

A MEMBRANE-FREE PLETHYSMOGRAPH FOR RECORDING VOLUME CHANGES INCLUDING MICROLITRES

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Abstract : A method of plethysmography which does not require an air/water tight chamber is described. The method is sensitive enough to record microlitre volumes/volume changes. Its application in two situations, viz. in experimental (artificial) edema and blood flow measurement in the human hand has been demonstrated.

Key words : plethysmograph

rat's paw volume

hand blood flow

INTRODUCTION

Traditionally, the volume changes in the organs of the body, especially distal portions of the limbs, are measured by either mercury strain gauge around the limbs or by air/water filled plethysmographs. Both methods have a few disadvantages; the earlier method requires the appropriate strain gauge and the associated computations while the latter method has the technical problem of maintaining an air tight chamber around the limb. Here we describe a method that overcomes considerably these disadvantages, to measure volume changes in the limbs of small animals and humans.

METHODS

Set up: The essential component of the set up (Fig. 1) is an electronic volume transducer (PT 05, Grass Inst. Co). With the help of a polythene tube of internal diameter (ID) 0.5 cm of short length (1-6 cm), the transducer is connected to an organ vessel. The vessel which we have used for the rat's paw is 5 ml syringe (ID=1.5 cm) and for the human hand a large vessel (ID=10 cm; length 20 cm). The vessel, the connecting tube and the part of the transducer were filled with

water upto about 1 cm or 8 cm (depending upon the size of the limb) from the level of the brim, for 5 ml syringe or the large vessel respectively. The only criterion for choosing the organ vessel is that the ID is just sufficient that the limb under test, gets immersed without touching the vessel wall and the immersion of the limb causes consi-

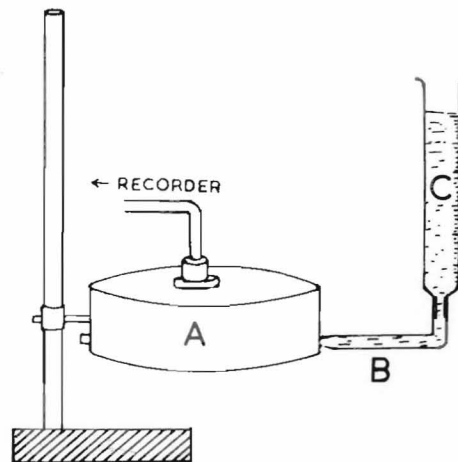


Fig. 1: Schematic drawing of the set up.
A: Volume transducer fixed in a stand.
B: Connecting tube.
C: Organ vessel (5 ml syringe/large vessel) containing water.

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derable increase in the vertical height of the water column in the vessel. Care should be taken as usual, that there are no air bubbles in the entire water filled part of the set up.

Working principle: Whenever there is an increase in the height of the water column in the organ vessel, either due to the immersion of the limb or due to external additions of water for calibration purposes, there is a small but proportionate increase in the pressure in the volume transducer. The output of the volume transducer is suitably amplified and recorded. A sensitivity of 0.5 mV/cm and high-cut frequency of 35 Hz was found to give adequate output of the recorder (7 Polygraph, Grass Inst. Co).

Experiments: Using the above described set-up, two types of experiments were carried out; one in the rat's paw and the other in human hand.

Volume changes (experimental) in the rat's paw: The nembutal anaesthetised rat was placed horizontally on a narrow (4-5 cm) platform on a stand, in such a way that the limbs were hanging freely at the sides of the platform. A 20 gauge needle, connected to 0.5 ml syringe with the help of a fine polythene tube, was introduced into the hind limb above the knee joint and passed down under

the skin till the needle tip reached the paw. The paw carrying the needle was immersed into the water column in the organ vessel (in this case, 5 ml syringe), so that the point of needle entry in the leg was well above the water column. The saline, 120 μ l was injected from the 0.5 ml syringe into the paw in 4 min with the help of a continuous slow injector (INCO) while the output of the volume transducer was recorded (Fig. 2A). Calibration was carried out with additions of 20 μ l water directly into the 5 ml syringe.

Blood flow experiment in the human hand: For this the organ vessel, namely, the large vessel was connected to the volume transducer. The subject seated comfortably, kept his hand to be resting on the bottom of the organ vessel so that the hand was immersed upto the wrist in the water (at room temperature) in the vessel. The blood flow in the hand was measured by the conventional venous occlusion method. Calibration was done by the additions of 5 ml of water directly into the organ vessel (Fig. 2B).

RESULTS AND DISCUSSION

In the rat's paw experiment the recorded amounts were almost equal to the actual injected amounts of saline and in an average, higher by a factor 1.1 ± 0.2 (Mean \pm SD of 10 observations).

The blood flow in the hand at room temperature (29°C) was found to be 12 ± 4.6 ml/min/100 ml of hand (Mean \pm SD of 10 observations) in the resting condition, a value comparable to the normal values reported earlier (1, 2). We also observed that the slope of the curve increased after exercise of the hand (Fig. 2B), as shown earlier (1).

The slightly higher value recorded in the rat's paw experiments might be due to the injected saline accumulating under the skin, causing venous occlusion and producing some additional amount of edema. The above possibility is very likely because, when water was similarly infused into a water filled balloon system (instead of the rat's

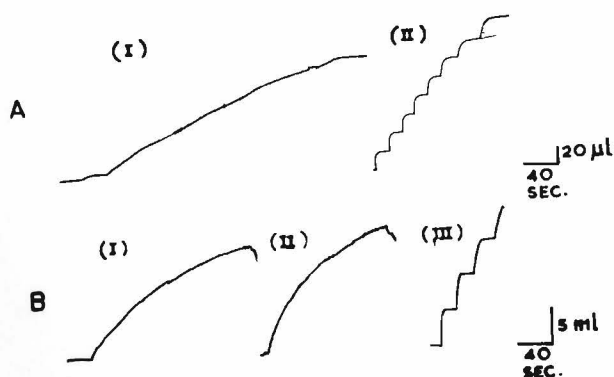


Fig. 2 (A): A typical recording of the changes in the rat's paw volume with saline injection into the paw (I). Calibration with additions of 20 μ l water (II).

(B): A typical recording of the human hand blood flow at rest (I), and after exercise (II). Calibration with additions of 5 ml of water (III).

paw) kept in the organ vessel, it was found that the (recorded) amounts were exactly equal to the injected amounts.

Finally, it may be mentioned that the pulse waves seen in most (not all) of the plethysmographic tracings of earlier methods, were absent in many of our recordings of blood flow measurement of hand and such absence of these pulse waves did not hamper the calculation of blood flow in any way.

CONCLUSION

An alternative method has been described for recording small volume changes in the end limbs. This method will be suitable for quantifying the experimental edema. Its merit lies in the fact that it does not require any leak free closed compartment for the limbs, and it records volumes in the range of microlitres.

REFERENCES

1. Roddie IC. Circulation. In: Bell GH, Donald Emslie Smith and Paterson CR eds. Textbook of Physiology. *Churchill Livingstone: ELBS*, 1980; 182.
2. Rudolf Thauer. Circulatory adjustments to climatic requirements. In: Hamilton WF and Philip DOW eds. *Handbook of Physiology, Section 2 (Circulation) Volume III*, Washington: *American Physiological Society*, 1965; 1928.