CONTINUOUS RECORDING OF BLOOD PRESSURE OF ANIMALS IN THE WAKING STATE

Karoy Turanski

Institute of Pharmacology (Director – Professor Mikhai Yancho, Active Member of the Academy of Sciences, Hungarian People's Republic), the Medical University, Seged, Hungary
(Presented by Active Member AMN SSSR V. V. Parin)
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Numerous methods for continuous recording of blood pressure in waking animals have been developed. Direct methods are the most suitable for long-term continuous recording.

Marquardt and Hildebrand [1] have developed a method involving direct access to the blood of experimental animals: It was used to record blood pressure in sleeping cats for 12 h, and was based on the introduction of a plastic tube into the femoral artery. However, the method was not suitable for prolonged recordings in waking animals.

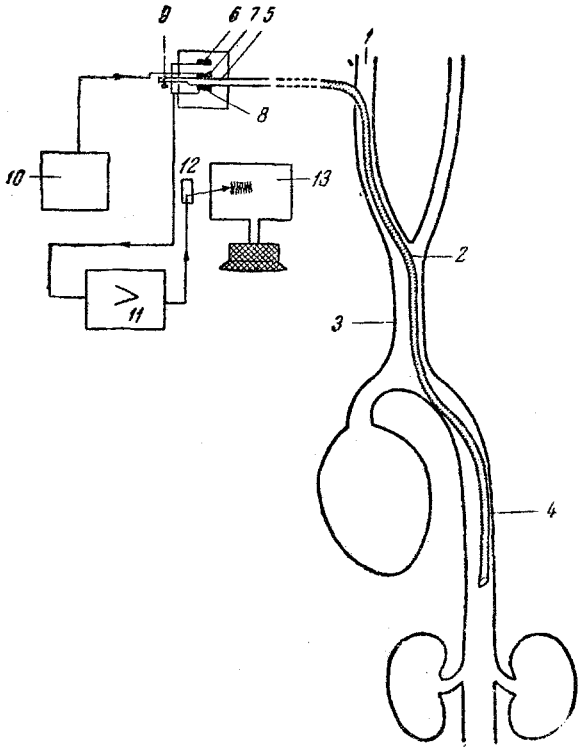

Fig. 1. Diagram illustrating the introduction of a polythene tube into the aorta. 1) Right carotid artery; 2) polythene tube; 3) innominate artery; 4) aorta; 5) glass-membrane manometer; 6) fixed coil; 7, 8) mobile coils of the manometer; 9) tap; 10) generator; 11) amplifier; 12) writer; 13) kymograph.

A considerable advance was made by Still [2,3]. At operation with sterile precautions, a polythene tube was introduced into the abdominal aorta of rats. After the operational wound had healed, the polythene tube which was brought out through the neck was connected to an electronic manometer. Blood pressure could be recorded for several weeks. The rats tolerated the operation well. However, this method has not been widely used because of the comparatively involved operative procedure.

The method described below has been used by us for four years. Blood pressure has been recorded in waking cats and dogs directly for many months. The operation required is not particularly involved or lengthy. Results of pharmacological investigations obtained by means of this method were first reported in 1960 [4,5].

It is easy to introduce a plastic tube of appropriate thickness into the thoracic aorta of cats and dogs through the right carotid artery, even without x-ray control. The principle of the method is illustrated in Fig. 1.

A membrane manometer connected to the tube should be sufficiently rigid for the internal volume of the system comprising the tube and manometer to vary very little in response to a change of pressure, so that when the pressure increases, only a small amount of blood flows from the artery into the tube, and when the pressure falls an equally small amount of fluid passes in the reverse direction from the tube into the vascular system. With the most suitable type of glass-membrane manometer, the internal volume does not increase by more than 0.015 ml for a pressure increase from 0 to 200 mm Hg. This constancy of the tube and manometer

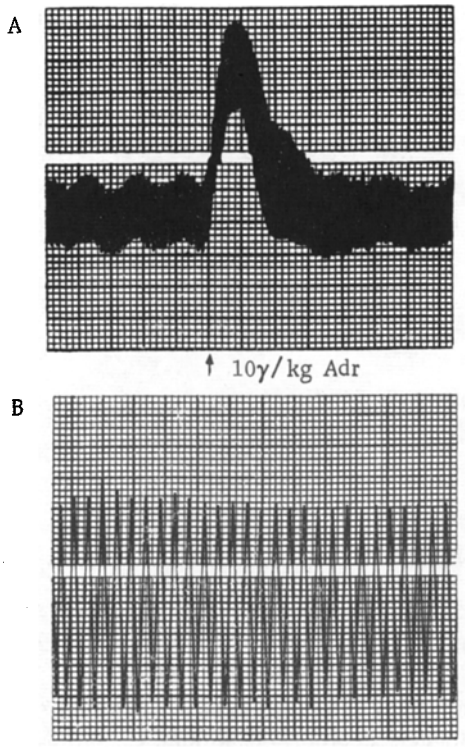

Fig. 2. Recording the blood pressure of waking cats. Rate of movement of paper 10 mm/min. A. Intravenous injection of 10 μg per kg adrenalin. B. Curves showing aortic pulse in the waking animal. Recording apparatus type "Khellige mul'tiskriptor."

volume enables blood pressure to be recorded without continually having to wash out the tube.

The polythene tube connecting the aorta with the manometer is filled with anticlotting fluid. The size of the tube introduced into the aorta depends upon the thickness of the carotid artery. We recommend a diameter not greater than three-quarters of the outer diameter of the carotid. With such a diameter, no disturbances to the blood supply of the head occurs. The outer surface of the tube should not be scratched or damaged in any way. The tube used should be one prepared for specifically medical purposes, such as a cardiac catheter.

Operation

The cat or dog is anesthetized (we used intravenous hexabarbiturate anesthesia), the skin is removed from the neck and occipital region, and the animal is then fixed to lie supine on the table. An incision 3 cm long is made in the midline of the neck. By blunt dissection the carotid artery is exposed at the internal border of the right sternocleidomastoid muscle. The cranial end of the carotid artery is then ligatured.

A polythene tube is then taken having a thickness three-quarters of that of the carotid artery, and is filled with physiological saline containing 50 ME of heparin per ml. One end of the tube is then plugged, and the tube introduced into the thoracic cavity so that its opened end lies at the apex of the xiphoid process. The tube is tied with a thread at that part of the carotid artery to which it is intended to introduce it, to mark the limit to which it is to be brought. The tube, filled with physiological saline, is introduced through a small incision in the carotid artery, in the usual way, and pushed forward until the point on it marked by the thread reaches the aperture in the wall of the artery. The carotid artery is then tied with a tight silk ligature, to hold the tube firmly in place. The closed distal end of the tube is brought out through an aperture in the skin of the occipital region to the surface. The wound is covered in the usual way. Neither the carotid artery or the tube from it should be attached to the skin or muscle. The tube brought out through each aperture of the occipital region is wound once or twice around the neck, so as to form a kind of collar. Where the tube is brought out, its several turns are bound together by thread or plaster. Next the plug is removed from the distal end of the tube, and 2-3 ml of physiological saline containing heparin are introduced. The tube is then once more closed. The "collar" formed by winding the tubes around the neck is protected by gauze, and after the wound has healed it is covered with a leather or plastic collar.

The blood pressure may be recorded immediately after the operation. Typical curves are shown in Fig. 2.

It is interesting that on awakening, the cats pay not the slightest attention to the "collar" formed by the tube. Several hours after arousal they take food, and for many weeks, or even months, make no attempt to tear away the collar around the neck. No previous habituation to wearing a collar is required. After the operation, the animals behave entirely normally.

Dogs also tolerate the tube well, but in them a pruritus develops during healing, and causes scratching. Therefore, in dogs, at any rate for the first week after the operation, the tube should be protected by a leather or strong plastic collar.

For the first eight days, the polythene tube should be filled twice a day (morning and evening) with fresh anticlotting solution. For dogs, 2-4 ml of physiological saline containing 50 ME per ml heparin are required. After eight days, it is sufficient to wash the tube once per day, and then only as a precaution, because if the tube is not damaged, the blood in it will not clot for many days. The polythene tube is most conveniently plugged by pushing into it a piece of thick-walled rubber tube of the appropriate diameter. The hollow of this second tube is then filled

with a metal plug along the whole of its length. When the plug is removed, it is easy to make a connection with the polythene tube running to the manometer.

If an intravenous injection is to be given during blood pressure recording, it is advisable during the operation to insert a plastic tube not only into the carotid artery, but also into the jugular vein. This tube is also introduced on the right side, and pushed up the vein as far as the clavicle. The technique used is the same as for the carotid artery, and both tubes may conveniently lie side by side.

Continuous recording of blood pressure is best made by means of a glass-membrane manometer (see Fig. 1). The transformation of the oscillation of the membrane manometer is effected by the principle of induction. Two coils are used, one fixed to the upper and the other to the lower membrane of the manometer. A third coil is mounted on the manometer itself, so that the three coils have a common axis, and at zero pressure the two outer coils are the same distance from the central coil. The center coil is supplied by an alternating current from a generator. The two outer coils are connected in series, and their ends taken to the input of an amplifier. At zero pressure the middle coil is equidistant from the two outer coils, and, therefore, no voltage will be supplied to the amplifier. When the pressure increases, the middle coil is displaced upwards, and the lower one downwards. Only the upper coil remains in position. Because of the disturbance of balance, a voltage appears at the input of the amplifier, and the pen of the recording device is set in motion. The recording device used was a kymograph.

In the system described, a movement of the membrane of 0.01 mm gives a pen movement of 2 cm. Alternatively, any kind of electronic manometer may be used.

Connection between the animal and the recording device may be made either by tube or by leads. In cats it is best to use a tubular connection, but in dogs it is more convenient to attach the manometer (sensitive element) to the collar, and to make the connection with leads. The dogs soon become acclimatized to laboratory conditions, and they need not be kept in a cage. With cats, a good connection can be maintained for several days if, while the animal is in a cage, the tube connecting it to the recording apparatus is held stretched by means of a springy fishing rod. The elasticity of the rod prevents the tube from slackening when the animal moves.

To begin with, a small amount of anticlotting fluid is introduced through the tap on the manometer, in order to remove blood which has been accidentally introduced during the manipulations. After the tap has been closed, recordings may be made.

In principle, it is possible to make a connection between the animal and the recording device without the use of leads. This method is the most convenient for dogs. Then it is best to use a capacitor manometer, which is of small size and may easily be attached to the collar. To the collar is also attached a short-wave transistor transmitter, which is connected to the capacitor manometer, and causes a frequency modulation of the latter. A wire attached to the collar serves as an aerial. A receiver placed at some distance transforms the frequency modulation into an amplitude modulation, which is then recorded. With modern methods, the transmission of the variations of the capacitor manometer is perfectly straightforward, and several methods are available.

We have made an attempt to find the simplest method of recording physiological data without the use of leads.

SUMMARY

A method is described for recording blood pressure in waking cats and dogs. A tube from a manometer, three-fourths of the diameter of the carotid artery, was introduced through the latter into the aorta to the required distance.

The membrane of the manometer is best made of glass, and should be sufficiently rigid. The tube is filled with saline containing 50 I.U. of heparin per ml, and is wound once or twice around the neck and fixed in position. In dogs the tube is best taken to a collar on which a condenser manometer connected to a miniature short-wave transmitter is fastened. In cats, connection to the manometer is made through a long tube.

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