REGIONAL DISTRIBUTION OF THE PULMONARY BLOOD FLOW DURING APNEIC OXYGENATION AND ALVEOLAR ANOXIA

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It has been shown by means of xenon-133 that under conditions of simultaneous apneic oxygenation of one lung and alveolar anoxia in the second lung with the patient in the horizontal position, the distribution of the pulmonary blood flow is unchanged. Alveolar anoxia causes a considerable decrease in the absolute pulmonary blood flow.

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A decrease in the blood flow in the lung ventilated with an anoxic gas mixture and an increase in the blood flow in the lung in which the oxygen concentration in the alveolar gas is normal or increased have been demonstrated [5, 10, 19]. The existence of a strict zonal distribution of the pulmonary blood flow has also been established under various normal and pathological conditions [8, 20]. However, it is not yet known whether the regional distribution of the pulmonary blood flow is altered in association with an absolute decrease in its level under artificial anoxic conditions.

Parin and Meerson [3, 4] consider that too much importance has been attached to the influence of respiratory movements [9, 12] on the pulmonary blood flow, but for purity of clinical investigation this factor must be removed. Accordingly, investigations were carried out in the absence of natural and artificial respiratory movements: under conditions of diffusion respiration [2, 11] or apneic oxygenation [16]. This method, first used in man in 1951, is nowadays employed on a comparatively large scale in clinical practice [2, 7, 18].

We have studied the regional distribution of the pulmonary blood flow under conditions of apneic oxygenation and alveolar anoxia.

EXPERIMENTAL METHOD

Nine patients aged 20-40 years, who had undergone various operations and who had no visible signs of diseases of the respiratory and circulatory organs, were investigated. The subjects were intubated with a modified double-lumen tube enabling separate intubation of the right and left main bronchi to be carried out. A catheter, isolated from its lumen, was introduced into each bronchial tube, enabling gases to be introduced separately into each lung with free escape of the gas back from the lung through the lumen of the intubation tube.

The distribution of the pulmonary blood flow was determined by means of xenon-133 [1] by the usual method [6]. Scintillation counters with a NaI crystal were placed above the upper and lower lobes of each lung. Conversion of the detected activity into an electrical signal was carried out by means of NZ-106 radiometers with a time constant of 1 sec. The radiographs were recorded on a type N320-5 multichannel self-writing instrument with a paper winding speed of 2.5 mm/sec.

The CO_2 concentration in the main bronchi was recorded by means of an OA-2209 self-writing infrared gas analyzer, and the oxygen saturation of the arterial blood was measured with a type 036m oxyhemograph. Indices of the acid-base balance and the pCO_2 of the arterialized blood were measured with an Astrup pH-meter (radiometer). During the investigation the pulse rate and arterial and venous pressures were recorded.

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TABLE 1. Regional Distribution of Pulmonary Blood Flow (Index of Perfusion, M±σ)

Zone of lung	Stage of investigation		
	normal ventilation	apnea	
		insufflation of oxygen into right lung	insufflation of oxygen into right lung and nitrogen into left
Right			
Upper	1.02±0.072	1.45±0.083	1.59±0.127
Lower	1.01±0.061	1.33±0.091	1.58±0.088
Left			
Upper	0.93±0.06	0.64±0.1	0.46±0.092
Lower	0.98±0.033	0.57±0.067	0.35±0.109

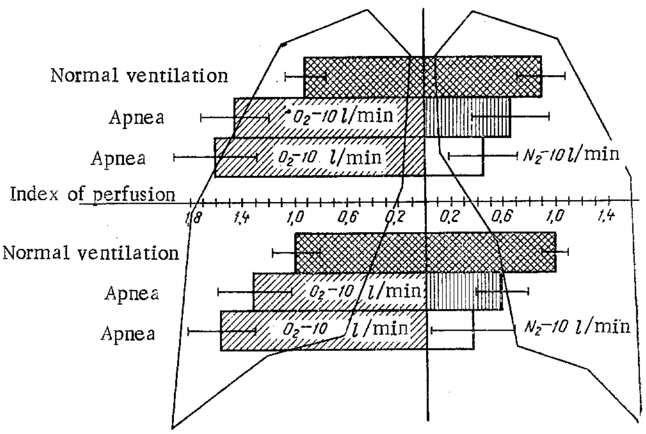

Fig. 1. Regional distribution of pulmonary blood flow (index of perfusion, M±σ).

Initially, the pulmonary blood flow was determined during natural respiration. Xenon-133 in a dose of about 600 μCi and dissolved in 3-5 ml sterile physiological saline, was injected into the cubital vein, and the vein was then quickly flushed out with 10 ml physiological saline. Because of the low solubility of xenon-133 in blood ($\alpha = -0.0845$ at 37° and 760 mm Hg), 95% of it is eliminated from the pulmonary blood flow into the alveoli, in proportion to the local blood flow, so that the relative perfusion of that part of the lung examined by the scintillation counter can be judged [6, 8, 20]. The blood flow was calculated per unit volume of the lungs (the distributive index of perfusion) by Ball's method [6] by equilibration of the xenon-133 concentration in a closed cycle with constant volume including a scintillation counter directly determining the xenon-133 concentration.

After the regional distribution of the pulmonary blood flow had been recorded during natural ventilation, spontaneous respiration was blocked by intravenous injection of 100-200 ml succinylcholine. After the development of apnea, oxygen (10 ml/min) was injected into the right lung through the catheter lying in the main bronchus, the left lung not being ventilated. Xenon-133 was injected intravenously 3 min after the beginning of apnea, and the regional blood flow was again recorded in the upper and lower zones of the right and left lungs, followed by clearance of the xenon for 8-10 min. Both lungs were then completely freed from xenon-133 by artificial hyperventilation.

The next stage of the investigation was to introduce oxygen into the right lung against the background of continuing apnea at the rate of 10 liters/min, and nitrogen into the left lung at the same rate, followed by a further determination of the regional pulmonary blood flow.

Artificial ventilation was then carried out to restore the normal gas composition of the blood, and the intubation tube was removed as soon as the natural ventilation had become adequate. The dose of radiation, calculated in accordance with Lassen's principle [15], did not exceed 150-200 mrad, i.e., it was close to the dose of irradiation received during radiological investigations.

All investigations were carried out under endotracheal ether anesthesia (III-I) with the patient horizontal in the supine position.

EXPERIMENTAL RESULTS

During normal ventilation of the lungs and with the patient supine, the pulmonary blood flow was relatively uniformly distributed (Table 1).

Absence of ventilation in the left lung and apneic oxygenation of the right lung caused displacement of the blood flow from the left lung into the right. During simultaneous insufflation of oxygen (10 liters/min) into the right lung and nitrogen (10 liters/min) into the left lung, the process of displacement of the blood flow was increased (Fig. 1).

Hence, under the conditions of aventilatory substitution of alveolar gas (aventilatory massflow [7]) a definite relationship exists between the pulmonary blood flow and the alveolar pO_2: anoxia causes a sharp decrease in the blood flow, confirming the hypothesis of Euler and Liljestrand [13].

The decrease in perfusion of the unventilated left lung when nitrogen was unsufflated into it is noteworthy. This can be explained by two circumstances: first (and this is more probable), nitrogen flushed out the remains of the oxygen from the lung, as a result of which the alveolar pO_2 fell still further; second, the possibility cannot be ruled out that an excess of CO_2 in the unventilated but perfused lung may have prevented a further decrease in perfusion. Most workers consider that hypercapnia acts in the same way as anoxia on the pulmonary blood flow. Admittedly, in Parin's opinion [3], the effect of hypercapnia is much weaker. The opinion has been expressed that an increase in alveolar pCO_2 has no effect on the pulmonary blood flow [14], or may even increase it [17]. Special verification of this second hypothesis is unquestionably required.

No significant differences were found in the regional distribution of the blood flow within each lung whether during apneic oxygenation or during anoxia under the experimental conditions used. This means either that no marked regional differences of pO_2 were present or that there is no regional mechanism of adaptation of the blood flow to such differences under these experimental conditions. It must be remembered that the apneic oxygenation was carried out in conjunction with unilateral pulmonary anoxia, against a background of anesthesia, and with the patients in the horizontal position.

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