Changes in the diameter and velocity of the blood flow in the terminal microvessels of the intestine and liver observed visually in these experiments correlated with the portal blood flow recorded instrumentally. This correlation was particularly clear after direct injection of physiologically vasoactive substances into the main blood vessels of the organs. The writers showed previously that acetylcholine, injected into the aorta at the level of origin of the superior mesenteric artery of a rat in a dose of 1.0-0.1 mg/kg causes transient generalized constriction of the microvessels of the intestine and stomach [1]. A fall in blood volume in the sinusoidal system of the liver was observed under these circumstances. Measurement of the linear and volume velocities of the portal blood flow after such an injection of acetylcholine in the above doses into the aorta showed a transient fall (Fig. 3), accompanied by a fall in the systemic BP.

The suggested method of combined evaluation of the portal circulation can be used to study relations between different levels of integration of the circulatory system in other regions of the body.

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MEASUREMENT OF THE GENERAL AND LOCAL BLOOD FLOW IN A TRANSPLANTED KIDNEY BY THE HYDROGEN CLEARANCE METHOD

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UDC 616.61-089.843-07:616.61-005-073.7

KEY WORDS: transplantation of the kidney; renal blood flow; hydrogen clearance method.

Quantitative determination of the general and local blood supply to the kidney after transplantation has hitherto been a very difficult problem. One of the most suitable methods for this purpose is the hydrogen clearance method, which requires introduction of platinum electrodes into the kidney or into the lumen of the renal vein [3, 5]. Unfortunately such a procedure, which involves destruction of kidney tissue and opening of the blood vessel, imposes substantial limitation of the use of the hydrogen clearance method, especially under chronic experimental conditions.

One of us (I.T.D.) recently showed that hydrogen diffuses freely through the wall of the renal vein, so that the total renal blood flow can be determined without opening the vessel [2]. Hydrogen has also been shown to diffuse rapidly through the fibrous capsule covering the kidney, which means that the blood flow in the cortical layer can be measured by a flat electrode without damaging the tissues. On the basis of these investigations a combined method of quantitative determination of the general and local blood flow in the transplanted kidney was developed and has been used at the First Leningrad Medical Institute in chronic experiments on dogs.

The object of the present investigation was to examine this method and, in particular, to describe the construction of the electrodes, the technology for recording hydrogen clearance, and methods of calculating the blood flow.

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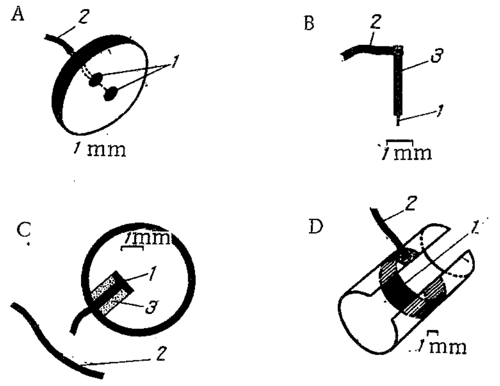
 0007-4888/82/9302-0222$07.50



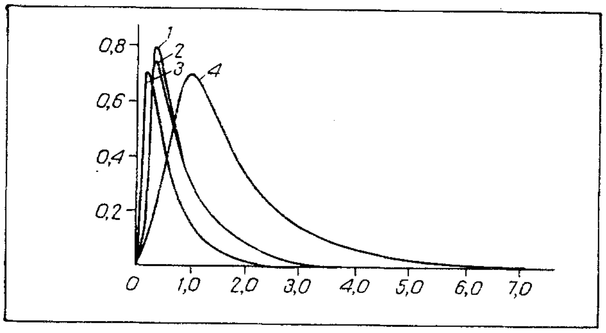


Fig. 1 Fig. 2

Fig. 1. Construction of electrodes for measuring local (A, B) and general (C, D) renal blood flow. 1) Platinum electrode; 2) lead; 3) case or insulation.

Fig. 2. Hydrogen clearance curves recorded in tissue and in venous blood of the transplanted kidney. 1, 2) In venous blood by intravascular and cuff electrodes, 3) in renal cortex, 4) in medulla. Abscissa, time (in min); ordinate, pH_2 (in μA).

Experiments were carried out on 16 mongrel dogs weighing 12-23 kg. Under endotracheal halothane anesthesia nephrectomy (usually on the left) was performed on a donor dog through a midline laparotomy incision. After perfusion of the kidney with cold (4°C) preserving solution it was transplanted to the receipient's right external iliac vessels by suturing the renal artery to the iliac artery and the end of the renal vein into the side of the iliac vein. Chronic catheterization of the renal vein was carried out through the external iliac vein. After revascularization of the graft, electrodes were fixed in the cortical and medullary layers of the kidney and also on the surface of the vein. The ureter was exteriorized on the skin together with the electrode leads and the catheter.

Four types of electrodes were used to measure the general and local blood flow (Fig. 1). The cortical blood flow was measured by means of flat electrodes 2 mm in diameter, made from platinum plate 0.2 mm thick. Two such electrodes were glued to a plastic base (Fig. 1A) sutured at three points to the kidney capsule. The blood flow in the medullary layer of the kidney was measured by means of needle electrodes 9-10 mm long, 0.15 mm in diameter, and insulated except for 2 mm at the tip (Fig. 1B). After insertion of the electrodes into the kidney, the leads were sutured to the capsule at two points. The total blood flow through the kidney was determined by analysis of hydrogen clearance curves recorded in venous blood [2]. Two types of electrodes were used for this purpose. One of them, the probe type (Fig. 1C), consists of a thin polyethylene tube into which the platinum electrode and lead are introduced. The working part of the electrode is the end of the probe. Such an electrode was introduced into the venous blood flow through the indwelling catheter only while the measurements were being made. If the renal vein was not catheterized, hydrogen clearance was recorded by means of a cuff transducer (Fig. 1D). This consists of a platinum electrode, semicircular in shape, and a Teflon cuff with a slit for introducing the blood vessel.

The hydrogen clearance was recorded by the ordinary polarographic method [1, 3]. The Ag–AgCl reference electrode, shaped like a staple, was fixed to the carefully shaved ear of the animal. The kidney was saturated with hydrogen by inhalation of a mixture of 5-7% H_2 in air.

Four hydrogen clearance curves recorded in the cortex and medulla of the kidney and also in the renal vein by means of probe and cuff electrodes are illustrated in Fig. 2. It will be noted that two curves coincide (1 and 2), evidence of free diffusion of hydrogen through the wall of the renal vein and confirming that pH_2 can be recorded through the intact vessel wall.

To calculate the local and total renal blood flow from the hydrogen clearance curves three basic methods are available: the "initial slope" method, component analysis, and determination of the height/area of the clearance curve ratio [1]. Considering that the choice of correct method depends on the shape of the curve, all the clearance curves were analyzed by transfer to semilogarithmic paper. This showed that 80% of the curves recorded in the cortex and 91% of the curves recorded in the medulla are monoexponential in form; consequently the blood flow can be calculated by the "initial slope" method, using the corresponding equation [1].

The clearance curves recorded in the renal vein by probe and cuff electrodes were close to monoexponential in 57% of cases, 32% consisted of two components reflecting the blood flow in the cortex and medulla of the kidney respectively, and the rest were polyexponential in character. To standardize the calculations in such cases the method of determining the height/area of the clearance curve ratio by the equation:

$$F = \frac{H \cdot V}{S} \times 100 \text{ ml/100 g/min},$$

must be used, where H is the initial height of the clearance curve (in mm), S the area beneath the clearance curve (in mm^2), and V the scanning speed of the process (in mm/min). However, when it is necessary to estimate the blood flow in the cortex and medulla separately, component analysis of the hydrogen clearance curves recorded in the renal vein must be used.

The method of measuring the cortical and total renal blood flow without destruction of the kidney tissue or opening the vein, examined in the course of this investigation, is simple to perform and reproducible. The values obtained for the blood flow by measurement by flat and cuff electrodes are similar to results obtained by other investigators [4, 5]. This method was developed for measuring the blood flow in the transplanted kidney, but the design of the electrodes and the whole technology of the measurements as described above are perfectly suitable both for the intact kidney and also for measuring the blood flow in other organs.

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