REFLEXES FROM MECHANORECEPTORS OF THE UPPER RESPIRATORY TRACT TO THE HEART DURING EXPERIMENTAL TUBERCULOSIS OF THE LARYNX

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Many works have been devoted to studying the reflex influences from various organs and systems on the heart [8, 9, 18, 20, 31, 32]. It has been established that, in the majority of cases, reflex reactions of the heart are limited to changes in the frequency of the cardiac contractions. Reflex changes in the conductivity and functional state of the myocardium arise only with disease in the cardiovascular system, or in those cases where the reflexes originate from the receptors of organs involved in a pathological process [3, 7, 9, 10, 16, 31, 33, 35, 38, 41].

Reflexes in the heart also arise from stimulation of the receptors in the mucosal membrane of the tonsils and of the upper respiratory tract [13, 15, 31, 34, 36, 40]. It is widely recognized that the upper respiratory tract are a manifest reflex zone [1-4, 6, 11, 12, 14, 19, 21, 23, 30, 37, 39, 41, 42]. We demonstrated certain principles in the reflex reactions from the mechanoreceptors in the upper respiratory tract of healthy animals [24, 25, 27].

With various experimentally induced pathological conditions of the organism (radiation sickness, hematogenous tuberculosis), as well as with local disease of the upper respiratory tract (tubercular nidus, aseptic inflammation in the region of the larynx), we noted a phasic change in the properties of reflexes from the mechanoreceptors of the upper respiratory tract [26, 27, 28, 29].

Investigation of mechanoreception in the upper respiratory tract of healthy and diseased animals was carried out previously, using blood pressure and respiration as the effectors. It was necessary to clarify whether or not the principles which we established extend to the reflex connections between the receptors of the upper respiratory tract and the heart.

We investigated reflexes from mechanoreceptors in various sections of the upper respiratory tract – the trachea, the subligamental space of the larynx, the larynx and the pharynx – to the heart, using healthy cats and cats with a tubercular, inflammatory nidus in the region of the larynx.

EXPERIMENTAL METHOD

We used 21 cats in the experiment. In 11 of the animals we injected tuberculous culture (Valle strain) into the extrinsic muscles of the larynx, using a dose of 0.2 mg in a volume of 0.2 ml of physiological saline. On the 12th-13th day after the inoculation, along with changes in the general condition of the cats (sluggishness, poor appetite, hoarseness), a dense, lobular inflammatory infiltrate arose in the region of the larynx's exterior, lateral walls, bearing a specific character, white color, and a size equal to that of a large pea (Fig. 1). On histological investigation, it was shown to consist of lymphoid cells, leukocytes, and epitheloid cells, with areas of caseous necrosis (Fig. 2). The mucosal lining of the larynx was initially unchanged, but after the 24th day it manifested a subacute inflammatory process, without signs of specificity: congestion and dilatation of the blood vessels, the presence of scanty infiltrates consisting of lymphoid and plasma cells and segmented leukocytes. On the 28th day of illness, signs of specific

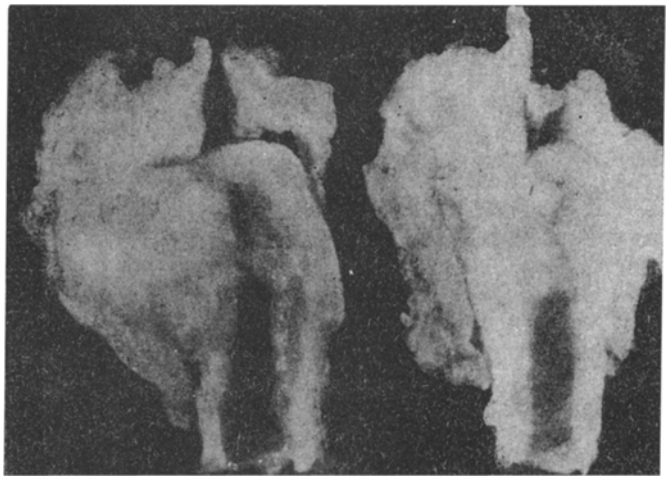

Fig. 1. Tubercular infiltrate in the region of the larynx and the perilaryngeal soft tissues. Normal larynx on the right.

inflammation were noted in the mucous membrane of the larynx. After the 20th day of illness, along with the appearance of the infiltrate in the region of the larynx, we observed specific changes in the lungs, spleen, and lymph nodes, in the form of miliary, epitheloid cell, tubercular tubercles. Thus, the pathological process underwent a transition from local to generalized.

Short term experiments were carried out under light uretane narcosis. The trachea was exposed and transected at the level between the 7th and 8th tracheal ring. In order to apply measured mechanical stimulations to the cranial end of the transected trachea, we inserted a small balloon made of thin rubber and connected to a rubber bulb and a mercury manometer. After mechanical stimulation was applied in the trachea, the balloon was moved to the subligamental, and then to the supraligamental space of the larynx, and into the pharynx.

The EKG was taken with the EKP-4 electrocardiograph, in lead II (amplification: 1 mv corresponded to a beam deflection of 10 mm), using needle electrodes inserted into the thickness of the muscles in the right anterior and left posterior extremities of the cat. On film we recorded the EKG, time markings, and stimulation markings. In analyzing the EKG obtained with stimulation of the upper respiratory tract, we determined the statistical significance of the cardiac reactions according to a special formula [17], and considered only those reactions which were shown to

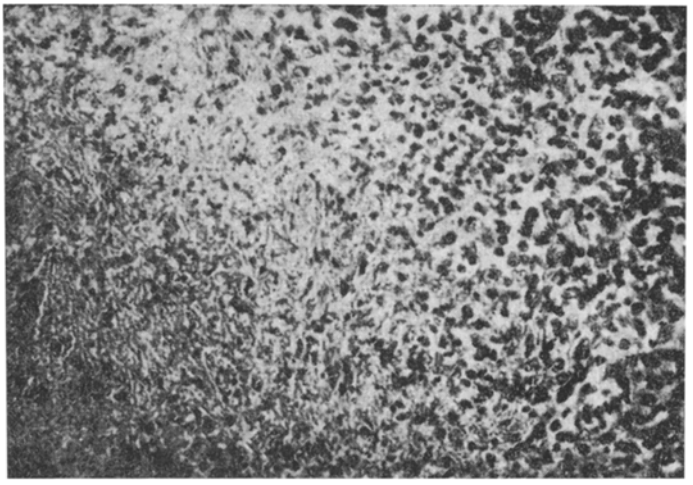

Fig. 2. Microscopic structure of the infiltrate: caseous necrosis and tubercular granulation tissue. Stained with hematoxylin-eosin, obj. 20 ×, ocul. 15 ×.

Changes in the Threshold Sensitivity of the Mechanoreceptors in Different Sections of the Upper Respiratory Tract to Stimulation (in mm Hg), Associated with a Tubercular Nidus in the Region of the Larynx (According to the Reaction of the Cardiac Rhythm)

Site of stimulation	Inoculated cats: day after inoculation										Uninoculated cats
	3	5	7	13	14	17	21	24	26	28	
Trachea	—	—	—	—	—	—	—	—	—	—	—
Subligamental space of the larynx	40	40	60	80	80	80	100	100	—	—	100
Larynx	20	40	40	40	60	80	80	60	120	120	60
Pharynx	40	40	40	20	40	40	60	80	100	100	40

be statistically significant. We also determined the stimulus thresholds of the femoral nerve in the cats, using an induction current from a sliding apparatus.

EXPERIMENTAL RESULTS

Stimulation of the tracheal mechanoreceptors with an intensity of up to 140 mm Hg did not cause any changes in the cardiac rhythm or any other components of the EKG within the healthy cats. Significant threshold changes in the EKG, manifested by slowing of the cardiac rhythm by 6 beats per minute, was noted with stimulation of the mechanoreceptors in the subligamental space of the larynx, using an intensity of 100 mm Hg, and of the mechanoreceptors in the supraligamental space of the larynx, using an intensity of 60 mm Hg. Threshold cardiac reactions arose with stimulation of the mechanoreceptors in the pharynx, using an intensity of 40 mm Hg. Thus, the gradient of mechanoreception in the upper respiratory tract, noted by us earlier from reactions in the respiration and blood pressure, was also demonstrated by the cardiac reaction (see table). In this case too, the mechanoreceptors of the pharynx were the most sensitive to mechanical stimulation, the supraligamental mechanoreceptors were less sensitive, and the mechanoreceptors of the subligamental space of the larynx were still less sensitive.

With an increase in stimulation intensity to the mechanoreceptors of the upper respiratory tract sections under study, a minimal intensification of the cardiac reaction was noted in a number of the cases (deceleration of the cardiac rhythm by 12 beats per minute), but even in this situation the change only involved the cardiac rhythm.

The reflex effects on the heart from the mechanoreceptors of the upper respiratory tract were investigated in the inoculated cats from the 3rd to the 28th day after the inoculation. The stimulation threshold for the femoral nerve in these animals, at the earlier intervals following the inoculation, was the same as in the uninoculated cats (distance between the primary and secondary coil of the sliding apparatus equal to 17-18 cm), and was elevated (to 13-15 cm) after the 20th day of illness.

Stimulation of the tracheal mechanoreceptors with an intensity of up to 120-140 mm Hg, did not cause any changes in cardiac activity throughout the course of the illness, just as in the case of the healthy cats. Stimulation of the mechanoreceptors in the supraligamental space of the larynx, its subligamental space, and the pharynx, as in the case of the uninoculated cats, caused only slowing of the cardiac rhythm on almost every day of the illness. The stimulation thresholds of the mechanoreceptors in the indicated sections of the upper respiratory tract were shown to be different on different days of the illness (see table). From the 3rd to the 7th day after the inoculation, significant threshold slowing of the cardiac rhythm arose with stimulation of the mechanoreceptors in the supraligamental space of the larynx and its subligamental space that was one half to one third as intense as that needed in the healthy cats. From the 13th to the 24th day after the inoculation, the stimulation thresholds for the mechanoreceptors in the supraligamental space of the larynx and its subligamental space were somewhat elevated. After the 25th day of illness, stimulation of the mechanoreceptors in the subligamental space of the larynx with an intensity of 100 mm Hg and greater had absolutely no effect on the cardiac rhythm. Threshold slowing of the cardiac rhythm (by 6 beats per minute) was noted with stimulation of the mechanoreceptors in the supraligamental space of the larynx, using an intensity of 120 mm Hg, i.e., 2 times as great as that in the healthy cats. Stimulation thresholds for the mechanoreceptors in the pharynx were the same as in the healthy animals up until the 21st day of illness (see table), but subsequently were elevated by more than twice.

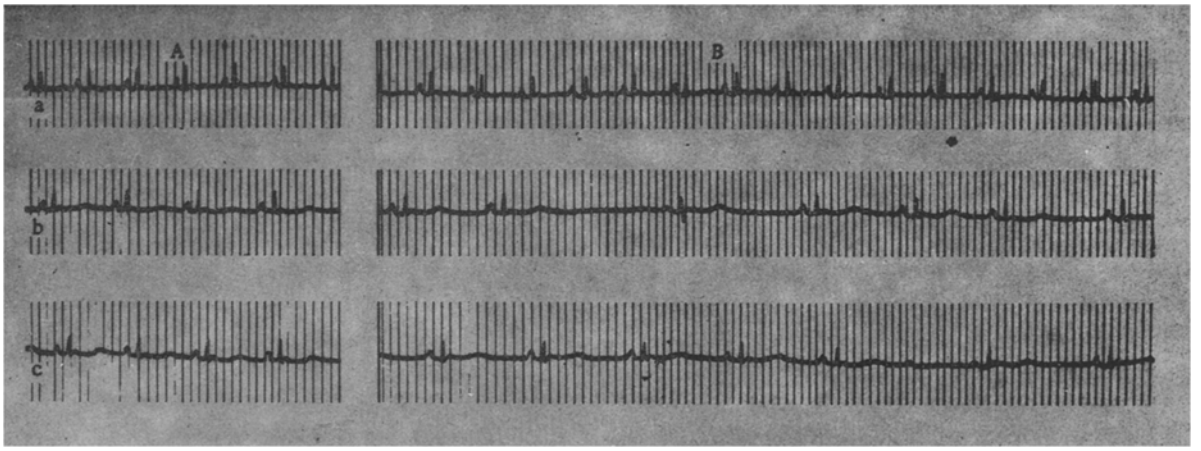

Fig. 3. The EKG of a healthy cat during stimulation of the laryngeal mechanoreceptors with an intensity of 40 mm Hg (a), of an inoculated cat (3rd day) during stimulation of the laryngeal mechanoreceptors with an intensity of 40 mm Hg (b), and of an inoculated cat (13th day) during stimulation of the pharyngeal mechanoreceptors with an intensity of 60 mm Hg (c). A) Before stimulation; B) during stimulation. Longitudinal line) stimulation marking.

In addition to changes in the stimulation thresholds of the mechanoreceptors located in the upper respiratory tract sections under study, in the cats with tubercular disease of the larynx we also observed a change in the expressivity of the cardiac responses. In the first 15-16 days after inoculation, these reactions were significantly more intense than in the healthy cats, while from the 17th-21st day on their magnitude was sharply decreased. For example, while superthreshold stimulation of the mechanoreceptors in the supraligamental space of the larynx, using an intensity of 80 mm Hg, caused a slowing of the cardiac rhythm of 12 beats per minute in the healthy cats, on the 13th day after inoculation it caused a slowing of the cardiac contractions by 24 beats per minute, and at the height of the reaction, by as much as 42 beats per minute. On the 26th-28th day of illness, stimulation with an intensity of 120 mm Hg caused a statistically significant slowing of the cardiac rhythm equal to only 6 beats per minute.

An increase in the stimulation intensity during the first 2-3 weeks after inoculation led to an intensification of the cardiac reaction which was appreciably greater than in the healthy animals. For example, on the 3rd day of illness, threshold stimulation of the mechanoreceptors in the supraligamental space of the larynx, using an intensity of 20 mm Hg, caused slowing of the cardiac rhythm by 6 beats per minute, while stimulation with an intensity of 40 mm Hg (Fig. 3, b) slowed the heart by 30 beats per minute. In uninoculated cats, this stimulation did not cause changes in the rhythm (Fig. 3, a). On the 13th day after inoculation, with a threshold intensity of stimulation delivered to the mechanoreceptors of the pharynx (20 mm Hg), the rhythm of cardiac contractions was slowed by 6 beats per minute, while with a stimulation intensity of 60 mm Hg it was slowed by 54 beats per minute (Fig. 3, c). Starting with the 22nd day after inoculation, an increase in the stimulation intensity did not lead to an increase in the cardiac reaction.

Thus, in healthy cats and in cats with a tubercular nidus in the region of the larynx, stimulation of the mechanoreceptors in various sections of the upper respiratory tract causes reflex changes in cardiac activity, which are expressed only by a slowing of the cardiac rhythm. In distinction to this, the conductivity and contractility of the cardiac muscle, which are related to more profound processes within the cardiac muscle, are more stable, guaranteeing a constancy in the work of the heart. Therefore, reactions that arise in response to various stimuli differentiate themselves by different alterations. L. Ya. Balonov [3] points out that development of conditioned reflex regulation of the heart is directed not only toward improving the adaptation of cardiac activity to the demands of the organism, but also toward a situation in which this adaptation is accomplished by means of minimal changes in the activity of the heart, and especially of its most stable and biologically important properties. The possibility has not been excluded that this concept can also extend, in some measure, to non-conditioned reflex regulation of cardiac activity.

The presence of a tubercular inflammatory nidus in the region of the larynx showed an essential effect on the character of the reflex effects from the mechanoreceptors in the sub- and supraligamental spaces of the larynx on the heart. This was manifested by phasic changes in both the expressivity of the reflexes and the magnitude of the stimulation thresholds for the mechanoreceptors in the indicated sections of the larynx. In the first 2-2½ weeks after the inoculation, along with a decrease in the stimulation thresholds, we noted a significant intensification in the reactions of the heart; at later intervals, we observed a weakening of these reactions and an elevation in the stimulation

thresholds. In the presence of unchanged reflexes from the pharynx, it seems to us that these changes in the normal stimulation thresholds for the femoral nerve by an induction current may be related to a change in the excitability of the receptor apparatus of the larynx (including the mechanoreceptors), which arises under the influence of an inflammatory nidus within this region. The latter may also be a source of pathological impulsation, influencing the functional state of nerve centers which receive afferent information from the larynx. The weakening of the reflex effects on the heart that stem from the mechanoreceptors in not only the larynx, but the pharynx as well, which occurred in our experiments beginning with the 20th day of illness, is related, in our opinion, to a generalization of the tuberculosis process, which lowers the reactivity of the central nervous system. This is also indicated by the elevation in stimulation thresholds of the femoral nerve by induction current which we observed in the corresponding experiments.

SUMMARY

Stimulation of mechanoreceptors of pharynx, larynx and its subligamentous space causes a deceleration of cardiac contractions in healthy cats. Other indices of the heart activity show no changes. Stimulation of tracheal does not cause changes in the cardiac rhythm. An experimentally induced tuberculous nidus in the laryngeal region exerts influence on the character of reflexes from mechanoreceptors of affected parts of the upper respiratory tract to the heart. This influence is manifested not only by phase alteration of reflex values characterized by cardiac rhythm change but also by alteration of values of stimulation thresholds. Generalizing of tuberculosis causes the same changes as described before in reflexes from mechanoreceptors of parts of the upper respiratory tract neighbor to the affected organs to the heart.

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