A NEW PLETHYSMOMETRIC APPARATUS (WITH AUTOMATIC ELECTRIC HEATING) FOR RUNNING MEASUREMENT OF THE ARTERIAL PRESSURE IN UNANESTHETIZED RATS BY A BLOODLESS METHOD *

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The apparatus which we have constructed differs from those suggested by other authors [5, 16, 17] firstly, by the presence of a group of plethysmometric measuring devices, enabling "running" determinations of the pressure to be made and shortening the time required for serial investigations; secondly, by a modification of the plethysmometer and , thirdly, by the method of local heating of the tail in the bath. Some authors [13] suggest using a Byrom and Wilson plethysmometric apparatus, with the addition of a photoelectric recording system to record both systolic and diastolic pressures. Besides the plethysmometric method, an oscilloscopic [6, 7], oscillographic [4], microphonic [8, 9] and other methods are described [3, 10-12].

PRINCIPLE OF THE PLETHYSMOMETRIC METHOD

The caudal vessels are compressed by a pneumatic cuff until the circulation is completely arrested. By releasing air from the cuff, the pressure within it is gradually reduced. When it becomes equal to the systolic pressure, blood begins to flow along the closed arteries into the peripheral part of the tail, which is placed in a plethysmometer. No blood escapes through the still compressed veins, so that the volume of the peripheral part of the tail begins to increase, causing the column of water in the capillary tube of the plethysmometer to rise. The start of this rise indicates the systolic arterial pressure, which is measured by a mercury manometer connected to the cuff.

We have shown that there are three main caudal arteries in rats (Fig. 1). The ventral (or median) caudal artery is the principal artery of the tail, and the largest in diameter, with a strong muscular layer, and it is the continuation of the median sacral artery; it is situated ventrally between the vertebral processes and is accompanied by two fine, variable branches. Two lateral caudal arteries, much smaller in diameter, are situated laterally and superficially; these are branches of the common iliac artery system. By using the compression cuff the pressure in the ventral caudal artery is usually determined, as it is largest in caliber, and therefore the one in which the pressure is slightly higher.

CONSTRUCTION OF THE APPARATUS

The apparatus consists of several (two or more, usually five) plethysmometric devices, mounted in a bath (Fig. 2, 1) with automatic electric heating to maintain a constant water temperature. Each measuring device consists (see Fig. 2 and Fig. 3) of a compression cuff, connected at the time of measurement of the pressure to an inflating balloon and a mercury manometer, and of a plethysmometer.

The compression cuff (Fig. 3) consists of a glass conical tube 1, through which is pulled a rubber tube 2

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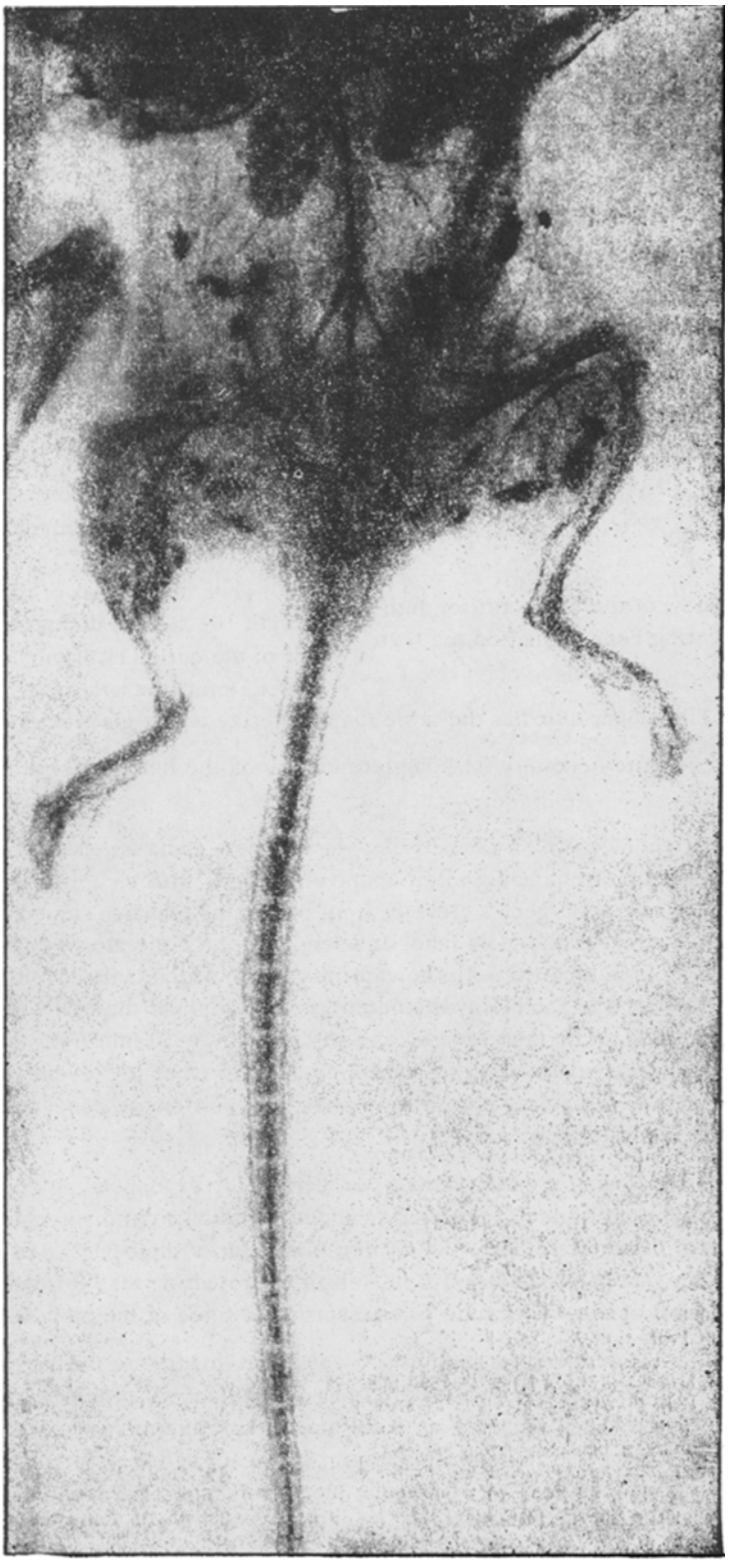

Fig. 1. The caudal arteries. Angiogram.

(made from a surgeon's glove), fixed by a thread to the everted edges of the glass tube; a side tube 3 is present, which is for connection to the inflating balloon and manometer. So that the rubber tube should not protrude through the rear opening of the compression cuff, which would cause a false rise of the column of water in the capillary tube of the plethysmometer, on this opening is placed a fixing ring 12, made of plexiglass or thin tin, fixed by threads 13 around the edges of the glass tube.

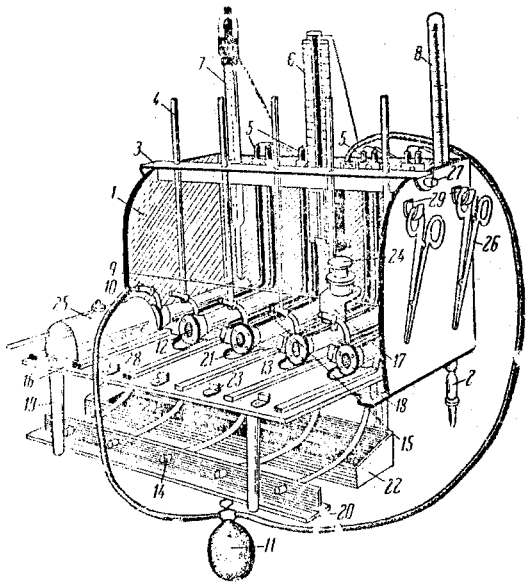

Fig. 2. General view of the apparatus for automatic electric heating. For explanation, see text.

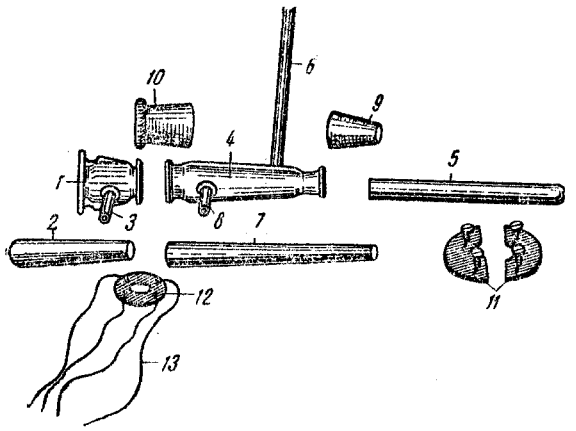

Fig. 3. Plethysmometric measuring apparatus in exploded view. For explanation, see text.

The dimensions of the glass tube are as follows: length 10-25 mm, diameter of the inlet 13 mm, diameter of the outlet 11.5 mm, internal diameter of the cylinder 18 mm, length of the side tube 3, 30-70 mm, its diameter 2-3 mm. The rubber tube has the same shape and size as the glass tube.

The minimum pressure necessary for complete closure of the inner edges of the rubber tube must not exceed 5-7 mm Hg.

The plethysmometer (see Fig. 3) consists of a working part 4 and an end tube 5. The working part consists of the conical glass tube 4 (corresponding to the shape of the tail) with a capillary tube 6, through which is drawn the rubber tube 7, made of fine surgeon's glove or from preserving rubber. The edges of the rubber tube are fixed by thread to the everted edges of the glass tube, as a result of which the closed cavity of the plethysmometer is formed between them (communicating with the capillary tube), which is filled with warm water during the experiment. The capillary tube of the plethysmometer 6 is fused in near the outlet (10-15 mm from its edge) and is directly vertically upward. The tube 8, fused at a distance of 10-15 mm from the edge of the inlet, is used for filling the plethysmometer with water and for draining it. In order to prevent water from the bath from entering the plethysmometers when they are placed in it, their rear portion are connected by thick rubber tubes 9 to end tubes 5 (Widal tubes are suitable).

In our experiments we used plethysmometers of different sizes, depending on the dimensions of the rats' tails. We give the dimensions of one of the plethysmometers which we most frequently used: length of the glass tube (see Fig. 3) 80 mm, diameter of the inlet 11 mm, diameter of the outlet, 8 mm, largest internal diameter 14 mm, diameter of the capillary tube 0.5-1 mm, length of projecting tube 8 from 25 to 30 mm and its diameter 2-3 mm. The dimensions of the rubber tube 7 corresponded to those of the glass tube.

The bath (see Fig. 2), designed for providing a constant temperature for the plethysmometric apparatus, consists of a rectangular box 1, on 4 legs, with the front cut out (for convenience in observing the plethysmometers, the manometer 6, the electrical contracts 7 and the mercury thermometers 8). The two hind legs 2 have screw adjustments with a maximum height of 120 mm, by means of which the rear portion of the apparatus can be slightly raised, which is essential when filling the plethysmometers with water, in order to expel air from them. A movable bar 3, through the holes in which pass the upper ends of the capillary tubes 4, and which can be firmly clamped to the upper edges of the sides of the box by the screws 27, serves the same purpose. The height of the front legs is 90 mm. For 5 plethysmometers the dimensions of the bath are as follows: length 450 mm, width 235 mm, height 240 mm. The bath is fitted with 4 heating coils, drawn through the glass tubes 5, which are filled with sand; they are situated between the plethysmometers. The coils are heated by the main supply (127 v). The temperature is regulated automatically by means of an electrical contact thermometer 7, included in the circuit to the coils through a relay. The mercury thermometer 8 is also provided for checking the water temperature.

In the front wall of the bath, near the top, the holes 9 are made (diameter 7 mm) for the short rubber connecting tubes 10, leading from the compression cuffs to the inflating balloon 11. In the front wall there are also holes 12 (diameter 15 mm) for introducing the rats' tails into the plethysmometric apparatus (distance from the lower edge of the hole to the bottom of the bath 20 mm). In the bottom of the bath are the special holes 13, into which the lower side tubes of the plethysmometers (see Fig. 3, 8), with their enveloping rubber tubes 14, through which the plethysmometers are filled with water, fit snugly. The free ends of these tubes fit in holes in the frame 20, fixed to the legs of the platform 16. In the center of the bottom of the bath is a hole with a metal tube 15 (diameter 15 mm) for emptying out the water.

The platform (see Fig. 2, 16), on which the chambers 25 containing the rats stand during the experiment, is removable and its dimensions are 450 x 220 mm; it is attached to the bath by the pins 18, and in front it is supported by two legs 19, 110 mm high. To the platform are fixed flat strips 28 (6 strips for 5 plethysmometers), 3-5 mm thick and 30-35 mm wide, between which the chambers for the rats are placed. Near the front edge of the platform, between each pair of strips, is a movable stop 23 for fixing the chambers with the rats. Semi-elliptical holes 21 are cut in the platform to allow escape of the feces and urine of the rats into the receiver 22, consisting of a rectangular plexiglass through, 450 mm long, 60 mm wide and 15 mm high.

Assembly of the apparatus. The compression cuffs, plethysmometers (see Fig. 3) and bath (see Fig. 2) are made ready beforehand. The plethysmometers and cuffs are tested for airtightness. The cuffs are fixed to the front of the bath near the holes for the animals' tails by means of two semicircular pieces of plexiglass (flanges) and 4 screws (see Fig. 3, 11). Next, by their lower side tubes, enclosed in rubber tubes 200-300 mm long, the plethysmometers are fitted into the special holes in the bottom of the bath (see Fig. 2, 13). The front portion of each plethysmometer is connected to the rear portion of the corresponding compression cuff by means of a wide rubber tube (part of a rubber teat) previously firmly fixed on to it. The end of this rubber tube is further secured to the compression cuff by means of a thread. In this way the internal cavities of the compression cuffs and plethysmometers are insulated from the water in the bath.

The upper ends of the capillary tubes are passed through the holes in the upper mobile bar of the bath (see Fig. 2, 3). This is fixed by the screws 27 on to the upper free edges of the sides of the bath in the required position. The platform for the animal chambers is placed in position by the front of the bath and fitted over the pins.

Temperature and duration of heating the animals' tails before measurement of the blood pressure. The minimum temperature in the measuring apparatus suitable for measurement of the blood pressure of intact rats with experimental renal hypertension, according to our preliminary findings, is 36-37°. At this temperature precise determination of the blood pressure, giving stable figures, is possible as a rule in intact rats after 5-15 minutes, and in rats with experimental renal hypertension from 10-30 minutes after the commencement of heating the tail (the rise in the level of the water in the capillary tube reaches 15-30 mm). The blood pressure varies little in the course of an hour (and sometimes longer) at this temperature, so that for standardization of the conditions of the experiment the selection of one single constant time of heating the intact rats and the rats with hypertension is recommended (in our experiments 20-30 minutes).

Measurement of the blood pressure. Measurements may be carried out on 4-5 rats at once. It is advisable at first to accustom the rats to sitting at rest in the chamber. The animals' tails are taken as far as the root covered with hair, and placed in the measuring apparatus, the chambers for the animals being placed on the platform. The chambers are anchored by the movable stops. The temperature of the water in the bath is raised to 37° by the electric heater. The plethysmometers are filled with water (37°) from the bath by means of a syringe, and clamps are placed on the rubber tubes (see Fig. 2, 14), best close to the bottom of the bath. After 20-30 minutes the measurement of the blood pressure begins. Three or four measurements are made on each rat in the course of 4-5 minutes and the limits of variation and the mean values are recorded. We may mention some sources of error: 1) false elevation of the column of water in the capillary tube of the plethysmometer due to movement of the animal; 2) pain on account of incorrect positioning of the rat in the chamber; 3) Incorrect placing of the rat's tail in the measuring apparatus (kinks, incomplete insertion); 4) measurement of the pressure in some rats without preliminary habituation to sitting in the chamber; 5) air pockets in the plethysmometer.

Systolic arterial pressure in normal and hypertensive rats. The systolic arterial pressure in normal rats, as measured by the apparatus just described, is as a rule between 70 and 110 mm Hg. In a few intact rats it may be higher (140 mm) or lower (65 mm). In experimental renal hypertension, resulting from the application of a cello-

phane capsule to both kidneys by our modified method [2], an increase in the blood pressure by 40-120 mm Hg was observed. The variation in pressure in the course of one experiment on intact rats was as a rule 10 mm or less, and only comparatively rarely was it 15-20 mm; in rats with renal hypertension it was usually below 20 mm. Day to day variations in the blood pressure of intact rats and in rats with hypertension (in the stage of stabilization wer usually 15 ± 5 mm. Quite rarely the day to day variations in intact rats were as much as 35 mm. Comparison of our figures for the normal systolic pressure in the main (ventral) caudal artery in rats with the figure obtained by the direct method in the femoral and carotid arteries by various authors [5, 13, 15, 16] showed that in many cases they were in agreement, and in a few cases they were slightly lower.

SUMMARY

A new plethysmometric apparatus with automatic local heating has been designed for conveyor (running) determination of the blood pressure in the caudal artery (ventral) in rats by the bloodless method. The apparatus differs from those already in use by:

1) the presence of a group of plethysmometric measuring instruments, which permits running determination of the blood pressure and reduces the time spent on serial work.

2) certain modifications of the plethysmometers,

3) the method of local warming, with the aid of a bath, of the tail. The temperature in the measuring instruments is 36-37° C and the duration of preliminary heating - 20 to 30 minutes.

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