METHODS

CONTINUOUS RECORDING OF THE SYSTOLIC BLOOD PRESSURE BY A BLOODLESS METHOD USING A SIMPLE TRACING SYSTEM

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(Received January 29, 1958. Presented by Academician K. M. Bykov)

Existing methods of bloodless recording of the blood pressure are less accurate than the direct method, but their use in physiological and clinical investigations is perfectly justified if the aim is simply to determine whether the pressure is raised or lowered, or to determine its relative value in cases where it is desirable to avoid operative procedures.

Among the many indirect methods of recording the blood pressure, one which deserves our attention is a metnoa ın which the air pressure in a sphygmomanometer cuff is maintained automatically at the level of the systolic (or diastolic) blood pressure by means of a mechanism controlled by the pulse waves. In recording the systolic pressure, air enters the sphygmomanometer cuff through an electromagnetic valve which opens only at the moment of passage of the pulse wave to the peripheral part of the limb. If the initial pressure in the cuff is at a lower level than the systolic blood pressure, with each pulse wave passing the cuff to the periphery a further quantity of air enters the system. The inflation of the cuff proceeds until its pressure is no longer below the systolic pressure. At this moment the pulse wave at the periphery disappears and the valve closes. In consequence of a controlled leakage of air from the system (or by means of the automatic opening of a special escape valve) the pressure inside the system begins to fall until the pulse reappears. The first pulse wave to reach the periphery opens the inlet valve, and the whole cycle is repeated once more. Thus the pressure inside the cuff follows the changes in the systolic pressure, sometimes rising above its level and at others falling below it.

The various modifications of this method are mainly concerned only with the method of detection of the pulse wave at the periphery of the limb. For this purpose additional cuffs [1, 4, 5, 6, 8], a pneumatic finger plethysmograph [2], a photoelectric finger plethysmograph [7] and a piezoelectric detector [3] have been used. In spite of the comparatively large number of schemes suggested, the method just described has not been widely used in practice, in view of the relative complexity of the apparatus and of a number of general disadvantages which reduce the accuracy of recording. The most important of these are: the fact that the working of the electromagnetic valve depends on volume changes in the peripheral part of the limb, unconnected with changes in pressure; the considerable overdistenion of the veins with blood; distortion of the recording by movements of the muscles and the high inertia of the system.

The system which we propose, which is suitable for investigations on man and for chronic experiments with dogs, differs slightly in its principle of action from the existing apparatus, and is free from certain of the disadvantages which have been mentioned. The main difference is that the working of the electromagnetic valve is controlled by oscillations of pulse pressure in the sphygmomanometer cuff itself, and not by pulse waves in the peripheral parts of the limb. This prevents distortion of the results from local vasomotor reactions and from passive changes in the filling of the vessels with blood, since the entire network of vessels smaller than the main

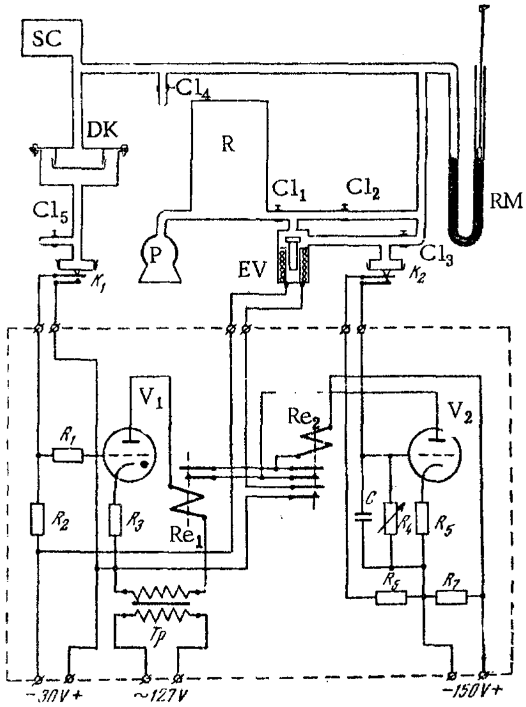

Fig. 1. Essential scheme of the apparatus.
P) Pump; R) compressed air reservoir; EV) electromagnetic valve; RM) recording manometer; DK) disconnecting capsule; K_1) capsule with thin rubber membrane and contacts; K_2) membrane manometer with contacts; Cl_1-Cl_5) screw clamps; V_1) TG1 thyratron 0.1/0.3; V_2) twin triode 6H8 (half the valve is used); Re_1 and Re_2) telephonic type relay; TR) transformer; C) 4 μf; R_1) 100,000 ohm, R_2) 1 meg; R_3) 500 ohm; R_4) 1 meg; R_5) 200 ohm; R_6) 1000 ohm; R_7) 5000 ohm.

artery is fully compressed and does not affect the pressure changes in the cuff.

The essential scheme of the apparatus is shown in Fig. 1. By means of the pump P the air pressure in the reservoir R (volume about 10 l) is maintained at a constant level (250-300 mm of mercury). Through the electromagnetic valve EV, air enters a system of tubes connecting the reservoir, the sphygmomanometer cuff SC and the recording manometer RM. The rate of entry of air into the system is regulated by means of screw clamps Cl_1 and Cl_2. The clamp Cl_4, is designed to regulate the rate of leakage of air from the system. The pulse oscillations are received by a capsule K_1 with a thin rubber membrane and adjustable contacts. So that the pressure inside the cuff and its slow variations should not be transmitted directly to this capsule, it is connected with the latter through a disconnecting capsule DK, with a thicker rubber membrane, and the capsule K_1 system is supplied with a controlled leakage of air through Cl_5.

The cuff is wrapped around the arm of the subject (or the dog's thigh), and the pressure inside it is at once raised to a value known to be higher than the systolic pressure. For this purpose the clamp Cl_2 is opened, to the accessory tube leading from the reservoir to the system and by-passing the electromagnetic valve. After this has been done the clamp Cl_2 is screwed home. Thanks to the leakage of air through the clamp Cl_4 the pressure in the system begins to fall. When it reaches the level of the systolic pressure, the capsule K_1 begins to respond to the pulse oscillations, which leads to closure of its contacts. This removes the negative voltage from the grid of the thyratron V_1, which is thereby made to discharge, and the relay Re_1 which is included in its anode circuit, is set in operation.

When the contacts in K_1 are broken, a negative voltage is once more applied to the grid of the thyratron and it is extinguished (the anode circuit is fed by an alternating current). The valve V_1 acts merely as an intermediate electronic relay, permitting the use of oscillations of very small amplitude and power of the membrane of capsule K_1 for controlling the operation of the electromagnetic valve, which requires greater power. Closure of the contacts in the relay Re_1 sets in operation the relay Re_2, which directly controls the electromagnetic valve. Thus the first variation in the pulse pressure in the cuff to appear when the pressure inside the cuff is lowered leads to opening of the electromagnetic valve and to a slight increase in the pressure in the system. So that with each operation of the valve roughly the same volume of air enters the system, there is a membrane manometer K_2 with adjustable contacts, on closure of which a negative voltage is applied to the grid of the second valve V_2, and the circuit of the electromagnetic valve is broken through the relay Re_2. The contacts of the manometer are so adjusted that they always close at a certain pressure (for example 250 mm of mercury).

When the pressure inside the cuff is higher than the systolic pressure, the oscillations cease, the valve cannot open and the pressure inside the system once more begins to fall gradually until oscillations reappear. The pressure inside the cuff automatically follows behind the systolic pressure, sometimes rising and sometimes falling below its level. By controlling the rate of entry of air into the system and the rate of its escape from it, it is possible to arrange that these variations of pressure inside the cuff do not differ by more than a few mm of mercury from the level of the systolic pressure.

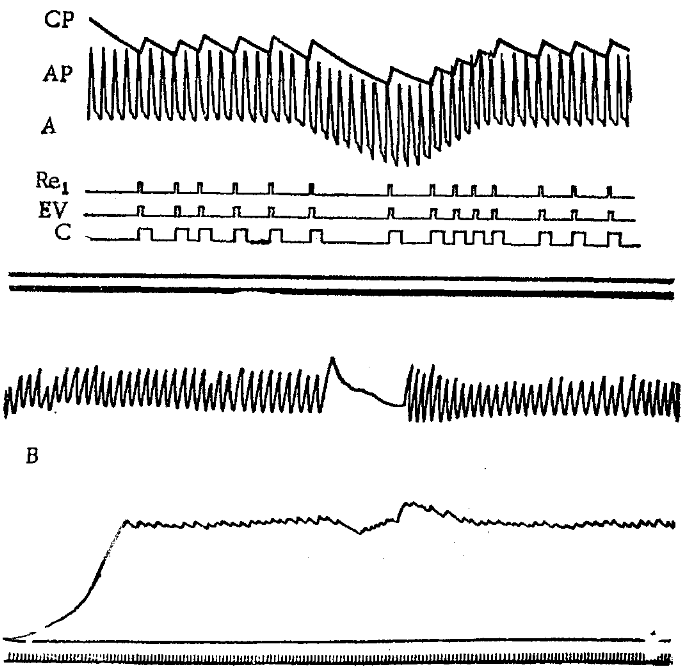

Fig. 2. Diagram illustrating the action of the apparatus (**A**) and an actual recording of the systolic pressure in a human subject by the method described, using a mercury manometer and an ink-recording apparatus (B); CP) pressure inside the sphygmomanometer cuff; **AP**) intra-arterial pressure; Re_1) moment of closure of the contacts in K_1 and operation of the relay Re_1; EV) operation of the relay R_2 and opening of the electromagnetic valve; C) time of cut-off of the valve V_2 as a result of the negative charge on the plate of the condenser connected to the grid of the valve. Significance of the curves for Fig. 2,B (from below upwards): respiration, systolic pressure, zero line, time marker (1 sec.).

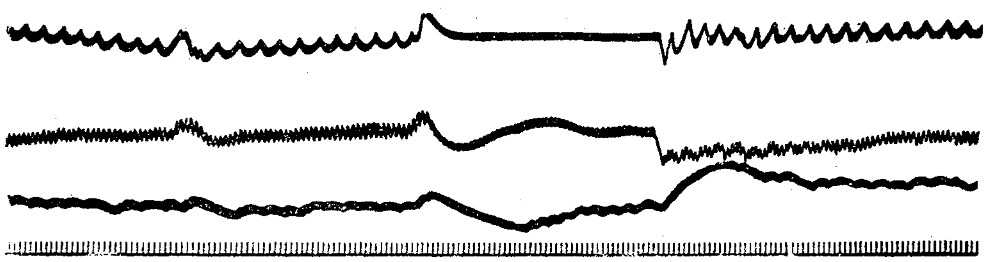

Fig. 3. Changes in the pressure during Valsalva's test (recording made with the same apparatus). The pointer of a mercury manometer was placed in front of the aperture of a photokymograph, illuminated with a parallel beam of light. Significance of the curves (from above down): respiration, finger plethysmogram, systolic pressure, time marker (1 second); the level of the time marker corresponds to 100 mm of mercury on the recording manometer.

The rate of fall of pressure inside the cuff in consequence of the escape of air must be from $^1/_3$ to $^1/_4$ of the rate of change of pressure inside the cuff at the moment of the pulse oscillation, otherwise in the course of recording of a rapidly falling pressure the gap between the contacts in K_1 will be increased and the pulse variations which appear will be unable to cause them to close. In precisely the same way the rate of increase of the pressure in the system must not be too great, otherwise the contacts will remian closed irrespective of the presence or absence of pulse oscillations. In this way the limit of mobility of the whole system is defined, and it is able to record without any delay only relatively slow changes in the systolic pressure.

The valve V_2 is provided so that a rapid increase in the pressure inside the system at the moment of operation of the electromagnetic valve does not lead to the same closure of the contacts in K_1 as occurs during the pulse oscillations. By selection of the values of the resistors R_6 and R_7, when the contacts in K_2 are closed a negative voltage is applied to the grid of the valve of a magnitude which can break the relay Re_2. At the same time the condenser C discharges. By means of the variable resistor R_4, the rate of discharge of the condenser is regulated in such a way that closure of the contacts in K_1, due to the increased pressure inside the system at the time of opening of the valve, takes place at the moment when the negative potential of the grid was still at a sufficiently high value for operation of the relay Re_2 not to occur. In this way it is possible, by means of the resistor R_4, to regulate the length of the time interval during which the routine closure of the contactacts in K_1 does not lead to opening of the electromagnetic valve.

In Fig. 2,A is given a diagram illustrating the working of the apparatus, and in Fig. 2,B and Fig. 3 – curves obtained during recording of the blood pressure in a human subject.

Comparison of the absolute values of the pressure obtained by means of the apparatus described with those determined by Korotkov's method of auscultation showed that with a minimal gap between the contacts in K_1 the apparatus always gives slightly higher figures. The average excess, calculated from the results of 200 measurements of the arterial pressure in 6 persons, was 15 ± 10 mm of mercury. This is due to the fact that the appearance of pulse oscillations during the gradual fall of the pressure inside the cuff takes place slightly earlier than the influx of blood into the peripheral part of the limb. By increasing the gap between the contacts in K_1 or the escape of air through Cl_5, it is possible to slightly reduce the sensitivity of the capsule and to obtain accurately corresponding values for the pressure as recorded by the apparatus and by the method of auscultation. However this adjustment has to be done afresh on each new subject, which is a great nuisance. Maintenance of the pressure inside the cuff a few mm above the level of the systolic pressure is an advantage, because when making the recording, on account of the total cessation of the flow of blood in the distal portion of the limb, no overdistension of the venous system with blood takes place, and the time of recording may be greatly increased without producing any undesirable subjective sensations in the subject. The influx of blood into the peripheral portion of the limb is possible only in cases where in the course of the investigation the systolic pressure rises so rapidly that the recording system lags behind the actual changes in pressure. The possibility of overdistension of the compressed limb with blood can be reduced still further by elevation of the limb for 20-30 seconds before the start of the investigation.

The influence of movements of the muscles on the working of the apparatus is slightly diminished, because the time of opening of the electromagnetic valve is independent on the duration of closure of the contacts in K_1, provided that this does not exceed the time of discharge of the condenser C. For this reason even a large movement leads only to a single operation of the valve and to a comparatively small rise in pressure inside the apparatus. However, repeated muscular movements may considerably distort the recording, and so the investigations must be performed with the greatest possible attention to prevention of movement of the subject. This is particularly so of experiments on dogs, which must lie immobile during the experiment.

The suggested method of bloodless recording of pressure is particularly suitable for recording the changes in blood pressure casued by transient reflex and humoral factors. In clinical research this method may be used to determine the reactivity of the cardiovascular system in different tests and to investigate the action of various therapeutic measures.

SUMMARY

The author describes a new method of bloodless registration of systolic pressure in man and in dogs. It differs from other methods, based on the principle of tracing system, by the fact that the entrance of air into the sphygmomanometric cuff is controlled by pulse oscillations in the cuff and not by pulse waves in the peripheral parts of the extremity. This method has the following advantages: the work of this apparatus is independent of the local vascular reaction, there is no overdilatation of the venous system by the blood; the sensitivity to muscular motions is lower.

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