MEASUREMENT AND RECORDING OF ARTERIAL PRESSURE, PULSE, AND RESPIRATION OF RATS DURING CHRONIC EXPERIMENTS

R. M. Lyubimova-Gerasimova,

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A method of objective recording of the arterial pressure, pulse, and respiration of rats during chronic experiments is suggested. By means of a clip housing two piezocrystals the pulse and arterial pressure can be recorded in the caudal arteries. To record respiration a thermopile consisting of 5-10 thermocouples (copper and constantan) is used; the pick-up is attached to the cage near the animal's nose. After appropriate amplification, the indices are recorded on a self-writing instrument.

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Various modifications of the plethysmographic method have been widely used in recent years for bloodless determination of the arterial pressure in small laboratory animals [2, 3, 4, 8, 9, 10]. An essential defect of this method is that it cannot be used to record the pressure objectively.

The respiration rate of small animals is usually recorded by means of a Marey's capsule [7], but this method is insufficiently sensitive, especially during shallow breathing.

We have attempted to find an objective method of recording these indices. The arterial pressure and pulse of the rats are measured in the main caudal arteries, the largest of which lies along the ventral surface of the tail, the other two along the lateral surfaces. The pulse waves are picked up by means of a piezoelectric element.

This principle of recording is not new but has been used for recording the pulse in man [5] and large animals.

The pick-up consists of a clip (Fig. 1, A) made of thin brass, inside which two piezoelectric elements (4), connected in parallel, are fixed by means of polyvinyl chloride insulating tape. The working area of the clip (2) is bent at an angle of 120-130°, and one of the piezoelectric crystals lies on each plane forming an obtuse angle. The planes of the angle are slightly curved (B). This shape is essential so that the crystal lies not on the smooth surface, but some distance from the ends (making it more sensitive).

The clip is applied to the rat's tail in such a way that the crystal lies above the lateral and the other above the ventral caudal artery.

The compression cuff (D), made of brass, is 14 mm in length, 11 mm in diameter at the center, and 15 mm at the edges. The slightly everted edges prevent the thread fixing the inner rubber part of the cuff, made from the finger of a surgical glove, from slipping.

A brass tube leaves the middle of the cuff and connects in to a manometer (11) for visual observation of the pressure created by a pumping balloon (12) and contact manometer (13).* With a change in pressure in the pneumatic cuff produced by the regulating screw of the pressure bulb (14) the contact manometer produces a pulse of current every 10 mm Hg, and this is recorded by the writing instrument.

The compression cuff (D) is placed on the rat's tail near to its base. The pick-up clip (A) is fixed 3-5 mm away. The free part of the tail is placed in a plexiglass tube (16), the beginning end of which is fixed to the front wall of a plexiglass bath (17). The bath is filled with tap water at a constant temperature of 37-

* For a description of the contact manometer, see the paper by Yu. G. Nefedov and co-workers [6].

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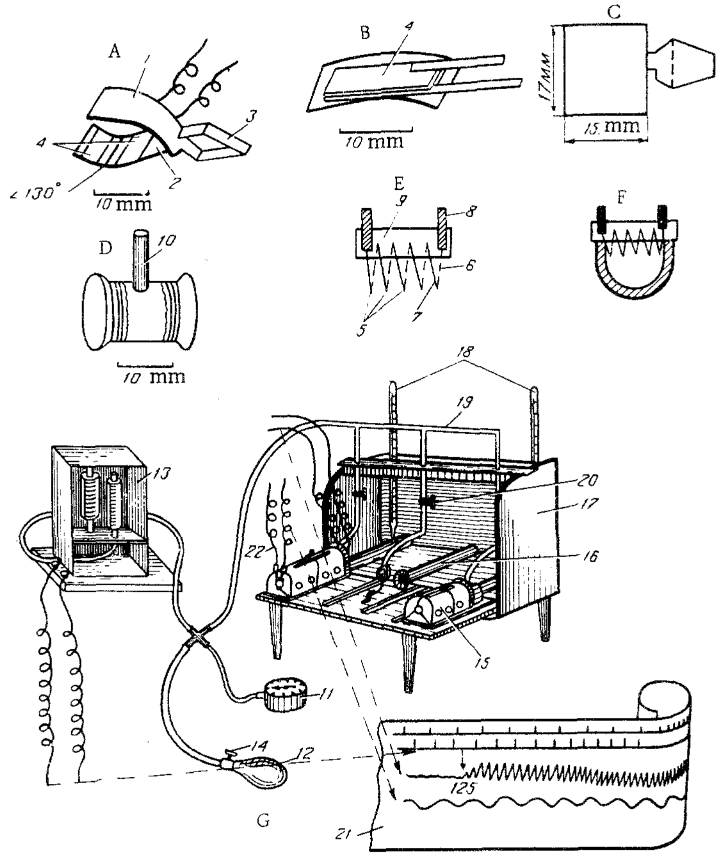

Fig. 1. Diagram of apparatus for recording arterial pressure, pulse, and respiration in albino rats. A) General appearance of clip; B) one of the working areas with the piezocrystal; C) blank for clip (two details); D) pneumatic cuff; E) respiratory pick-up; F) arrangement of respiratory pick-up near nasal aperture of cage; G) general view of apparatus. Remainder of explanation in text.

40°. The temperature of the bath is checked by two thermometers (18), placed where the water enters the bath and leaves it. To maintain a constant water temperature a heating system should not be used as recommended by A. Kh. Kogan [3], because this would lead to the appearance of electrical interference affecting the purity of the pulse recording. Tap water of the required temperature can be used, supplied to the bath through tubes.

The rat's tail must be warmed for about 5 min, and after this as a rule a clear pulse appears which can be recorded by the writing instrument. During work with a large number of animals, two or three sets of equipment for measuring arterial pressure and respiration must be available. In these cases the pressure bulb (12) and the two manometers (11, 13) are connected with two or three pneumatic cuffs by means of a metal tube (19). When measuring pressure the remaining cuffs are disconnected by means of the taps (20). A careful check on the airtightness of the system must be kept. The pulse pick-up must operate alone, and it must be fitted immediately before the measurement.

When recording the pulse, the respiratory rhythm is often recorded on the sphygmogram curve. This usually indicates that the tail does not lie in one plane (from its base to the place where it enters the heating tube), and that a small kink is present somewhere. Sometimes the position of the pick-up must be changed, bringing it slightly nearer to the pneumatic cuff, because the pulse is recorded better at the base of the tail.

The arterial pressure begins when a clear pulse is recorded. As the sphygmogram is recorded the pressure in the pneumatic cuff is raised until the pulse disappears. The adjusting screw is opened, the

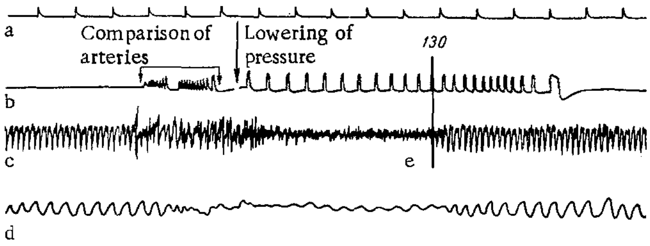

Fig. 2. Kymogram of arterial pressure, pulse, and respiration of albino rats. a) Time marker (1 sec); b) pulses of contact manometer (interval 10 mm); c) pulse; d) respiration; d) line drawn from first pulse wave to readings of contact manometer.

pressure in the pneumatic cuff lowered, and when it becomes equal to systolic and the first portion of blood passes through the vessel, the pen of the self-writing instrument (with the aid of the piezoelectric pick-up) once again starts to record the pulse. The recording must be continued until impulses from the contact manometer are no longer recorded. The number of impulses of the contact manometer from the first pulse wave (Fig. 2, e) recorded after compression shows the systolic pressure (in the recording illustrated it is 130 mm; Fig. 2).

Four such measurements must be made and the mean obtained. The intervals between separate measurements must be not less than 2-3 min.

Respiration of the rats is recorded by means of a thermopile [1].

Depending on the sensitivity of the recording apparatus, the thermopile consists of 5 or 10 thermocouples (Fig. 1, 5). It is fixed near the nasal aperture of the cage (Fig. 1, f). This arrangement does not interfere with the animals' breathing. With a change in temperature of the inspired and expired air, an electromotive force is generated in the thermopile. Each thermopile consists of a length of copper and constantan measuring 15 mm in length and 0.2 mm in diameter. The thermocouples are welded by means of an electric arc. They are connected in series to form a pile. Firm metal plates are folded to the outer free ends (Fig. 1, 8). All the top junctions are placed between two thin organic glass plates (Fig. 1, 9). Crocodile clips are fixed to the projecting free ends of the metal plate (Fig. 1, 22), connecting the thermopile through the amplifier to the self-writer. They are easily removed and fix the wire securely to the output of the thermopile.

When measuring the arterial systolic pressure of 22 rats (initial weight 120-140 g) over a period of six months we found that the variation in pressure of individual animals during the experiment did not exceed 5-10 mm, or on some days 10-20 mm. The pressure of most rats was 110-120 mm.

The pulse rate of rats is a more labile index, fluctuating by 30-60 per minute on different days. However, in the course of one experiment the values were more stable and fluctuations did not exceed 5-15 per minute. The pulse rate of most animals investigated was 390-490/min.

We also found considerable variability of the respiration rate in individual animals, although the respiration rate of most of them lay within the range 100-40/ min.

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