# Structure of Microvascular Networks in the Lungs and Peculiarities of Blood Circulation in Them

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Microvessels and their relationship with alveoli in the lungs of albino rats under physiological condition in the thorax were studied by intravital microscopy. The structure of a network of large microvessels 20-30 μ in diameter surrounding each alveolus along the perimeter from all sides was demonstrated. Blood flow was investigated by video.

**Key Words:** *lungs; alveoli; microvessels; blood flow*

Peculiarities of the brain, muscle, and liver microcirculation were described in published reports and in our investigations [3-14,17]; however, until now little is known about lung microcirculation due to great experimental difficulties. The lungs cannot be removed from the thorax, stretched, and microscopically investigated in transmitted light, because the structure of the vascular network will be immediately disturbed. Therefore, old speculative representations of microcirculation in the lungs, according to which "alveoli like grape berries are suspended on thinnest pulmonary arterioles" [2,6,7,13,15,16], survived up to the present moment. After detailed investigation of microcirculation in different tissues and organs, we proceeded to investigation of this process in the lungs and attempted to answer a number of questions. First, whether all alveoli receive blood only through individual lung arterioles or many arterioles are supplied with blood from one and the same source? This question was raised by D. P. Dvoretskii, B. I. Tkachenko, E. R. Weibel, and J. West [2,6,15,16]. This question is fundamental, because it touches upon the general structure of pulmonary microcirculation and microvessel functioning. The second issue is more complicated. The point is that lungs are comparatively small organs by their weight (~600 g in man). However, 5 to 6 liters of blood pass through the lungs per minute under physiological conditions (cardiac output). This blood volume is 7-8-fold higher than blood supply to the brain. It brings up a question about the structure of pulmonary microcirculation ensuring transmission of such a huge amount of blood per time unit? The third question is about oxygenation of such a great volume of blood per minute? This one is even more complicated, because it touches upon a number of important issues of oxygen diffusion, blood physiology, and physiology of pulmonary circulation.

In this experimental work we made an attempt to find at least partial answers to these questions using *in vivo* lung microscopy with contact optic system under physiological conditions and physiological location of the lungs within the thoracic cage.

## MATERIALS AND METHODS

Experiments were carried out on rats ($n$=15) weighting 200-230 g under Nembutal anesthesia (40 mg/kg body weight). An aperture in the thorax wall 5×5 mm in size was made with resection of one rib. Pleura incision was performed through the aperture; the lung collapsed, and then inflated with oxygen through a tracheotomy tube. The tube of a contact microscope was introduced through the hole in the thoracic tissues, which aperture (1.5 mm in diameter) gently touched the lung surface. Images of 10-15 alveoli per frame were obtained at low magnification (300-400). Images

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of one or two alveoli were obtained at high magnification (600-800). The principles of operation of contact optic system were previously described by us [12].

## RESULTS

We succeeded to obtain a number of panoramic images of the lung surface (*i.e.* images of the surface of a flat object). They show several (from 10 to 15) alveoli and wide microvessels (20-30 μ in diameter) between them (Fig. 1). Relatively rapid blood flow in those vessels could be observed directly or on video. Under conditions of good lung supply with oxygen, the blood in these vessels is hot pink in color. Rare sites with darker (venous) blood were noted in some parts of these channels between the alveoli. In panoramic images, alveoli looked dark-red or brown. Each alveolus was surrounded along the perimeter by thick streams of blood. There was no evidence of capillary blood flow in the alveoli. Apparently, the blood flow within

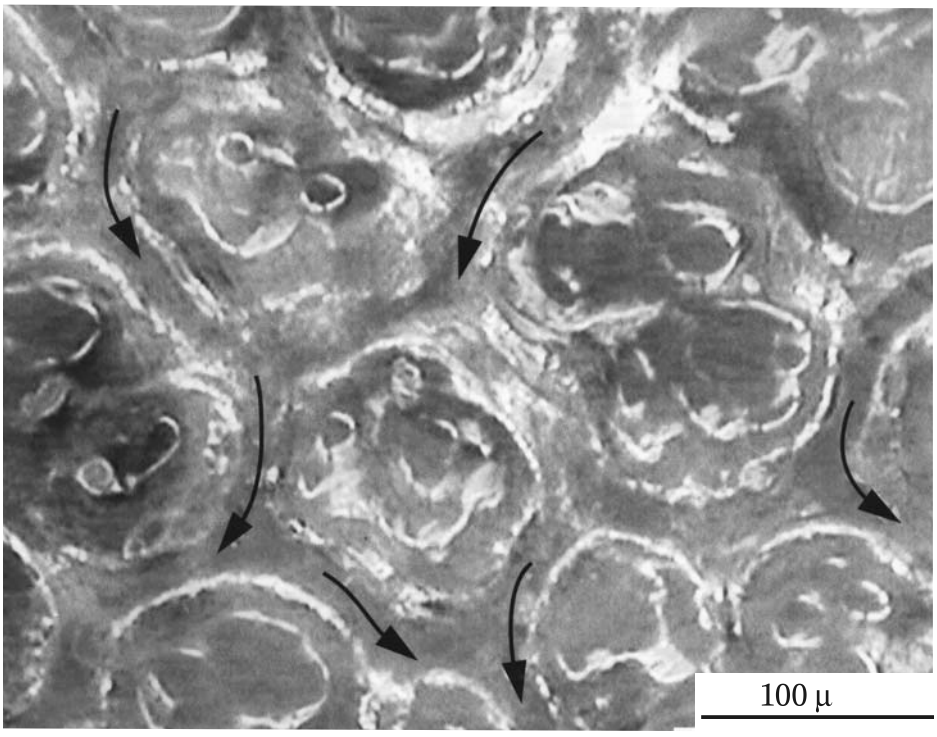


**Fig. 1.** Panoramic image of several arterioles and blood streams 20-30 μ in diameter between them. Almost each alveolus is surrounded by large microvessels. Arrows indicate direction of the blood flow.

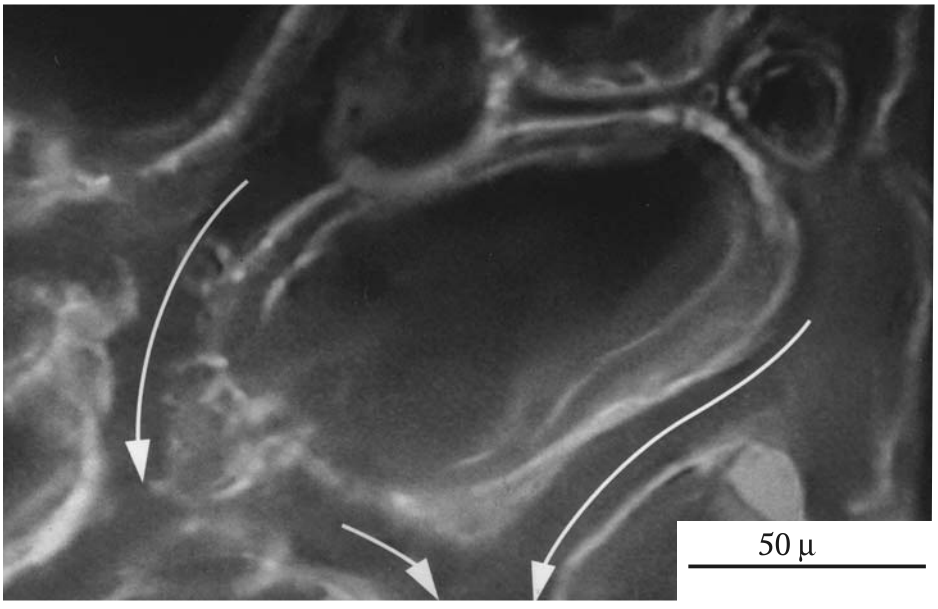


**Fig. 2.** Panoramic image of a large alveolus from the middle lobe of the lung. Alveolus is surrounded by thick streams of blood, 20-30 μ in diameter. Arrows indicate direction of blood flow.

the alveoli has a lacunar pattern, *i.e.* flows between the inner and outer alveolar membranes without baffles. The directions of blood flow in vessels near the alveolus are shown with arrows (Fig. 2). The flow is so rapid, that individual red blood cells or white blood cells cannot be visualized, although our magnification allows visualization of these blood cells when the blood flow is stopped.

Images of lung surface under physiological conditions (within thoracic cage) showed that alveoli at the surface of the lungs and probably deep in the lungs are arranged in parallel lines. Individual alveoli have no individual blood supply. We observed no cases of individual pulmonary arterioles. We believe that wide blood streams (which we call blood "rivers") between the alveoli represent microvessels originating from lung arteries filled with venous blood. As the blood flows between the alveoli, a portion of the blood from these wide microvessels goes to alveoli, is oxygenated there, and again enters the system of microvessels. The area of blood streams on a plan between the alveoli is about 30% from total lung area in our images. It suggests that the volume ratio of these large microvessels to the total lung volume is virtually the same. Large volume of microvessels explains extremely high conveying capacity of the lungs for the blood.

Relatively high rate of oxygenation can be explained as follows. It is known that blood oxygenation rate exceeds blood desoxygenation rate by 2-3 times [3]. In alveoli, the blood is oxygenated intensively, because huge amount of the blood runs through alveoli, and alveolar membrane separating the blood from the air space of the alveolus is only 0.2 μ thick along 60% of the surface [16]. This by many times increases oxygen diffusion from the alveolar air to the blood. There is one more reason for rapid blood oxygenation: in 1980 D. P. Dvoretskii and R. L. Conhaim [1,8] found lung ability to oxygenate venous blood in small pulmonary arterioles, *i.e.* even before the alveoli. This feature probably contributes to intensification of blood oxygenation.

Certainly, we only partially answered the questions raised in this study and made a number of assumptions in virtue of obtained facts. Panoramic images of several and individual alveoli contain a lot of information, which needs to be decoded. Video also provides plenty of interesting material, reflecting peculiarities of blood flow in wide capillaries and between the alveolar membranes, but this is completely unique demonstration material, which is impossible to use within the published article.

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