Great Toe Calorimetry in Peripheral Vascular Diseases

By Milton Mendlowitz, M.D., and Harold A. Abel, M.D.

Blood flow was measured in the great toe calorimetrically in various peripheral vascular diseases, after release of sympathetic nerve tone by indirect heating supplemented by tetraethylammonium chloride. There was a striking decrease in blood flow in thromboangiitis obliterans.

The DIGITAL calorimetric technic for measuring blood flow has recently been evaluated critically and found to be sound when employed after release of sympathetic nerve tone. The two most important sources of error are the possibilities that arterial blood may arrive at the digit below mouth temperature and that venous blood may leave above calorimeter temperature. The latter source of error, although important for the hand calorimeter, where a considerable contribution to venous return is made by the deep tissues, has been shown to be absent in the digit especially when blood flow is measured per unit surface. When freezing calorimeter temperatures are employed, however, both venous and arterial errors become more significant and the actual blood flow is probably greater than that calculated from calorimetric data. In these studies calorimeter temperatures were always about 31.0 C. Moreover, after release of sympathetic nerve tone the temperature of arterial blood was found in average to be 0.7 C. below mouth temperature, a correction factor incorporated in the calculations. It is possible that at low rates of flow arterial blood temperature falls below this level, although this has not as yet been demonstrated. The values presented here, therefore, represent actual blood flow determinations with the qualification that the very low readings may on further investigation prove to be somewhat higher than represented.

The calorimetric method was first adapted to the great toe in a study of patients with residua of trench foot. Blood flow was determined after 45 to 90 minutes of indirect heating. In order to reduce the time of the procedure, heating has been decreased to 30 minutes or until positive heat balance and sweating are achieved. This is supplemented by the intravenous administration to the recumbent patient of 5 mg. per Kg. of tetraethylammonium chloride.

Those patients over 55 or with severe hypertension or heart disease were not given tetraethylammonium chloride. In such patients, blood flow was measured after 60 to 90 minutes of indirect heating alone. Patients were instructed to rest for one hour after the test and not to drive vehicles during the day of the test. In a series of approximately one thousand determinations in which tetraethylammonium chloride was used in this manner, the only untoward reaction was transient vomiting in 2 patients. Indirect heating and tetraethylammonium chloride were somewhat more effective in blocking vasoconstrictive "break through" of psychic and reflex origin than indirect heating alone. Indirect heating supplemented by tetraethylammonium chloride has been demonstrated to be as effective as spinal anesthesia in releasing sympathetic nerve tone if the calorimetric method is used. The normal range of variation of blood flow in the toe with this procedure was 0.15 to 0.29 cc. per cm.² per minute. The average was 0.21 cc. per cm.² per minute ± a standard deviation of 0.041. This is nearly the

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same distribution as was obtained using prolonged indirect heating alone to release sympathetic nerve tone. It has recently been shown in dogs that tetraethylammonium chloride in large doses, in addition to blocking sympathetic nerve impulses, may release vasoconstrictive substances from the adrenal medulla and the liver which counteract its vasodilating action on nerves. In view of the correspondence between results with prolonged indirect heating alone and indirect heating supplemented by tetraethylammonium chloride in the dosage used, it is unlikely that this factor is of importance in these studies.

Blood flow measurements were made in 800 additional cases of trench foot. Inasmuch as the results in these cases were in accord with those already reported, they will not be considered in detail in this communication. Studies were also completed in 35 cases of thromboangiitis obliterans, 5 cases of peripheral arteriosclerosis, 6 cases of Raynaud's disease, 1 case of scleroderma, 5 cases of thrombophlebitis and 3 cases of acrocyanosis. The results in thromboangiitis obliterans are analyzed statistically in Table 1.

Of the 35 cases of thromboangiitis obliterans the diagnosis was definite clinically and from oscillometric data in 17 and presumptive in the remaining 18 cases. Blood flow was below the lower limit of normal in all but one of the definite group and in 13 of the 18 cases in the presumptive group. In peripheral arteriosclerosis well established clinically and by objective tests including oscillometry and roentgenographic demonstration of peripheral arterial calcification, blood flow was below the lower limit of normal in 4 of the 6 cases. Blood flow was below the normal range in 4 of the 6 cases of Raynaud's disease and in the single case of scleroderma studied, and was within the normal range in 4 of the 5 cases of thrombophlebitis and in the 3 cases of acrocyanosis. Since digital blood pressures, especially diastolic, are often inaccurate in the great toe, digital vascular resistance could not be studied and the difference in the pressure-flow pattern in large as against small arterial obstruction could not be as well defined as in the fingertip.

Great toe calorimetry is useful as a diagnostic test in doubtful cases of peripheral vascular diseases and as a measure of the degree of impairment of the circulation in the great toe in established cases. It should be of value in following the effects of therapy in various types of vascular disease.

### Table 1. Statistical Analysis of Data

<table>
<thead>
<tr>
<th></th>
<th>No. of cases</th>
<th>Range</th>
<th>Mean X</th>
<th>Standard Deviation of mean $\sigma X$</th>
<th>Standard Deviation of difference of means $\sqrt{(\sigma X^2)+(\sigma X^*)^2}$</th>
<th>Significance Ratio $X^2 = X^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>24</td>
<td>0.15-0.29</td>
<td>0.21</td>
<td>0.041</td>
<td>0.012</td>
<td>9.2</td>
</tr>
<tr>
<td>Thromboangiitis obliterans</td>
<td>35</td>
<td>0.01-0.23</td>
<td>0.10</td>
<td>0.047</td>
<td>0.008</td>
<td>9.2</td>
</tr>
</tbody>
</table>

### Summary and Conclusions

Blood flow measured calorimetrically in the great toe after release of sympathetic nerve tone by indirect heating supplemented by tetraethylammonium chloride was usually below normal in peripheral arteriosclerosis, scleroderma and Raynaud's disease and usually within normal limits in thrombophlebitis and acrocyanosis. The number of cases in each of these groups, however, was too small for statistical conclusions. In thromboangiitis obliterans there was a statistically valid striking decrease in blood flow.

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### REFERENCES

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