MORPHOMETRIC AND DISPERSION ANALYSIS OF LUNG ACINUS COMPONENTS DURING WHOLEBODY COOLING

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KEY WORDS: acinus; cooling; morphometry.

The high prevalence of diseases of the respiratory organs in persons resident in the Far North is known to be attributable to prolonged exposure to cold [1, 3]. However, the immediate mechanisms of cold injury to the lungs and its severity are not yet known. There have been isolated studies of the ultrastructure of the alveolar wall in animals [5, 7] exposed to below comfortable temperatures, and the ultrastructure of type II alveolocytes and surfactant during acute cooling, but no analogy can be drawn between these experiments and human residence in high latitudes.

The object of this investigation was to study structural changes in the principal components of the acinus as the structural-functional unit of the lung in rats exposed to long-term gradual cooling within the range of actual temperatures experienced in the Far North in the fall and winter.

EXPERIMENTAL METHOD

Experiments were carried out on 60 noninbred male albino rats weighing initially 100 g. Some rats were cooled for 6 h daily except on Sundays, in a "Feutron" climatic chamber (East Germany) in individual cages by the following scheme: 1st week 5°C, 2nd week 0°C, 3rd week −5°C, 4th week −10°C, 5th week −15°C, and 6th week −20°C. The rest of the time the experimental and control animals were kept at a temperature of 22°C. At the end of the 2nd, 4th, and 6th weeks the experimental and control rats were given an intraperitoneal injection of thiopental in a dose of 35 mg/kg. Fixing solutions (glutaraldehyde and Lillie's solution) were injected through an incision in the trachea into the lungs of the sleeping rats by Weibel's method [8]. After isolation of the completely straightened out lungs the volume of the right lung was measured, the lung was then postfixed in formalin and paraffin sections were cut and stained with hematoxylin and eosin, picrofuchsine, and fuchseline. Semithin sections were stained with toluidine blue. The area of the lumen of the terminal bronchioles (TB), arterioles, and venules was measured by the dot counting method. The diameter of the alveoli was measured as the mean length of the cord [2] and the total alveolar surface area (S_{AT}) calculated; the diameter of the alveolar capillaries was determined from photographs taken from semithin sections. The numerical results were subjected to statistical analysis by Student's test and Fisher's dispersion test (f) for each stage of cooling of the animals [4].

EXPERIMENTAL RESULTS

After 2 weeks of exposure to cold the rats showed significant structural changes in their acini (Table 1). Whereas in the control, few swollen Clara's cells were visible in semithin sections through TB (Fig. 1a), at the end of the 2nd week of cooling they were more numerous, their nuclei were larger, and dark granules began to accumulate in their apical zones (Fig. 1b). In some cases capillary loops "intruded" into the epithelium of TB (Fig. 1c). Thickening of the layer of bronchiolar epithelium led to relative narrowing of the lumen of the bronchioles. Considering the passive character of expiration, the decrease in the total area of the lumen of the dense network of TB gave rise to significant widening of the diameter of

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TABLE 1. Results of Morphometry of Acinus at Different Stages of Cooling

Material tested	Group of animals	Stage of cooling		
		2nd week	4th week	6th week
Area of lumen, μ^2				
TB	Experimental	13992±851,9	13368±1661,2	20256±1109,1
of arterioles	Control	14592±844,9	17611±840,0	18888±1536,3
	Experimental	2152±144,3	2134±139,3	2785±294,3
	Control	1778±130,9	1554±116,1	1909±74,2
of venules	Experimental	2889±216,3	P 0,01	P 0,05
of venules	Experimental	2889±216,3	2209±157,8	2592±179,8
	Control	2998±341,6	2934±428,4	3465,5±355,3
				P 0,05
Area of total alveolar surface (S_{AT}, m^2)	Experimental	0633±0,02	0,33±0,02	0,66±0,03
	Control	0,32±0,01	0,35±0,01	0,51±0,05
				P 0,001
Diameter of alveoli, μ	Experimental	35,10±0,49	42,75±0,20	32,45±0,34
	Control	31,91±0,30	36,40±0,31	33,30±0,45
		P 0,001	P 0,001	P 0,05
Diameter of capillaries, μ	Experimental	4,30±0,04	5,64±0,14	5,30±0,06
	Control	4,62±0,07	4,48±0,11	4,69±0,05
		P 0,001	P 0,001	P 0,001
Volume of unfixed right lung, ml	Experimental	3,43±0,06	4,48±0,21	6,65±0,40
	Control	3,50±0,15	3,97±0,11	5,22±0,48
			P 0,05	P 0,05
Respiration rate, cycles/min	Experimental	120,5±1,12	108,0±2,13	105,0±1,97
	Control	101,0±1,16	100,0±1,82	103,0±2,0
		P 0,01	P 0,05	

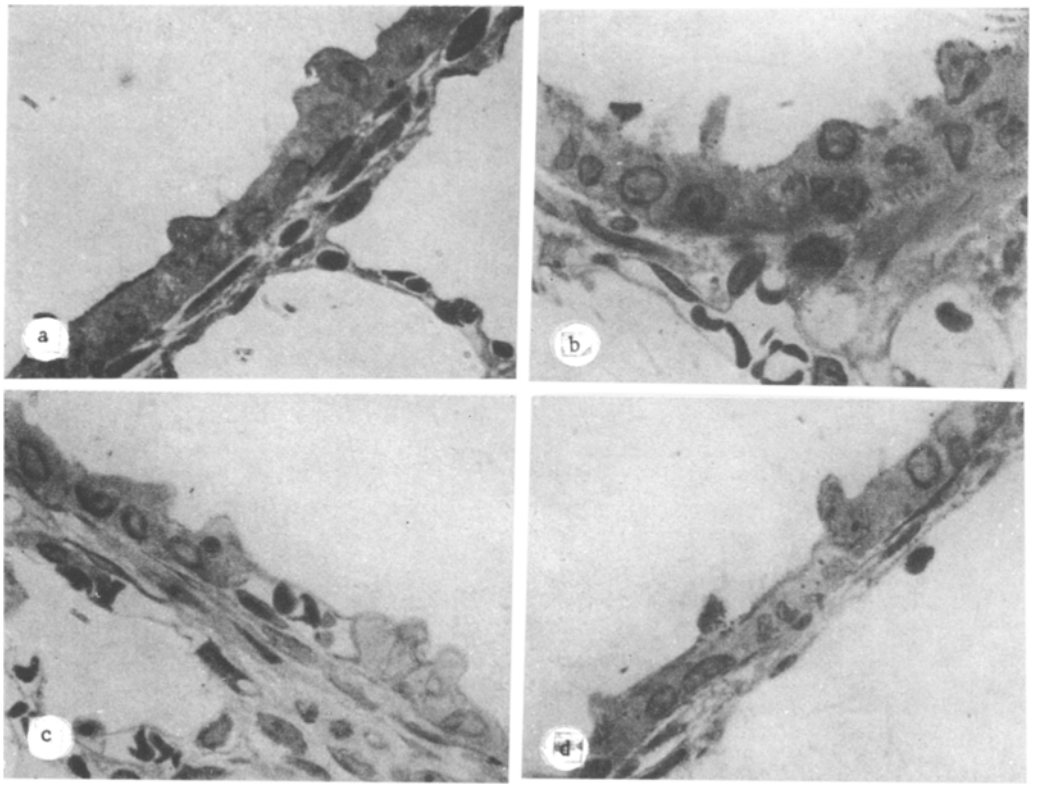

Fig. 1. Structural changes in bronchiolar epithelium: normal epithelium of terminal bronchiole; single swollen Clara's cells and ciliated epitheliocytes; b) thickening of epithelial layer, increased number and hypertrophy of Clara's cells; c) "intrusion" of capillary loop into bronchiolar epithelium; d) atrophy of bronchiolar epithelium. Here and in Fig. 2: semithin sections, toluidine blue, 1000×.

the alveoli and, in consequence of this, the capillary lumen in the stretched alveolar walls was narrowed (Fig. 2a, b). The volume of the lungs had a tendency to decrease but S_{AT} was unchanged. Consequently, in the initial stage of exposure to below comfortable temperatures, opposite changes in caliber of their air passages and vascular network were already observable in the acinus. Partial blocking of the capillary blood flow led to congestion of the afferent arterioles with blood and to emptying of the venules. Constriction of the capil-

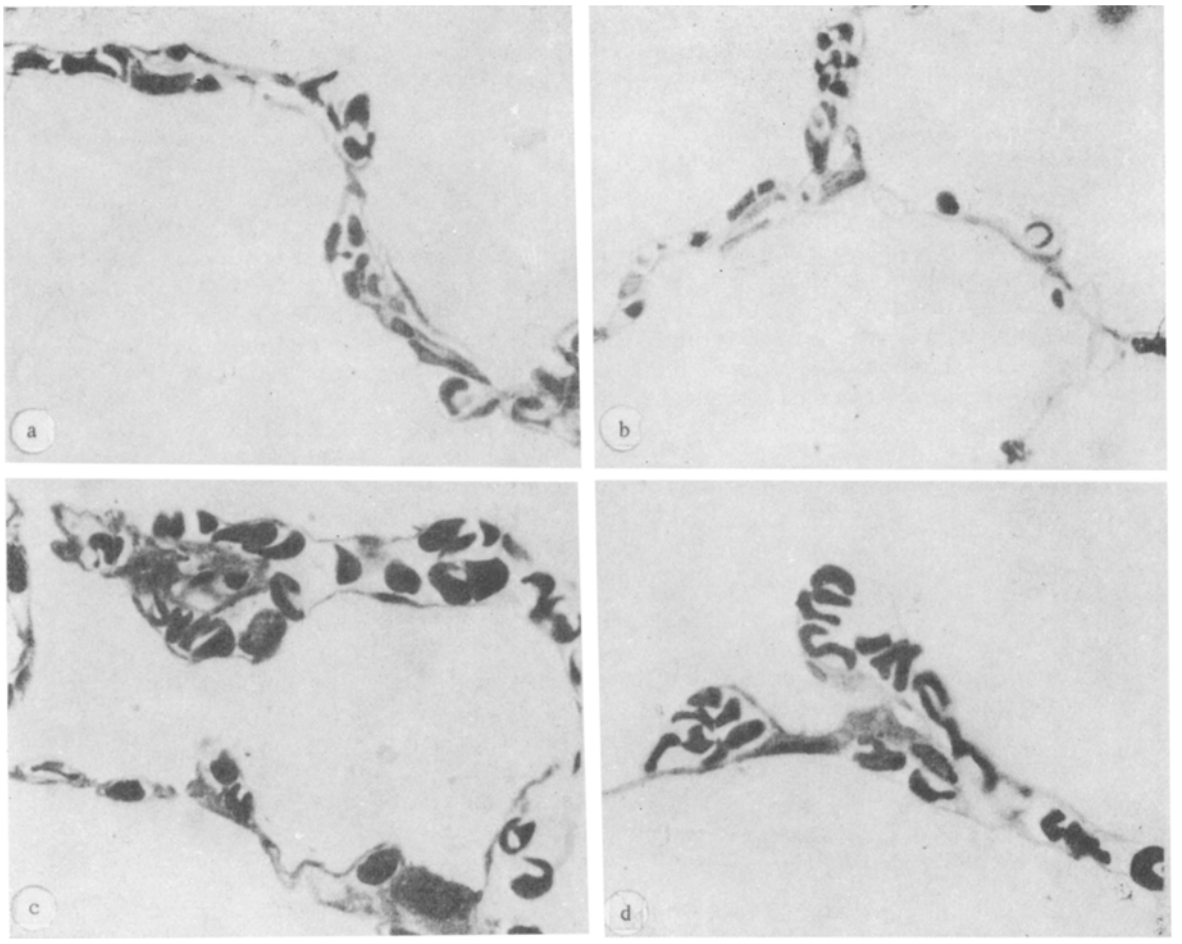

Fig. 2. State of alveolar capillaries: a) normal alveolar septum, b) narrowing of capillary lumen, c) irregular dilatation of capillaries, d) capillary loops projecting into alveolar lumen.

lary network and widening of the diameter of the alveoli constitute the structural basis for disturbances of ventilation-perfusion relations. The lungs of the experimental rats worked under definite stress, and this was confirmed by the significant increase in the animals' respiration rate.

After 4 weeks of cooling, besides evidence of stress in TB and the alveoli and considerable narrowing of the venules, evidence of adaptive changes in the acinus appeared, especially in the alveolar capillaries. The diameter of the capillaries attained its highest value (Table 1), they projected considerably into the alveolar lumen (Fig. 2c), thereby increasing the area of the air-blood barrier. The hypervolemic response of the arterioles continued. The volume of the lungs became significantly greater but this was not reflected in the value of S_{AT}. Corresponding to this stage of undoubted stabilization of lung function, the animals' respiratory rhythm was normal.

At the end of the experiments predominance of atrophy of the bronchiolar epithelium (Fig. 1d) led to some widening of the lumen of TB, and on aggregate this increased the anatomical dead space of the lungs. Normalization of the diameter of the alveoli and synchronized increase in volume of the lungs explained the considerable increase in S_{AT}. A hypervolemic response was dominant in the arterioles and capillaries (Fig. 2d). The lumen of the venules was significantly reduced, probably due to deposition of blood in the alveolar capillaries. Conditions for better coupling of perfusion and ventilation arose in the acinus. This, in turn, explained the adequate adaptation of the lungs and the normal respiration rate of the experimental rats.

Dispersion analysis showed that the effect of the stages of cold was reflected most strongly in the diameter of the alveoli ($f = 139.8$) and alveolar capillaries (34.0), the total

alveolar surface area (33.3), volume of the lungs (25.2), and area of the lumen of the venules (11.8), arterioles (8.2), and bronchioles (4.7).

Exposure to gradually increasing cold, simulating the gradual transition from fall to winter temperatures in the Far North, thus leads to the formation of stable and adequate adaptation of the lungs of experimental rats, even in the case of severe hypothermia (–15, –20°C). Morphometric analysis of the acinus confirmed the general trend of structural adaptation to cold toward an increase in the alveolar and capillary surface area, the anatomical dead space, and hypervolemia of the arterial and capillary components of the pulmonary circulation, described previously both experimentally [5, 6] and in adapted inhabitants of the north [3]. The new data revealed by the present investigation are to the effect that long-term gradual cooling causes a series of stages of structural changes in the acinus: After initial functional stress definite stabilization took place, followed by adequate adaptation of the lungs of the experimental rats. These experimental data form the theoretical basis for the planning of preventive measures against lung diseases in the inhabitants of the North not only in the harsh winter season, but also at below comfortable temperatures (5 and 0°C).

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ULTRASTRUCTURAL CHANGES IN SENSOMOTOR CORTICAL NEURONS DURING PROLONGED HYPOKINESIA IN RATS

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KEY WORDS: neurons; sensomotor cortex; hypokinesia; posthypokinetic period.

Many clinical and experimental studies have demonstrated the adverse effect of restricted movement on activity of all systems of the body and, in particular, the CNS. However, the study of the structural organization of the CNS and of the brain in particular during hypokinesia is essentially only just beginning [7, 9, 13].

There is no information in the literature on reversibility of structural changes in cortical neurons after the end of long-term hypokinesia.

The aim of this investigation was to study changes in ultrastructure of sensomotor cortical neurons in rats during 90 days of hypokinesia and at different times of the posthypokinetic period.

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