Digital Blood Flow

I. Correlative Study of the Electrical Impedance and the Venous Occlusive Plethysmographs*

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VENOUS OCCLUSIVE PLETHYSMOGRAPHY

for the measurement of digital blood flow is widely accepted in spite of its limitations. On the other hand, the electrical impedance method, although believed to give an accurate measurement of digital blood flow, had not received the same clinical trials in spite of the ease with which these measurements are performed and its sensitivity to rapid changes when the extremity is exposed to various stimuli.

The purpose of this study was to correlate the values obtained by these two methods in normal individuals and to investigate the effect of environmental temperature on the obtained values.

METHODS AND MATERIALS

The electrical impedance plethysmographic method used was a modified tetrapolar method described by Nyboer. The input electrodes and the two stainless steel sampling electrodes were placed 4 cm. apart on a wide bandage made from overlapping strips of adhesive tape to assure the maintenance of the correct spacing when in position on the middle digit of one hand. The proximal input electrode was placed around the wrist by the use of a second piece of tape. The electrodes were covered with electrocardiogram electrode paste to assure good contact with the skin. The volume of the finger between the sampling electrodes was calculated as a frustum of a cone. The hand was placed at the side and kept covered with a hospital sheet at all times. The pulse waves were recorded on an Electronics for Medicine recorder. The digital blood flow was expressed in ml. of blood per 100 cc. of tissue per minute.

The venous occlusive plethysmograph was placed on the middle digit of the opposite hand. The finger was invaginated in a rubber glove finger, and the covered finger was surrounded by a circulating controlled temperature water bath kept at 32° to 33°C. A Gaertner cuff was placed immediately adjacent to the plethysmograph and served as a gasket when inflated. Pressure differences were measured by a Statham strain gauge and recorded on the previously mentioned recorder. The hand and fingers not in the plethysmograph were covered by a sheet and rested on cotton pads at the side. Several occluding pressures were used in each experiment. The flow was calculated by taking the tangent of the slope produced by the occlusive pressure. The unit of flow was again ml. of blood per 100 cc. of tissue per minute.

The subject was in a supine position during the whole study and two hours postprandial. He was allowed to stabilize for

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30 minutes in a quiet room at 22° to 23°C, while dressed in street clothes and covered with a hospital sheet.

The effects of room temperature on the digital blood flow using the electrical impedance method was investigated in 15 individuals. In eight, the subjects were allowed to remain at rest for 30 minutes with no covering sheet over them. In the remaining seven, the subjects were covered during the entire period of the experiment. Measurements were made initially and at 15 minute intervals.

In a second group of 17 individuals, simultaneous measurements of the digital blood using the middle fingers of each hand were made with the venous occlusive and electrical impedance methods. Measurements in four individuals with unusually tough skin were also made for comparative purposes.

In a third group of 48 individuals, 37 men and 11 women, the digital blood flow was measured with electrical impedance plethysmography under the previously stated conditions to determine the normal range for our experimental conditions.

**RESULTS**

The effects of body exposure to room temperature at 22° to 23°C on the digital blood flow are depicted in Table 1. In the first eight individuals, after 15 minutes of exposure, the mean digital blood flow decreased to 82 per cent of the baseline value and to 75 per cent at the end of the 30 minutes. In the covered seven individuals, no significant change was found in their mean values. Normal fluctuations in digital blood flow appeared to occur in these individuals.

In Table 2, the results of the digital blood flow as obtained by these two techniques are shown. A correlation coefficient of 0.89 was observed between them. In Fig. 1, the digital blood flow obtained by the
impedance method is related to the value obtained by the occlusive method in each case. A perfect relationship between these two techniques would be represented by the dotted line in Fig 1. For comparison, the digital blood flows in the four laborers (MH, WN, AH, CL), who had tough palms and skin covering of the fingers, are seen as triangles in Fig. 1. The observed values in these latter cases did not correlate as well as the previous 17 with the normal appearing skin. In these four laborers, a higher digital blood flow was obtained with the electrical impedance method.

In Fig. 2, the normal range of the digital blood flow in men and women is shown. In 37 men subjects, the digital blood flow ranged from 3.8 to 17.4 ml. per 100 cc. of digital tissue per minute and in the 11 women, from 6.5 to 14.6 ml. per 100 cc. per minute, with a mean of 11.23 and 10.89 ml. per 100 cc. per minute respectively. The combined mean and standard deviation for the 48 individuals were 11.15±2.78 ml. per 100 cc. per minute.

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**Table 1—The Effect of 22° to 23°C. Room Temperature on the Digital Blood Flow**

<table>
<thead>
<tr>
<th>Case</th>
<th>A. Uncovered Group</th>
<th>B. Covered Group</th>
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</tr>
<tr>
<td>%</td>
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</table>

*Measurements are expressed in cc. per 100 ml. of tissue per minute.*

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**Figure 2:** Range of digital blood flow in women and men.
DISCUSSION

The present observations of a decreasing digital blood flow in a cool environment confirm earlier reports. This finding emphasizes the necessity of specifying the experimental conditions, in particular the ambient temperature and the subject covering, when defining a normal range of values for the digital circulation. It would appear, as expected, that changes in flows are less marked or minimal in individuals with larger digital blood flow, as seen in cases 1 and 8 (Table 1). This is not surprising, as in these individuals the moderate coolness of the environment would be ineffective to significantly constrict vasodilated digital vessels.

Fluctuations in digital blood flow existed in those covered subjects. Such variability in flow was believed to result from environmental stimuli other than cold. In our experimental set-up, it was not possible to perform these studies in a completely quiet environment.

It is not surprising that wide range of digital blood flow has been reported in the literature, especially when these studies have been performed under differing room or bath temperatures. Greenfield, et al. found a digital blood flow of 4.8 to 53 ml. per 100 cc. of tissue per minute under an ambient temperature of 11.5°C to 30°C. Wilkins, et al. and Burton reported a digital blood flow in a comfortable room temperature at 1.8 to 20 ml. per 100 cc. per minute. Our normal range and mean measurement of flow using the venous occlusion method was determined as 6.5 ml. per 100 cc. of tissue per minute. Our results indicated that the values fell within the above reported values and therefore could be considered valid only under the used experimental conditions.

At 30°C it was observed that the digital blood flow in men differed and exceeded that in women. In men, a value of 36 ml. per 100 cc. per minute and in women, a value of 21.6 ml. has been reported by Farber, et al. However, at 9°C to 15°C, no significant difference was observed. At a room temperature of 22°C to 23°C, we observed no significant difference in digital blood flow between the sexes. It is our impression that under these conditions, the existing peripheral vasoconstriction reduced the difference between the sexes to a minimum.

In the normal digit a good correlation coefficient existed between the two values of digital blood flow obtained by the two techniques, venous occlusive and electrical impedance plethysmographies. However, when comparing the values obtained on subjects with tough skin covering of the digits, a poor correlation was observed, indicating that perhaps in these individuals the lack of skin distensibility induced a source of error in the measurements. In all four cases, the impedance method gave a higher flow value than the occlusive method, and a marked difference in flows was found in the two cases with larger digital blood flow. It would appear that the abnormal consistency of the skin of the digits interfered to a greater extent with the occlusive method.

<table>
<thead>
<tr>
<th>Case</th>
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<th>VOP</th>
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<th>EIP</th>
<th>VOP</th>
<th>Case</th>
<th>EIP</th>
<th>VOP</th>
<th>B. Tough Skin</th>
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*EIP=electrical impedance; VOP=venous occlusive.
*Measurements are expressed in ml. per 100 cc. of tissue per minute.
SUMMARY

In a cool environment (22° to 23°C), the digital blood flow, using electrical impedance plethysmography, averaged 11.2 ml. per 100 cc. per minute. A small but not significant difference was observed between the values obtained in men and women.

In normal digits, a correlation coefficient of 0.89 was observed between the digital blood flows of opposite middle fingers using the electrical impedance and venous occlusive techniques. A consistently higher digital blood flow was obtained in individuals with tough skin, using the electrical impedance method.

REFERENCES


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BASOPHILIC MUCOID DEGENERATION OF HEART

The historic background, microscopic appearance, and staining reaction of basophilic mucoid degeneration of the heart have been presented and another instance of its occurrence in progressive myoclonic epilepsy has been reported. Some progress has been made in subdividing the lesions according to their staining properties after phosphorylation, but further study of the lesions as they occur in association with different diseases is necessary. The possibility that the occurrence of these lesions in the heart in progressive myoclonic epilepsy may represent an enzymatic depression of carbohydrate metabolism has been suggested but not clinically proved.