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SEGMENTAL RECIPROCAL REFLEXES OF THE THORACIC PORTION OF THE SPINAL CORD

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Under ordinary experimental conditions stimulation of the central end of a divided intercostal nerve causes reflex discharges simultaneously in several intercostal nerves on the same and opposite sides of the chest. No reciprocity is observed between these reflexes. It is shown as a result of this investigation that mechanical stimulation of the parietal pleura of unanesthetized spinal cats facilitates reflex discharges in the intercostal nerves on the side of stimulation of the pleura and inhibits them on the opposite side. The presence of reciprocal segmental reflexes between the left and right halves of the chest was thus established for the first time.

KEY WORDS: *respiratory muscles; intercostal nerves; polysynaptic reflexes; pleura; reciprocal innervation.*

It has been known since Sherrington's time that the lumbosacral and cervical segments of the spinal cord have mechanisms which provide reciprocal relations between the homonymous muscles of the opposite limbs. At the thoracic level of the spinal cord no such mechanisms have been found: stimulation of the central end of a divided intercostal nerve evokes reflex discharges simultaneously in several intercostal nerves on the same and opposite sides of the chest [7]. This corresponds to the fact that the two halves of the chest function in phase during respiration.

Besides their role in ventilation of the lungs, the respiratory muscles also participate in the maintenance of posture. During the performance of this function, reciprocal relations are observed between the respiratory muscles of the left and right sides of the chest. Usually this reciprocity is ascribed to descending influences from the cerebellum and the receptors of the neck [1, 5, 9, 10]. However, certain clinical observations suggest that reciprocity between the respiratory muscles of the left and right sides of the chest may also be due to segmental mechanisms in the thoracic part of the spinal cord. A well known example of such observations is the restriction of respiratory movements of the chest on the side of pleurisy. It seems likely that this asymmetry of the respiratory movements is caused by sensory impulses arising in the inflamed pleura and exerting a reciprocal effect on the reflex mechanisms of the left and right sides of the thoracic segments of the spinal cord.

The investigation described below was undertaken to study this problem. The effect of mechanical stimulation of the parietal pleura on reflex discharges evoked in the intercostal nerves by stimulation of neighboring intercostal nerves was studied.

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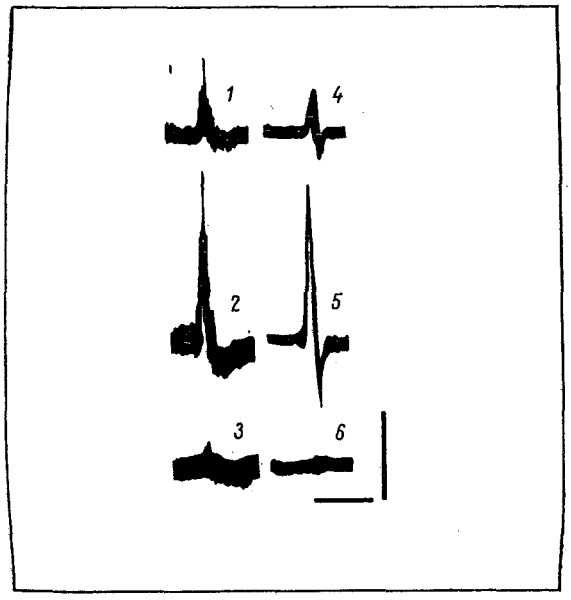

Fig. 1. Reflex discharges in 9th internal (1-3) and 10th external (4-6) intercostal nerve evoked by testing stimulation of 8th internal and 9th external intercostal nerves on the same side respectively. During mechanical stimulation of ipsilateral pleura discharges become larger (2, 5), but during the same stimulation of the contralateral pleura they become smaller (3, 6) than before stimulation of the pleura (1, 4). Each record formed by 3-5 sweeps of the beam. Calibration: 10 msec, 500 μV.

EXPERIMENTAL METHOD

Experiments were carried out on 12 cats weighing 2.3-4.1 kg. Under ether anesthesia a cannula was introduced into the trachea, an artificial ventilation apparatus was connected, and the spinal cord was divided at the level C1 or C5. All tissues covering the intercostal muscles T5-T12 on one side of the chest were removed. The nerves supplying the external and internal intercostal muscles were dissected in two or three adjacent intercostal spaces, mobilized from surrounding tissues, divided at the level of the costochondral junction, and placed on bipolar platinum electrodes. To prevent drying and cooling, the nerves were covered on all sides with cotton generously soaked with warm mineral oil. One pair of electrodes was used for stimulation, the other for recording polysynaptic reflexes. The parietal pleura were stimulated mechanically either with a blunt metal hook, introduced through a small (1-2 mm) hole in the thoracic wall, or by means of a cotton swab soaked in physiological saline. In the latter case, to obtain free access to the thoracic cavity the caudal half of the sternum was removed together with the adjacent costal cartilages, and the thoracic wall was retracted by ligatures.

EXPERIMENTAL RESULTS

As Fig. 1 shows, single stimulation of the central end of the divided intercostal nerve evoked discharges of impulses in other intercostal nerves on the same side of the chest. This is in agreement with the observations of Downman [7], who first described these reflexes, and with observations by other workers [2-4, 6, 8]. Dorsal root reflexes play no appreciable part in these discharges, for after division of the ventral roots the discharges ceased completely [7].

The present experiments showed that these reflex discharges are greatly altered by mechanical stimulation of the parietal pleura: they were increased by stimulation of the ipsilateral pleura and reduced or even totally abolished by similar stimulation of the contralateral pleura. These influences from the pleura were particularly well marked whenever the reflex discharges were evoked by submaximal testing stimuli (Fig. 1). Records 1-3 in Fig. 1 demonstrate polysynaptic discharges in the ninth internal intercostal nerve evoked by sub-

maximal testing stimulation of the eighth internal intercostal nerve on the same side of the chest. Polysynaptic reflexes, reflected in record 1, were obtained before mechanical stimulation of the pleura. Record 2 demonstrates the same reflex discharges during gentle stroking of the ipsilateral parietal pleura with a cotton swab. The amplitude of the polysynaptic reflexes at this time was clearly increased two- to threefold. The opposite effect was observed during mechanical stimulation of the contralateral pleura. As record 3 shows, gentle stroking of the contralateral pleura caused the almost total inhibition of the responses.

Mechanical stimulation of the parietal pleura had a similar action also on reflex discharges in the external intercostal nerves. Responses reflected by records 4-6 were evoked in the 10th external intercostal nerve by submaximal stimulation of the eighth external intercostal nerve on the same side. Clearly during gentle stroking of the ipsilateral pleura with a cotton swab (record 5) the amplitude of these responses became twice or three times greater than their amplitude before mechanical stimulation (record 4). Conversely, the same stimulation of the contralateral pleura caused the almost total disappearance of reflex discharges (record 6).

These observations thus show that reciprocity between the respiratory muscles of the left and right sides of the chest can be produced not only by descending influences from the cerebellum and receptors of the neck, as is generally considered, but also by segmental mechanisms in the thoracic part of the spinal cord. Under ordinary experimental conditions, when stimulation of the intercostal nerve is unaccompanied by stimulation of the parietal pleura, the inhibitory effect of afferents innervating the pleura is masked by the stronger excitatory action of the other afferent fibers of the intercostal nerve. That is evidently why the segmental mechanisms responsible for reciprocal relations between the respiratory muscles of the left and right sides of the chest have not previously been discovered.

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