# PHOTOELECTRIC RECORDING OF PULSE VOLUME OF THE CORONARY ARTERY IN CHRONIC EXPERIMENTS

V. R. Zakharzhevskii, A. O. Olesk, and V. N. Strochkov

UDC 612.172.4:612.143

By using miniature selenium-cadmium photoresistors and baseless microtubes with a tungsten filament, a photoelectric detector of small size and weight has been made, suitable for recording the pulse volume in medium-caliber arteries of dogs for several months.

* * *

Most methods used for the estimation of vascular tone (resistography, oncometry, etc.) are suitable only for acute experiments, and for that reason the state of the coronary vasomotor function in chronic experiments is usually judged indirectly [1]. Although a number of investigations [5, 6, 9] have shown that it is possible, in principle, to use photoelectric cells to record arterial pulse volumes, until recently this method has also been limited to acute experiments. With the appearance of miniature highly sensitive hermetically sealed semiconductor photoresistors, these could be used for implantation into the animal body [7, 8].

In this paper we describe an implantable photoelectric device suitable for recording the pulse volume in the coronary artery of dogs. Its main elements are: a photoelectric detector, a Wheatstone bridge, a power source, an amplifier, and a recording instrument. The photoelectric detector consists of a photoresistor and tube mounted together in an organic glass well. The sensitive element of the instrument is a selenium-cadmium photoresistor, of Soviet manufacture, with brand number SFZ-1 [2]. It is small in size (0.5 × 1.5 mm), its photosensitive layer is hermetically sealed, and it possesses very high sensitivity (3 A/lm). In addition, selenium-cadmium photoresistors possess optimal spectral characteristics for plethysmography (Fig. 1). Their sensitivity maximum (780 mμ) coincides with absorption spectrum of blood, so that very slight changes of blood volume can be detected. At the same time, an increase or decrease in the blood oxygen saturation has practically no effect on the translucence of the organ, for in the near infrared region (from 750-900 mμ) the difference in light absorption of oxidized and reduced hemoglobin is negligible [3]. Type SFZ-1 photoresistors are designed for low working voltages (2-15 V), and this is very important from the standpoint of safety and convenience of use.

Photoresistors possess definite inertia and the relationship between luminous flux and photoelectric current is not linear. Let us consider to what extent these disadvantages affect plethysmographic investigations. According to many authors [3, 4], the intrinsic frequency of the plethysmograph must not exceed 75-100 Hz. The frequency characteristic curve of selenium-cadmium photoresistors (time constant $10^{-3}$ sec) illustrated in Fig. 1 can yield a practically undistorted recording of the arterial pulse. The character of the lux-ampere relationship is no less important for quantitative analysis of the data. Special investigations under acute experimental conditions showed that the fall in intensity of illumination of the photoresistor associated with pulse fluctuations in the volume of blood in the vessel must not exceed 32 lx (if the tube current is 63 mA and the vessel completely emptied of blood, the intensity of illumination of the photoresistor is 50 lx, and with maximal filling of the vessel with blood, it is 18 lx, whereas without the vessel it is 65 lx). Over this narrow range of changes in luminous flux, the nonlinear character of the lux-ampere relationship is practically not observed, for a limited segment of a curve can always be approximated by a straight line.

Baseless microtubes with a tungsten filament were used as source of light. The small size of the tubes (diameter 2.5 mm, length 6 mm) and the low heating temperature of the bulb are of great importance for implanted instruments. Because of the high sensitivity of the photoresistor, the tubes can work on the

---

Laboratory of Corticovisceral Physiology and Pathology, I. P. Pavlov Institute of Physiology (Presented by Academician V. N. Chernigovskii). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 65, No. 6, pp. 113-116, June, 1968. Original article submitted November 28, 19[illegible].

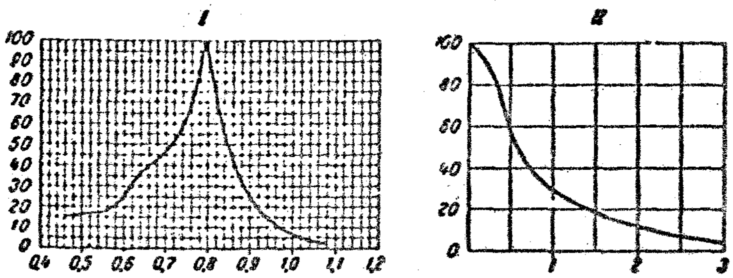


**Fig. 1.** Spectral and frequency characteristics of the type SFZ-1 selenium-cadmium photoresistor. I) Spectral characteristic curve; II) frequency characteristic curve. Ordinate, photoelectric current (in percent); abscissa, wavelength (in μ; I), frequency (in kHz, II).

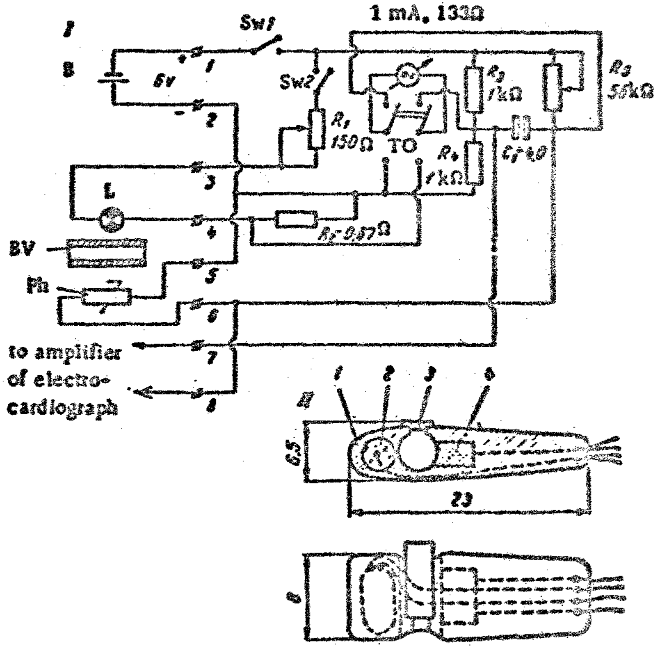


**Fig. 2.** Theoretical circuit of photoelectric device (I) and structural diagram of photoelectric detector for blood vessels (II). L) Detector bulb; BV) blood vessel; Ph) Photoresistor; B) battery; 1) Plexiglas block; 2) bulb; 3) slide for closing gap after inserting vessel; 4) photoresistor.

conditions of underheating (the current applied to the tube did not exceed 65 mA), so that the heating temperature of the bulb can be reduced (not exceeding 45°) and the service life of the tube increased considerably.

A structural diagram and the dimensions of the detector are shown in Fig. 2. The base of the detector is made of organic glass. The mutual arrangement of the bulb and photoresistor allow transillumination of the vessel. As a rule, a series of electrodes was made with holes for the blood vessel of different diameters, although the photoelectric method of recording does not demand such precise agreement between dimensions of the vessel and detector as in the case of the thermoelectric and other methods. Hermetic sealing of the detector was carried out with acrylic glue, the photosensitive surface of the photoresistor not being covered (this was hermetically sealed at the factory) so as to ensure unobstructed access of light to the photoresistor. The weight of the detector with its leads does not exceed 2.5 g. Sterilization of the de-

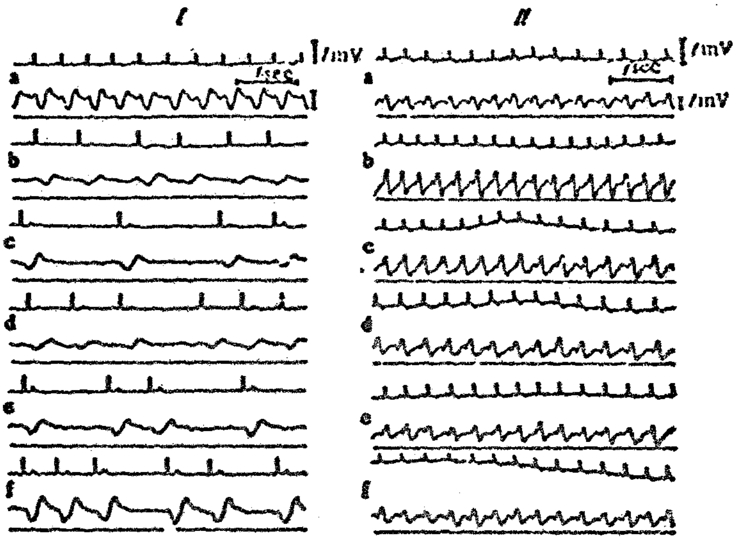


**Fig. 3.** Changes in ECG and pulse volume of coronary artery after injection of 0.5 units pituitrin (I) and 10 mg papaverine (II). a) Before injection; b) 30 sec; c) 1 min; d) 3 min; e) 5 min; f) 10 min after injection; above, ECG; below, pulse volume of artery.

tector and conditions of the operation on the heart are indistinguishable in principle from those described earlier for investigations using a thermoelectric method [1]. The detector is fixed on the vessel (as a rule of the circumflex branch of the left coronary artery) by means of a Plexiglas slide covering the gap in which the vessel is inserted, and acrylic glue is then applied on top.

The theoretical electrical circuit for the photoelectric detector is shown in Fig. 2. Power for the circuit is provided by a 6 V battery through the switch Sw 1. The heating current for the bulb (L) of the detector is determined by the resistor ($R_1$) and controlled by a measuring instrument in the lower position of the throw-over switch TO from the fall in voltage on the shunt ($R_2$). The photoresistor (Ph) is connected into one arm of the bridge in corporating the resistors $R_3$, $R_4$, and $R_5$. The voltage at the differential input of the amplifier of the type ÉKPSCh-3 two-channel electrocardiograph is supplied from the diagonal of this bridge. The scheme of operation is as follows. When the bulb of the detector is switched on the throw-over switch (TO) is transferred into the upper position, connecting the measuring instrument to the bridge diagonal; the bridge is balanced by varying the resistor ($R_4$). The measuring instrument is again switched over to controlling the bulb current. As a result of pulse changes in volume of the blood vessel, a fluctuating luminous flux falls on the photoresistor, leading to the appearance of corresponding electrical oscillations in the measuring diagonal of the bridge. Under conditions of transillumination of the blood vessel, the intensity of illumination of the photoresistor and, consequently, the photoelectric current at each given moment of time will be determined by what, in practice, is the only variable factor, the volume of blood in the vessel, and this relationship will be close to linear for the reasons given above. By applying a standard voltage (1 mV) to the input of the electrocardiograph amplifier, we can compare the amplitude of the calibration signal with the amplitude of the arterial pulse and thus assess the recorded sphygmograms quantitatively.

Experiments demonstrated that the pulse volume of the coronary artery of dogs can be recorded for a long period after implantation of the detector (more than 6 months). High sensitivity of the photoelectric instrument was found, and it could be used to estimate changes not only in the amplitude, but also in the shape of the pulse wave after various procedures. Synchronized recordings of the ECG (lead 2) and the pulse volume of the coronary artery of a dog 2 months after operation and following administration of various humoral stimuli are shown in Fig. 3. By recording the pulse volume of the coronary artery in dogs under chronic experimental conditions, especially in conjunction with determination of other indices (arterial blood pressure, volume velocity of the coronary blood [illegible]), a sufficiently complete estimate of the coronary vasomotor function can be obtained during the action of [illegible] stimuli.

The method as developed for the coronary artery can also be used successfully for the study of other arteries.

## LITERATURE CITED

1. M. E. Marshak and G. N. Aronova, Fiziol. Zh. SSSR, No. 8, 770 (1958).
2. A. O. Olesk, Highly Sensitive Selenium-Cadmium Photoresistors [in Russian], Leningrad (1958).
3. V. V. Orlov, Plethysmography [in Russian], Moscow-Leningrad (1961).
4. N. N. Savitskii, Some Methods of Investigation and Functional Assessment of the Circulatory System [in Russian], Leningrad (1956).
5. A. B. Hertzman and J. B. Dillon, Am. J. Physiol., 130, 56 (1940).
6. F. Lippay, Aust. J. Exp. Biol. Med. Sci., 34, 301 (1956).
7. T. Posteli and G. Garbini, In: Proceedings of the 2nd International Conference on Medical Electronics London (1960), p. 319.
8. T. Posteli, In: 4th International Conference on Medical Electronics, New York (1961), p. 248.
9. H. de Waele and J. van de Velde, Arch. Int. Physiol., 56, 408 (1949).