

FUNCTIONAL STATE OF THE RESPIRATORY CENTER
AND CHANGES IN RESPIRATORY ARRHYTHMIA
ASSOCIATED WITH INCREASED TONE OF THE VAGUS CENTER*

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The respiratory center and the center for the vagus nerve are known to be in a state of constant functional interconnection [2,3,6,7,8,12]. Acute experiments on dogs anesthetized with morphine and chloralose have shown that strong excitation of the respiratory and cardio-inhibitory centers cannot occur together [6]. When the excitation of the respiratory center is increased, the tone of the cardio-inhibitory center of the vagus is lowered, and when the tone of the vagus center is raised the activity of the respiratory center is depressed to some degree.

The functional state of the respiratory center and the changes in respiratory arrhythmia were studied during an increase in the tone of the vagus center.

EXPERIMENTAL METHOD

Investigations were carried out on three adult dogs weighing from 18 to 25 kg in chronic experimental conditions. The animals remained under observation for 3-6 months. The tone of the vagus center was raised by means of the subcutaneous injection of small doses of morphine (0.01-0.03 g) [10,11]. A further increase in the tone of the vagus center was attained by means of the intravenous injection of a 10% solution of CaCl_2 in a dose of 0.05 g/kg body weight.

In these experiments the heart rate was counted, the pneumogram recorded on a kymograph, and the cardiocyclogram recorded on a cardiac electrical activity analyzer (ANEK). The technique of cardiocyclography, suggested by I. T. Akulinichev and coworkers [1], differs from the ordinary electrocardiography in the fact that the separate complexes of the ECG are recorded one below the other. When this method of recording is used, the ECG may be taken for long periods of time and the fluctuations of the sinus rhythm are readily seen.

The duration of the cardiac cycles was determined from the cardiocyclograms. The values of the duration of 25 cardiac cycles when the tone of the vagus center varied in level were analyzed statistically, and the coefficients of arrhythmia (the coefficient of variation) calculated. Because the respiration rate was recorded simultaneously on the cardiocyclograms, the sinus arrhythmia could be compared with the respiration.

EXPERIMENTAL RESULTS

With a moderate increase in the tone of the vagus center (the heart rate slowed from 100-120 to 50-60 beats per minute) respiration became slower and deeper. With a further increase in the tone of the vagus center, caused by intravenous injection of calcium chloride (heart rate slowed to 44-32 beats per minute) respiration became still slower, and the minimal heart rate corresponded to the minimal frequency of respiratory movements. To illustrate these findings the results of several typical experiments are shown in Table 1. It must be noted that the mean arterial pressure (recorded by a direct method in the femoral artery) remained sufficiently high in the presence of a considerable slowing of the heart rate.

In our experiments the degree of respiratory arrhythmia was studied during an increase in the tone of the vagus center. Most workers [4,5,9,15,17,20] consider that respiratory arrhythmia is related mainly to the tone of the vagus centers, although there are indications [13] that the sympathetic innervation of the heart may also be important.

TABLE 1. Changes in Pulse and Respiration Rates in Dogs after Injection of Morphine and Calcium Chloride

date of experiment (1961)	Pulse rate per minute			Breaths per minute		
	before injection of morphine	after injection of morphine	after injection of CaCl ₂	before injection of morphine	after injection of morphine	after injection of CaCl ₂
Dzhek						
6/III	112	60	40	54	21	18
11/III	200	72	44	56	18	12
20/III	100	64	32	36	26	16
22/III	120	62	40	56	22	18
13/V	112	66	42	36	24	20
Laska						
22/IV	132	84	60	26	16	14
25/IV	98	80	46	48	12	12
28/IV	110	64	52	38	12	10
Vagus (dog's name)						
23/VIII	132	72	54	116	64	40
25/VIII	92	60	48	40	20	16

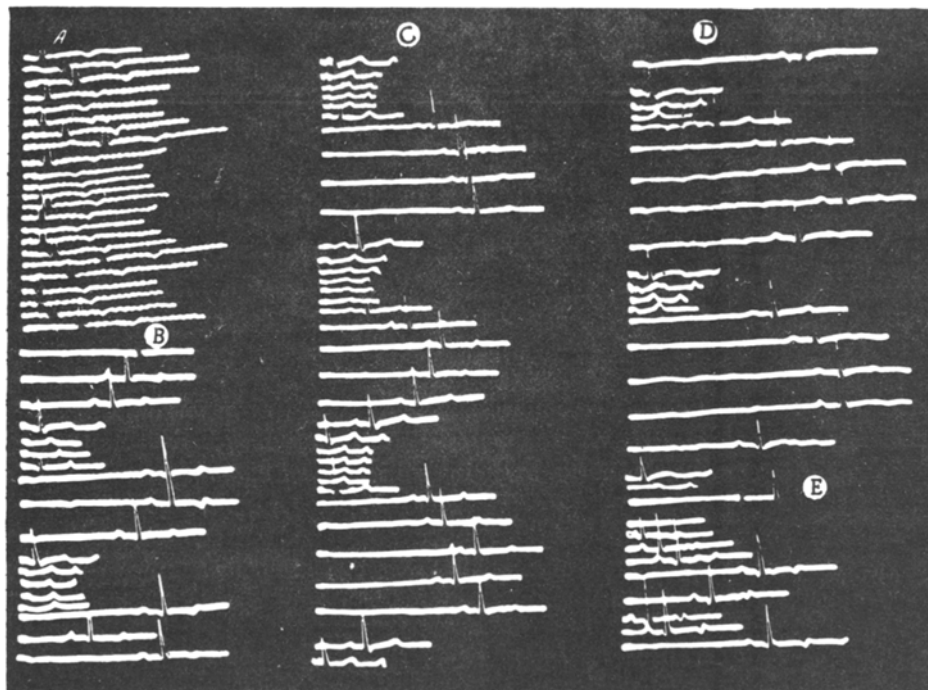
In the experiments with a relatively low respiratory rate the sinus arrhythmia that was observed was always related to respiration. The slower the heart rate, the greater the coefficient of respiratory arrhythmia (Table 2, figure).

In some experiments, with a considerable increase in the tone of the vagus center, when an atrioventricular rhythm appeared (the P wave disappeared on the cardiocyclograms), the respiratory fluctuations in the pulse rate disappeared completely. This fact is in agreement with the findings of Carlsten [16], who considers that the atrioventricular node is less under the control of the autonomic nervous system than the sinus node and the atria.

In our experiments, which were carried out in summer on dogs with an initial respiration rate of up to 200 per minute, no connection was likewise observed between the sinus arrhythmia and respiration. After injection of morphine into these animals the heart rate became much slower, but, if the respiration rate remained high (up to 80 per minute),

TABLE 2. Increase in Coefficient of Arrhythmia in Dogs during an Increase in the Tone of the Vagus Center

Date of experi- ment (1961)	Before injection of morphine			After injection of morphine			After injection of CaCl ₂					
	pulse	respi- ration	coeff. of arrhyth- mia (%)	pulse	respi- ration	coeff. of arrhyth- mia (%)	10 min			40-60 min		
							pulse	respi- ration	coeff. of arrhyth- mia (%)	pulse	respi- ration	coeff. of arrhyth- mia (%)
per minute	per minute	per minute	per minute	per minute	per minute	per minute	per minute	per minute	per minute	per minute	per minute	
Laska												
10/V	120	34	8.4	68	16	20	50	9	30	88	16	11.8
15/V	88	48	6.5	52	16	16.1	44	14	27.5	48	9	18.5
19/V	84	26	5.4	60	18	18.6	54	16	29.3	60	12	27.6
Vagus												
30/VIII	120	40	4.5	60	20	28.6	56	16	30.2	60	24	15
4/IX	84	28	22.1	60	10	24.4	40	48	27	52	12	23.3
Dzhek												
19/V	128	22	23.3	84	12	51.6	52	11	57.4	88	10	33.8
7/VI	100	38	8.3	76	24	29.4	56	16	39.3	56	20	22.3



Increase in degree of respiratory arrhythmia during an increase in the tone of the vagus center in the dog Dzhek. Cardiocyclograms of an experiment on 5/19/61. The dots denote the beginning of inspiration. Velocity of movement of paper 4 mm/sec, time marker 0.05 sec. A) Before injection of morphine (pulse 128/min, respiration 22/min, coefficient of arrhythmia 20.3%); B) after injection of morphine (pulse 84/min, respiration 10/min, coefficient of arrhythmia 51.6%); C) after injection of morphine, while breathing in mask (pulse 72/min, respiration 10/min, coefficient of arrhythmia 44.1%); D) 10 min after injection of CaCl_2 (pulse 52/min, respiration 12/min, coefficient of arrhythmia 57.4%); E) 46 min after injection of CaCl_2 (pulse 88/min, respiration 10/min, coefficient of arrhythmia 33.8%).

the observed variations in the duration of the cardiac cycles were unrelated to respiration, although the coefficient of arrhythmia increased slightly. With a considerable decrease in the respiration rate (to 40 per minute or below), while the heart rate remained the same the sinus arrhythmia became respiratory in nature.

The changes described above in the respiratory arrhythmia in association with slow respiration demonstrate a functional interrelationship between the vagus center and the respiratory center. When the respiration was fast the sinus arrhythmia was not connected with respiration despite the significant slowing of the pulse.

SUMMARY

Chronic experiments were staged on 3 adult dogs. For a period of 3-6 months a study was made of the functional state of the respiratory center and dynamics of respiratory arrhythmia during increase of the vagus center tone induced by subcutaneous administration of low morphine doses and subsequent intravenous injection of calcium chloride. When the heart rate is slow there is a reduction of the frequency of respiratory motions; the least respiration rate corresponded to the least pulse rate. The coefficient of respiratory arrhythmia increased against the background of relatively slow respiration with a gradual slowing of cardiac contractions. Against the background of frequent respiration, sinus arrhythmia was not connected with respiration, notwithstanding the considerable reduction in pulse rate.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
