONCLUSION.

1. A method of measuring intravascular temperatures in anesthetized dogs has been described.

2. The temperature in the abdominal aorta is uniform throughout, and varies only with the systemic temperature.

3. The temperature in the inferior vena cava rises as the thermocouple approaches the heart, reaching its maximum at about the level of the hepatic veins. Between the hepatic veins and the right chambers of the heart there is no further elevation in venous temperature.

4. The temperature of the right heart blood normally exceeds that of the left heart blood by 0.05–0.2°C.

5. During the application of high frequency currents to the thorax, this relationship is reversed.

6. This indicates that the lungs are being heated but that the blood passing through the pulmonary vessels is removing the heat at approximately the rate of production.

BIBLIOGRAPHY.

