PULMONARY ARTERIAL PRESSURE AND TRANSBRONCHIAL ELECTROPLETHYSMOGRAPHY IN RATS

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The first attempt to investigate the pulmonary hemodynamics in small laboratory animals (rats) by catheterization of the pulmonary artery was made in 1966 [5]. For various reasons, however, the practical realization of this method is quite difficult [7]. Several investigations on rats have now been published [7] in which such an approach has been shown to be possible. However, the pressure levels in the pulmonary artery of these animals thus obtained have differed appreciably. Data on cardiac output can be obtained by indicator dilution methods [6, 7]. Data on the blood volume and air content of the lungs, etc., also are important.

The aim of the present investigation was to develop an atraumatic (without thoracotomy) method of combined evaluation of the circulation in the lungs of rats, the basic components of which would be catheterization of the pulmonary artery and transbronchial regional electroplethysmography [1], which is now widely used in clinical medicine and also experimentally (on dogs, cats, and rabbits).

METHODS

Experiments were carried out on 40 adult rats weighing 328.0 ± 10.2 g. The animals were anesthetized by intraperitoneal injection of pentobarbital (0.3 mg/100 g in 2% aqueous solution). To keep the body temperature constant, the animal was heated. Tracheotomy was performed in the neck and a cannula inserted through the branches of which artificial respiration was applied and a catheter-transducer inserted to record the transbronchial electroplethysmogram. Natural breathing was blocked by intraperitoneal injections of succinylcholine (0.3 mg/100 g, 2% solution); some experiments were conducted with natural breathing. To catheterize the pulmonary artery, the right jugular vein was dissected. The pressure curve in the pulmonary artery and the electroplethysmogram were corded synchronously with the ECG. The position of the catheter and of the catheter-transducer of the electroplethysmograph was verified roentgenographically on the ARMAN-1 apparatus.

To catheterize the pulmonary artery a guide tube (external diameter 1.67 mm, internal 0.9 mm) was introduced through the jugular vein. The guide, bent to an angle of about 30°, lightly smeared with mineral oil and filled with physiological saline with added heparin, was connected to the transducer of a Mingograf-34 automatic-recording electromanometer (Siemens-Elema, Sweden), and was introduced with the bent and uppermost, after which it was moved forward through 2-3 cm, during which procedure the pressure curve in the superior vena cava or in the right atrium was observed on the oscilloscope screen. The tube was then turned to the left and at the same time moved forward about another 1 cm until characteristic ventricular complexes of the pressure curve appeared on the oscilloscope screen, which, with the exercise of a little skill and with careful manipulation, is not difficult. Next, instead of the guide tube, a catheter with its working end bent through an angle of 90°, and also filled with physiological saline, was connected to the pressure transducer, and introduced into the lumen of the guide so that on emerging from the guide tube, the bent end faced upward. It was then moved forward through about 2 cm, passing into the lumen of the pulmonary artery, as could be judged by the appearance of a diastolic gradient on the pressure curve, characteristic of passage of the end of the catheter from the right ventricle into the pulmonary artery. In most cases this can be done after two or three attempts. After several trial experiments with

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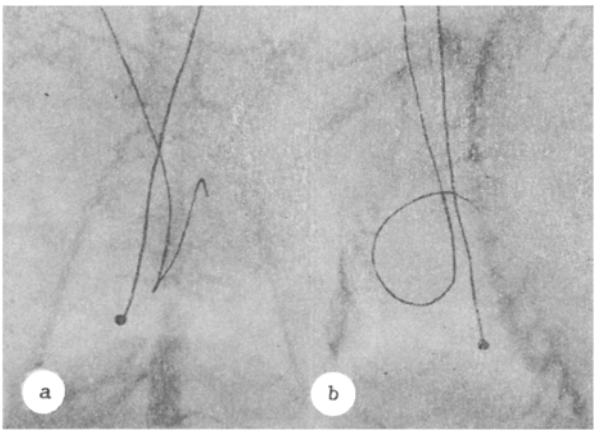

Fig. 1. Roentgenogram of rat's chest: a) anterior, b) lateral projection. The catheter-transducer of the electroplethysmogram can be seen against the background of the right lung field. The x-ray-opaque stylet (introduced into the lumen of the catheter), the end of which lies in the lumen of the pulmonary artery, can be seen on the outline of the heart.

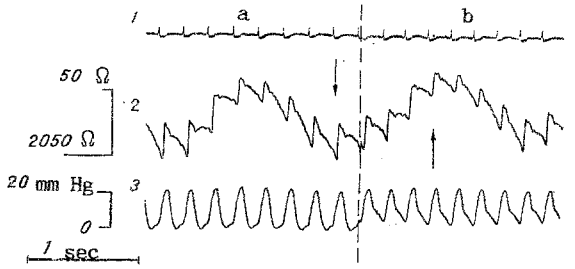

Fig. 2. Electroplethysmogram and pressure in pulmonary artery of a rat: 1) ECG; 2) electroplethysmogram of posterior lobe of right lung; 3) pressure in right ventricle (a) and pulmonary artery (b). Artificial respiration: arrow pointing downward indicates inspiration, upward expiration. Basic resistance and corresponding calibration signals shown on left. Time marker 1 sec.

different catheters, we selected a catheter with an external diameter of 0.84 mm and an internal diameter of 0.48 mm. This choice was based on two criteria: absence of a systolic pressure gradient between the right ventricle and pulmonary artery and preservation of the basic contour of the pressure curve in the pulmonary artery. During transbronchial electroplethysmography electrodes with significantly different sizes were used for practical application of the method to rats. The external (indifferent) electrode was a plastic disk 30 mm indiameter, which was applied to the rat's shaved abdominal wall. The internal electrode, a cylinder 1 mm in diameter and about 1 mm long, soldered to an insulated wire (0.2 mm), was introduced through the respiratory passages until it wedged in a narrow bronchus. To investigate regional functions of the pulmonary circulation, the two electrodes were connected to the input of an RPG1-02 rheoplethysmograph (the EPG-2 electroplethysmograph in B. I. Mazhbich's modification), made by the Experimental Factory, Siberian Branch of the Academy of Sciences of the USSR, and which also was connected to the Mingograf-34.

TABLE 1. Parameters of Transbronchial Electroplethysmography and Pulmonary Arterial Catheterization in Rat and Man

Test object	Pulse rate, beats/min	Blood flow, ml/100 cm³		Blood volume, ml/100 cm³	Air content, ml/100 cm³	Diameter of catheter for rats, mm		Pressure in pulmonary artery, mm Hg			Anesthesia
		stroke	minute			external	internal	systolic	diastolic	mean	
Rats	392,5±10,3	1,67±0,16	650,9±69,4	16,70±0,93	64,7±2,08	1,00	0,60	27,7±1,65	6,6±0,72	16,6±2,0	Pentobarbital (0.03 mg/kg), succinylcholine (0.3 mg/kg)
						0,84	0,48	22,0±0,99	6,5±0,84	13,9±0,85	Trimeperidine (1% solution, 1 ml), atropine sulfate (0.1% solution, 1 ml), heoxobarbital (200-250 ml), suxamethonium (80-120 mg)†
Man	107,10±4,69	1,56±0,14	167,2±15,1	17,0±0,77	63,4±1,65	—	—	22—25*	8*	10—15*	

Legend. *Data taken from[5], †data relate to electroplethysmographic parameters only.

RESULTS

A roentgenogram of the rat's chest is shown in Fig. 1. With films taken in two projections, it is possible to verify the position of the catheter and the catheter-transducer of the electroplethysmograph and to correlate their positions with the corresponding traces of the electroplethysmogram and pressure in the pulmonary artery.

The transbronchial electroplethysmogram of the rat lung and the blood pressure curve in the pulmonary artery, recorded synchronously with the ECG, are shown in Fig. 2.

The universal nature of the method of transbronchial electroplethysmography, based on the transition from measured values of electrical resistances to specific values, and on calculations of physiological parameters per unit volume of the organ on the basis of unified formulas [2], means that the results obtained on rats ought to correlate to some degree with results obtained on higher species of animals [1, 3], and in the absence of any firmly established data on values of hemodynamic parameters in rats, is a matter of great importance.

Mean values of electroplethysmographic parameters and pressure in the pulmonary artery are given in Table 1. The same parameters for man also are given in the same table. It will be clear, in particular, that most of the parameters for man and the rat under consideration, despite the very great difference in body weight, are virtually equal in magnitude. This applies both to the volumes of blood and air in the lungs, levels of the diastolic, mean, and systolic pressure, and even to the stroke ejection, expressed per unit volume of the organ. Only the heart rate differed significantly, which demonstrates the well known fact that the circulation in small animals is under greater strain than that of larger animals or man. As will be clear from Table 1, the minute volume of the circulation per unit volume of the lungs was almost four times greater in the rat than in man.

The data on catheterization of the pulmonary artery in rats by catheters of two closely similar yet different sizes showed that the diastolic and mean pressure in the pulmonary artery were virtually identical, whereas the systolic pressure in the pulmonary artery was significantly higher when a catheter of larger size was used ($P < 0.01$). Moreover, in the last case, a systolic pressure gradient was sometimes observed between the right ventricle and the pulmonary artery.

On the basis of the facts described above it can be concluded that it is preferable to use a thinner catheter, which in the present experiments could remain in the lumen of the pulmonary artery for up to 30 min without any changes of pressure, provided that it was periodically washed out with a minimal volume of physiological saline. However, the use of catheters with an even smaller internal diameter does not permit a distortion-free record of the pressure curve to be obtained, even with the use of high class electromanometers. The use of catheters with greater external diameter both in the present experiments and in investigations by other workers [7] led to the appearance of the systolic gradient mentioned above.

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