RESPIRATORY RHYTHM OF IMPULSES FROM THE CUTANEOUS AND VENOUS RECEPTORS OF THE CHEST WALL

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Electrophysiological investigations of the afferent impulses in the intercostal nerves have shown that the receptors of the respiratory muscles react to the respiratory movements of the chest wall by a stream of impulses, the properties of which depend on the phases of respiration [2, 3, 9]. Electrophysiological studies have also been made of the cutaneous receptors of the chest wall. However, hardly any information is available on the respiratory rhythm of this flow of impulses, except that in a paper by Sumi [12] the respiratory rhythm of the impulses in certain cutaneous fibers of the posterior roots of the thoracic segments of the spinal cord is mentioned. There is no information on the respiratory rhythm of impulses from the venous receptors of the chest wall, except in a paper by O. P. Minut-Sorokhtina [5], who made an electrophysiological analysis of the venous receptors and describes the periodicity of the flow of afferent impulses from the receptors of the lateral thoracic vein of the rabbit, which may be associated with the respiratory movements.

The object of the present investigation was to determine the presence and origin of the respiratory rhythm of impulses arising from the cutaneous and venous receptors of the chest wall.

EXPERIMENTAL

Experiments were carried out on cats and rabbits anesthetized with urethane or hexobarbital. Impulses from the cutaneous receptors were recorded in the peripheral ends of the fine cutaneous twigs of the lateral intercostal nerve. To investigate the bioelectrical activity of the receptors of the lateral thoracic vein, the anterior cutaneous twigs of the lateral intercostal nerve supplying this vein were used after preliminary denervation of the skin in the corresponding zone. To ensure complete blocking of the activity of the muscle receptors during dissection of the cutaneous and venous nerves, all the twigs supplying the large cutaneous muscle were carefully divided. The fibers from the receptors of the respiratory muscles, however, are known not to contain cutaneous twigs of the lateral intercostal nerves. The biopotentials were detected by platinum electrodes, fed into a type UBP-1 amplifier, and recorded on a type EMOF 2-01 apparatus. By means of a photoelectric detector, the pneumogram was recorded simultaneously in the second channel of the oscillograph. In the last series of experiments the efferent impulses in the respiratory fibers of the lateral intercostal nerves were recorded and the changes in the flow of impulses caused by denervation of the skin and the subcutaneous blood vessels of the corresponding half of the chest were studied. For this purpose, microelectrodes 5-10 μ in diameter were used to record the potentials in the central end of the nerve before and after division of the cutaneous twigs of the lateral intercostal nerves.

EXPERIMENTAL RESULTS

The object of the 32 experiments of series I was to demonstrate the rhythmic activity associated with the phases of the respiratory cycle in the anterior cutaneous branch of the lateral intercostal nerve containing afferent fibers from the cutaneous and vascular (venous) receptors. In 20 cases a clear periodicity of the impulses was observed, with an increase in the frequency of the rhythm coinciding as a rule with the phase of inspiration (Fig. 1a). Sometimes double volleys of impulses were noted, one of which coincided with the beginning of inspiration and the other with the beginning of expiration. In two cases, when discoordination of the respiratory movements of the chest wall and the abdominal wall was present, the increase in the frequency of the impulses coincided with the phase of expiration.

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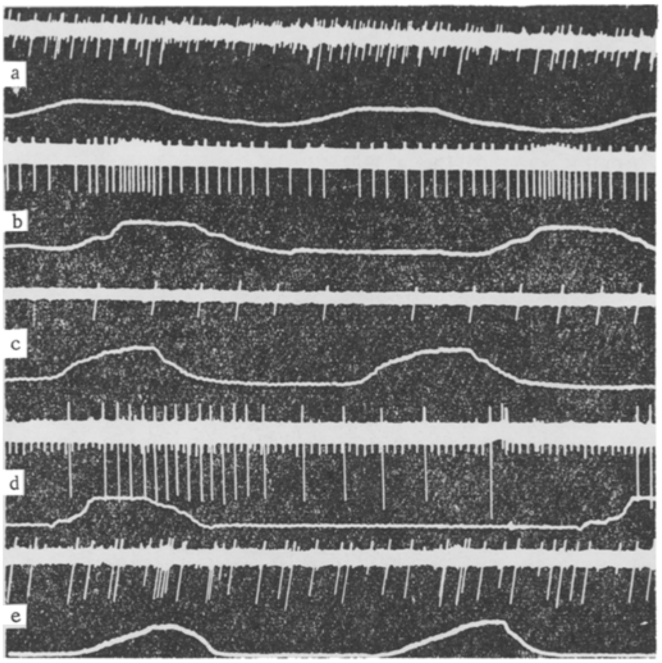

Fig. 1. Afferent impulses in the cutaneous and venous fibers of the intercostal nerves. Top line–tracing of impulses; bottomline–pneumogram; a) in the anterior twig of the lateral intercostal nerve before denervation of the skin; b) after denervation of the skin (from a single venous receptor); c) expiratory respiratory rhythm of the venous receptors; d) electrical activity of venous receptors with a respiratory rhythm; e) respiratory rhythm of impulses from the cutaneous receptors.

To continue the analysis, a separate investigation was made of the activity of the venous and cutaneous receptors. The impulses from the venous receptors traveling along the same nerve twigs, but after denervation of the skin, were studied in 43 experiments. In nearly all the oscillograms, uninterrupted rhythmic impulses of equal amplitude were seen, indicating the activity of one or only a few receptors. In 28 cases (65%) the frequency of the impulses from the venous receptors showed obvious respiratory periodicity. In most cases, the increase in the frequency of the impulses coincided with the beginning of inspiration and continued until the beginning of expiration. The intensity of the impulses increased on the average by 18 cps. The duration of the respiratory quickening of the rhythm usually corresponded to the duration of those phases of respiration with which it coincided (Fig. 1b). Only in 5 experiments was an increase in the frequency of the rhythm of impulses observed in the expiratory phase, and in three of these cases there was discoordination of the respiratory movements of the chest wall and the abdominal wall (Fig. 1c). On some oscillograms high and low impulses were seen, and the high impulses had a respiratory rhythm, while the frequency of the lower impulses was constant (Fig. 1d).

Similar results were obtained when the impulses from the cutaneous receptors were recorded in the posterior cutaneous twigs of the lateral intercostal nerves. A respiratory rhythm of the afferent impulses in the cutaneous nerves was observed in 16 of the 28 oscillograms recorded (Fig. 1e). As with the impulses from the venous receptors, the frequency of the impulses in the cutaneous afferent nerves nearly always increased in the inspiratory phase of respiration. Only in two cases, when discoordination of the respiratory movements was present, was a respiratory rhythm of expiratory type observed.

The results of these experiments thus showed that a definite relationship exists between the impulse activity of the cutaneous and venous receptors and the phases of respiration, and it can be demonstrated in recordings made from the cutaneous and venous nerve fibers both together and separately. In most cases the respiratory rhythm of the impulses is inspiratory in character, i.e., the frequency of the impulses is increased during inspiration.

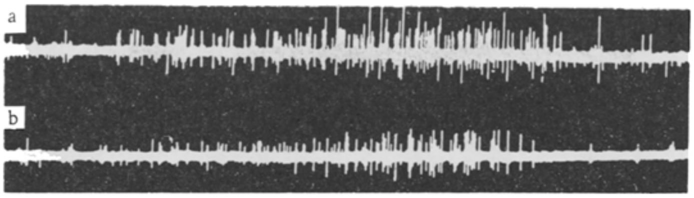

Fig. 2. Changes in the flow of efferent impulses along the lateral intercostal nerve in response to denervation of the skin and the subcutaneous vessels of the chest wall. a) Original frequency of potentials; b) electrical activity of the same nerve after blocking the cutaneous and venous afferent impulses from the chest wall.

The respiratory rhythm of the impulses recorded from the cutaneous receptors of the chest wall may be attributed to the reaction of the mechanoceptors to stretching of the skin as the chest expands. This explanation is supported by the fact that the respiratory rhythm coincides with the expiratory phase, for in these cases expiration is accompanied by expansion of the chest as a result of the asymmetry of the respiratory movements.

It is a much more complex problem to establish the cause of the respiratory rhythm of the impulses arising from the venous receptors. Respiratory oscillations of venous pressure [1, 11] and also respiratory waves of the plethysmograms [4, 6, 7, 8] have been described. However, there is no general agreement regarding the origin of the respiratory fluctuations in venous pressure. Some investigators consider that they are due to functional interaction between the respiratory and vasomotor centers, the influence of the respiratory center being predominant [4, 7]. Other workers relate the origin of the respiratory waves of venous pressure to peripheral hemodynamic changes resulting from the sucking action of the chest. It is not clear whether the respiratory rhythm of the afferent impulses from the receptors of the lateral thoracic vein described in the present experiments is associated with one of these factors or whether its appearance is due to other causes, and a further study is required.

The receptors of the skin and the subcutaneous veins of the chest wall undoubtedly react to respiratory movements by a change in their activity, as a result of which periodic volleys of impulses reach the central nervous system in time with respiration.

Several investigations have demonstrated changes in the excitability of the spinal respiratory motor neurons under the influence of impulses from the cutaneous receptors of the chest wall and the proprioceptors of the respiratory muscles [10, 12]. However, these observations are not yet adequate to allow conclusions to be drawn regarding the participation of the receptors of the skin and subcutaneous vessels in the reflex regulation of respiration. For that reason, it was decided to investigate the effect of blocking the cutaneous and venous receptors on the magnitude of the flow of impulses directly responsible for the motor activity of the respiratory muscles. In 25 experiments the electrical activity of the efferent fibers of the lateral intercostal nerve was recorded before and after denervation of the skin and subcutaneous vessels of the chest wall. In 20 cases the frequency of the potentials was reduced in response to interruption of the cutaneous and venous afferent impulses on the average by 28% (Fig. 2).

It may be concluded from these results that some part in the reflex regulation of the respiratory movements is played by stimuli traveling along the posterior root afferent fibers, not only from the muscle proprioceptors, but also from the mechanoceptors of the skin and the subcutaneous veins of the chest wall.

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