BLOODLESS METHOD OF MEASURING THE BLOOD PRESSURE IN CHRONIC EXPERIMENTS

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An apparatus for measuring the blood pressure in chronic experiments is described. It consists of an implantable blood-pressure transducer placed on the vessel without disturbing the integrity of its wall, a stabilized ac generator, a self-stabilizing amplifier, detector, load resistor, and recorder. Tests of an experimental model of the implantable transducer on animals were successful.

An apparatus for the bloodless measurement of blood pressure in vessels during chronic experiments and consisting of an implantable transducer of the blood pressure, placed on a vessel without disturbing the integrity of its wall, a stabilized, transitorized ac generator (frequency 10 kHz), a self-stabilizing amplifier, detector, load resistor, and recorder, is described. To measure the blood pressure in the vessels it is customary to use transducers of various types inserted into their lumen. The chief disadvantages of these methods are disturbances of the circulation and the inevitable damage to the vessel wall, leading to thrombosis, thus interfering with the course of long experiments.

The miniature implantable blood-pressure transducer developed by the writers* can be used on intact vessels of different caliber without disturbing the integrity of the vessel wall. This means that experiments can be carried out over periods of many days with continuous recording of the blood pressure. The sensitive element of the blood-pressure transducer consists of a hermetically sealed differential transformer-coupled transducer of displacements of solenoid type with spring-loaded plunger, the body of which on the shaft side is fitted with a cylindrical collar with two grooves, bulb-shaped in cross-section, across its diameter and a threaded plug while the working surface of the plunger is a circular area, perpendicular to the above-mentioned diameter, and separated from the medium by a thin elastic membrane. The primary winding of the sensor element is an oscillating electrical circuit tuned to the frequency of the ac generator providing the power.

The general appearance of the transducer in assembly is shown in Fig. 1A, the components of the system in the order of their arrangement in Fig. 1B, and the basic electrical circuit in Fig. 1C. The implantable blood-pressure transducer is cylindrical in shape (Fig. 1A), hermetically sealed, and fitted with a flexible multistranded thin cable 2, ending in the plug 3. The transducer (B) consists of a cylindrical coil 4 with two equal sections 5 for the windings and an inner hole 6 for the shaft 7 of the plunger of the differential transformer-coupled transducer of displacements of solenoid type. The shaft 7 is fixed to the plunger 8, the working surface of which is circular. The spring 9 counteracts the pressure of the vessel. The case 10 is made of stainless steel, and at its thin end 11 an elastic membrane 12 is fitted to make an airtight joint. The case 10 is fitted with a cylindrical collar 13 on the side of the plunger 8, with two gaps 14 made along

* Apparatus for bloodless measuring of the blood pressure in vessels. S. Kh. Bogorad and N. V. Bekauri, Discoveries, Inventions, Industrial Samples, and Trade Marks (1971), 16, 17, Author's Certificate No. 303055.

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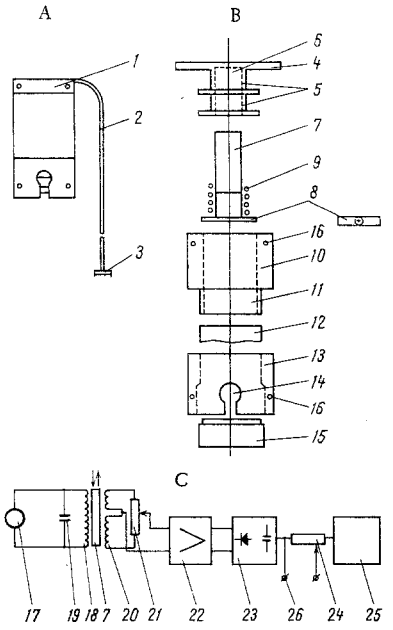

Fig. 1

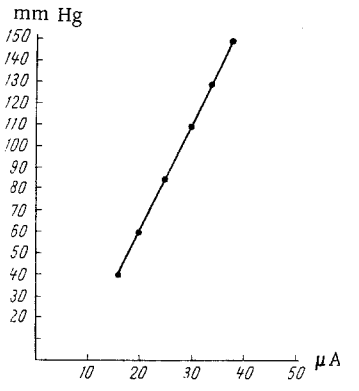

Fig. 2

Fig. 1. Implanted blood pressure transducer: A) general appearance of transducer: 1) cylindrical blood pressure transducer; 2) flexible multistranded thin cable; 3) plug. B) Diagram of assembly of transducer: 4) cylindrical coil; 5) two sections for windings; 6) internal hole in coil for plunger shaft; 7) plunger shaft (of differential transformer-coupled transducer of displacements of solenoid type); 8) plunger; 9) spring (counteracting pressure of blood vessel wall); 10) case of transducer; 11) thin end of transducer; 12) elastic membrane; 13) cylindrical collar; 14) grooves; 15) threaded plug; 16) lugs in case and in walls of collar. C) Basic electrical circuit of apparatus for measuring blood pressure: 17) stabilized ac generator (YuKGTs); 18) primary winding; 19) capacitor; 20) secondary windings of coil 5; 21) potentiometer; 22) self-stabilizing amplifier; 23) detector; 24) load resistor; 25) source of calibration voltage. Remainder of explanation in text.

Fig. 2. Readings of microammeter (abscissa) connected with implanted transducer placed on blood vessel, as a function of readings of mercury manometer (ordinate) connected to the same vessel.

the diameter of the collar, and bulb-shaped in section, and also with a threaded plug 15. To secure the apparatus to the tissues holes (or lugs) 16 are provided in the case 10 and in the walls of the collar 13.

This apparatus is used as follows. The plug 15 is unscrewed from the collar 13, and threads for securing the transducer to the tissues of the experimental animal are introduced into the holes 16. The required blood vessel is exposed and by gentle traction it is introduced into the grooves 14 as far as their expanded part, the bulb-like shape of which prevents the vessel from slipping out. Once the apparatus is fixed in position in the tissues, it is secured as required and the plug 15 is screwed in until it presses the vessel gently against the membrane 12, against the other side of which the shaft 7 of the plunger 8 is pressed by the spring 9. The cable 2 is laid beneath the skin, and the plug 3 is secured in a special plastic fistula tube to the skin. The pressure is transmitted from the wall of the blood vessel to the shaft 7 of the plunger, and by its movement within the hole 6 it changes the induction coupling between the primary (18) and secondary (20) windings, wound simultaneously and together (like a bifilar winding) on the coil 4 in the section 5. Since the primary winding 18 is tuned by means of the capacitor 19 in resonance with the frequency of the generator 17, very little power (less than 10 μW) is required to work the transducer, thus ruling out the possibility of thermal, mechanical, or electromagnetic back-effects of the transducer on the experimental animal.

The voltage from the diagonal of a bridge formed in series and in phase with the connected secondary windings 20 and the potentiometer 21 is amplified by the self-stabilizing amplifier 22, rectified, and smoothed by the detector 23, after which it is compared on the load resistor 24 with the source of the calibration voltage 25. Display, warning, or recording instruments are connected to the output terminals 26.

The experimental model had the following basic parameters:

Diameter (in mm)	10
Height (in mm)	16
Force of spring plus displacement (in g/mm)	6
Conversion factor (with amplifier) (in μ A/μ)	2
Output resistance (in Ω)	150
Drift – symmetrical	±1%

Tests of the experimental model of the implantable blood pressure transducer on five cats, six rabbits, and one dog in acute and chronic experiments were successful. The implantable transducer was graduated against a mercury manometer and, within the range of pressure from 40 to 150 mm Hg used, a linear relationship was found between the readings of the secondary (recording) instrument and the readings of the mercury manometer (Fig. 2). It was shown that the pulse pressure could be recorded on a type ÉPP-09-M3 automatic recorder for several days after implantation of the transducer.