STATE OF EXCITABILITY OF THE RESPIRATORY CENTER IN ANIMALS AFTER REMOVAL OF THE LUNG

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The results of neurophysiological investigations conducted in P. K. Anokhin's laboratory [1, 4, 5] have shown that removal of a lung leads to changes in the activity of the respiratory center, as revealed by asymmetry of the efferent impulses.

The state of excitability of the respiratory center after pneumonectomy was the subject of a short paper by E. L. Golubeva [6], who concluded from her experiments in which the vagus nerve was stimulated in rabbits 3-9 months after the operation that, in these conditions, considerable changes take place in the lability and excitability of the respiratory center (no indication was given in the paper of which of the vagus nerves are stimulated).

The object of the present investigation was to study the reflex excitability of the respiratory center at various times after removal of a lung.

EXPERIMENTAL METHOD

The reflex excitability of the respiratory center was determined in the usual manner [2, 3, 7] from the threshold reaction of respiration to stimulation of the central end of the divided vagus nerve. Experiments in which the nerve was stimulated by an induction current were carried out on 63 rabbits between 19 days and 26 months after removal of the left lung, and on 28 normal rabbits. The threshold values of stimulation were determined, first, giving a minimal decrease in the amplitude of the respiratory movements, and second, producing apnea. The strength of stimulation was expressed by the distance between the coils in centimeters.

EXPERIMENTAL RESULTS

The data showing the threshold values of stimulation of the nerve in the pneumonectomized rabbits on the side of the remaining lung and in normal rabbits are given in Table 1.

The results given in Table 1 show that 19-34 days after removal of the left lung there was a tendency for the threshold of stimulation to increase when the right vagus nerve was stimulated, but later, $1^1/_2$-$8^1/_2$ months after the operation, a regular increase in the excitability of the respiratory center was discovered. The threshold value was on the average normal $12^1/_2$-$16^1/_2$ months after the operation.

A similar pattern of results was obtained when the strengths of stimulation of the vagus nerve capable of causing transient respiratory arrest were measured.

The results described above give the details of the reaction of the respiration of the pneumonectomized animals to stimulation of the vagus nerve on the side of the residual lung. Since removal of the lung may affect the excitability of the corresponding half of the respiratory center, experiments were carried out in which the vagus nerve was stimulated on the side of the operation. These showed that in order to obtain a threshold reaction of respiration in this case, the intensity of stimulation had to be increased considerably by comparison with normal (Table 2).

TABLE 1. Threshold Values of Stimulation of the Central Segment of the Divided Vagus Nerve (as increase in amplitude of respiratory movements) in Control Rabbits and in Animals after Removal of the Left Lung

Index	Control rabbits	Pneumonectomized (times after operation)			
		19–34 days	1½–4 months	5–8½ months	12½–16½ months
n	25	10	21	14	8
$M \pm m$	76,2 ± 2,28	68,9 ± 3,84	84,0 ± 2,71	94,4 ± 2,34	76,2 ± 3,87
P	—	0,1	< 0,05	< 0,001	

TABLE 2. Threshold Values of Stimulation of Central Segment of Divided Left Vagus Nerve in Control Rabbits and Rabbits after Removal of the Left Lung

Index	Normal rabbits	Pneumonectomized (times after operation)		
		19–34 days	1½–4 months	6–8½ months
n	5	8	10	5
$M \pm m$	76,0 ± 5,10	59,4 ± 5,30	51,0 ± 5,56	40,0 ± 8,66
P	—	< 0,05	< 0,01	< 0,01

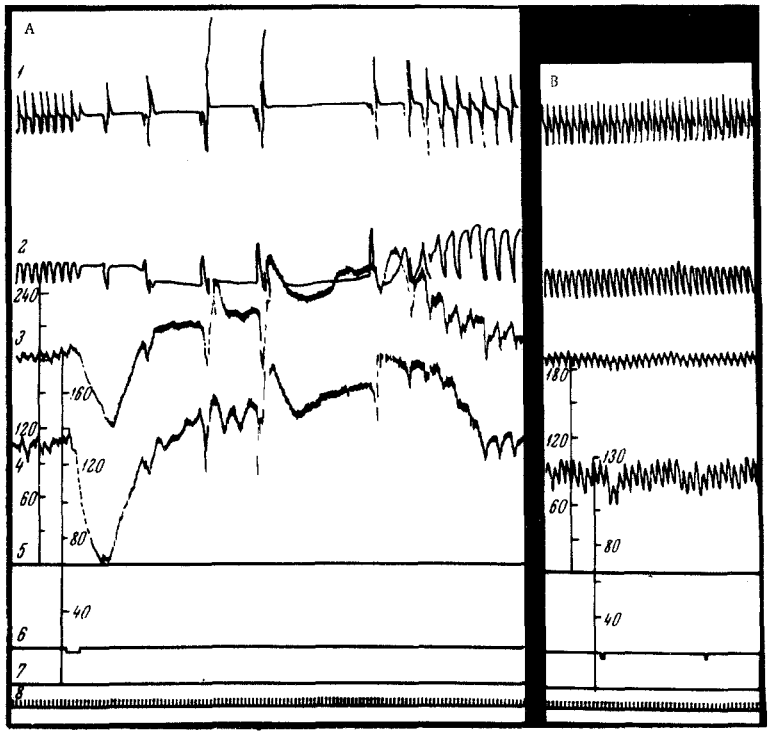

Fig. 1. Changes in respiration and blood pressure as a result of division of the right (A) and left (B) vagus nerve 7 months after removal of the left lung. 1) Respiration (trachea); 2) respiration (pneumograph); 3) pressure in right ventricle (in mm water); 4) arterial pressure (mercury manometer); 5) zero line of manometer recording pressure in right ventricle; 6) marker of stimulation; 7) zero line of mercury manometer; 8) time marker (1 sec).

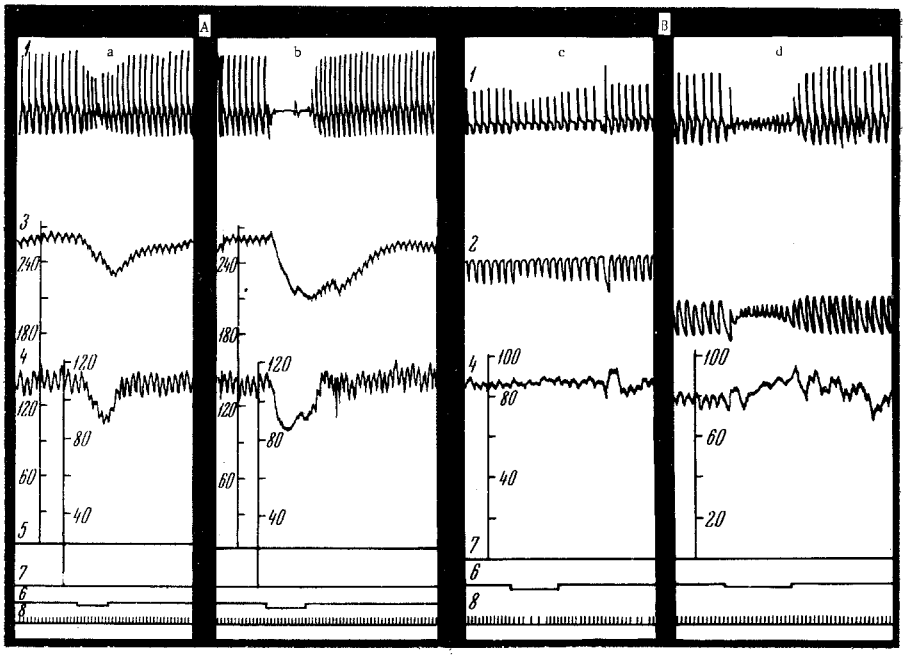

Fig. 2. Stimulation of vagus nerve on the same side as the operation (a, c) and on the opposite side (b, d) 1 month, 25 days after removal of the left lung (A, rabbit No. 265) and 94 days after removal of the right lung (B, rabbit No. 237). Intensity of stimulation as distance between coils of induction apparatus 20 cm (a), 40 cm (b), 45 cm (c), and 45 cm (d). Remainder of legend as in Fig. 1.

Comparison between the results of the experiments of this and of the previous series showed that whereas the excitability of the respiratory center, assessed from the reaction to stimulation of the vagus nerve on the side of the remaining lung, increased after a certain time, its excitability assessed from the reaction to stimulation of the nerve on the same side as the operation fell considerably.

In one series of experiments both vagus nerves were stimulated in the same animals. After vagotomy it was found that in the great majority of the animals, especially from $1^1/_2$ to $8^1/_2$ months after the operation, the changes in respiration were more marked when the nerve was divided on the side of the remaining lung (Fig. 1).

When the vagus nerves were stimulated electrically 19-34 days after removal of the lung, the threshold was usually higher for the nerve on the side of the operation than for the opposite nerve by 15-25%. In the animals $1^1/_2$-4, and even as long as $8^1/_2$ months after the operation, for a minimal reaction of respiration in most cases it was necessary to increase the strength of stimulation of the vagus nerve on the side of the operation by 50-100%. Sometimes, for approximately equal changes in respiration, the intensity of stimulation of the nerve on the side of the operation had to be increased by 100% or more (Fig. 2A). In the late periods after the operation, the asymmetry of the response reactions of respiration was less than in the preceding group.

The fact that the results obtained, so far as asymmetry is concerned, obey a general rule is emphasized by the discovery that after removal of both the left and the right lung stimulation of the nerve on the side of the operations was less effective (see Fig. 2).

Hence, after removal of the lung in rabbits, the functional state of the respiratory center on the side of the remaining lung is characterized by phased changes in reflex excitability: a tendency towards a decrease in excitability in the first period (19-34 days) after the operation is followed by a clear increase in excitability (between $1^1/_2$ and $8^1/_2$ months after); later (1 year or more after operation) the reflex excitability of the respiratory center is relatively depressed.

It must also be emphasized that the excitability of the respiratory center on the side of the operation is considerably lowered at various periods after pneumonectomy. Consequently, it may be concluded that asymmetry of excitability of the control nervous apparatuses of regulation of respiration arises in the course of the compensatory adaptive changes caused by removal of the lung.

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