SPINAL CURRENTS IN REGULATION OF RESPIRATORY MOVEMENTS (ELECTROMYOGRAPHIC STUDY)

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It has been shown that after division of the posterior thoracic roots, thoracic respiration is reduced. Numerous investigators [4, 6, 7, 11] have observed that in the cat there is a reduction of thoracic respiration on the operated side. In cats aged 10 days this operation caused thoracic respiration to cease. It has been shown [2, 3] that division of posterior thoracic roots 5-7 in the dog reduces the amplitude of contraction of the intercostal muscles on that side. However, certain authors [9, 13] found no change of thoracic respiration to follow deafferentation at this level.

In these investigations, respiratory movements were recorded pneumographically. Later it was found in cats [12] that there was a reduction of electrical activity of the expiratory intercostal and oblique abdominal muscles on the side on which the posterior thoracic roots had been divided. Numerous authors [10], using needle electrodes in human subjects have observed a reduced activity of the intercostal muscles on the operated side after division of the 4th, 5th, and 6th thoracic dorsal roots.

Less is known about the influence of deafferentation upon the activity of the diaphragm. In some studies [5, 8] on the cat a considerable reduction of movements of the diaphragm was found after division of the dorsal cervical roots. However, others [9, 13] found no appreciable changes in diaphragmal respiration after this operation. Stella observed low changes of diaphragmal respiration in decerebrate cats after division of the posterior roots from C_1 to T_{11}. These contradictory results were obtained in studies made with pneumographic recording. X-ray studies of the human diaphragm after division of the posterior cervical roots [10] showed that the deafferented half of the diaphragm moved more weakly than the other half. We have found no reports of electromyographic studies which give an accurate functional picture of the condition of the diaphragm after deafferentation.

We here report a comparative investigation of the electrical activity of the respiratory muscles (intercostal and diaphragmal) before and after division of the posterior roots. The division was made at C_5, C_6, and C_7 for measurement of diaphragmatic activity, and between T_2 and T_8 for records from the intercostal muscles.

EXPERIMENTAL METHODS

The experiments were carried out on 19 cats under 1.5-2 g/kg urethane anesthesia. The potentials were picked up from silver plate electrodes which had been sewn directly to the respiratory muscles 3-5 days previously [1]. Plate electrodes 6 x 4 mm separated by 1-1.5 cm were stitched to both leaflets of the diaphragm through an abdominal incision. Smaller electrodes (4 x 3 mm) separated by 0.5-1 cm were sewn to the right and left intercartilagenous portion of the internal intercostal muscles in the 5th intercostal space near the sternum. Potentials from muscles were recorded with a "Diza" 3-channel electromyograph. Division of the dorsal roots was made in the usual way, after a laminectomy.

EXPERIMENTAL RESULTS

In 9 animals, laminectomy in the cervical region caused a reduced electrical activity of the diaphragm on both sides followed by recovery to approximately 2/3 of the original activity 1-2 h after the operation; in 5 animals the

diaphragm showed no change. Laminectomy in the thoracic region caused a considerable reduction or a disappearance of electrical activity in the intercostal muscles on both sides, followed by recovery to approximately one-third of the original level 4-6 h or more later. Suppression of electrical activity after this operation may be due to trauma at operation caused by pressure on the spinal cord and by hemorrhage into it. The fact that electrical activity was suppressed to a greater extent in the intercostal muscles than in the diaphragm may be because laminectomy is far more complicated surgically in the thorax than in the neck.

Division of the posterior roots was made 2-3 h after laminectomy in the neck, and 4-7 h after laminectomy in the thorax. The first record of electrical activity was made 5-10 min after division of the roots.

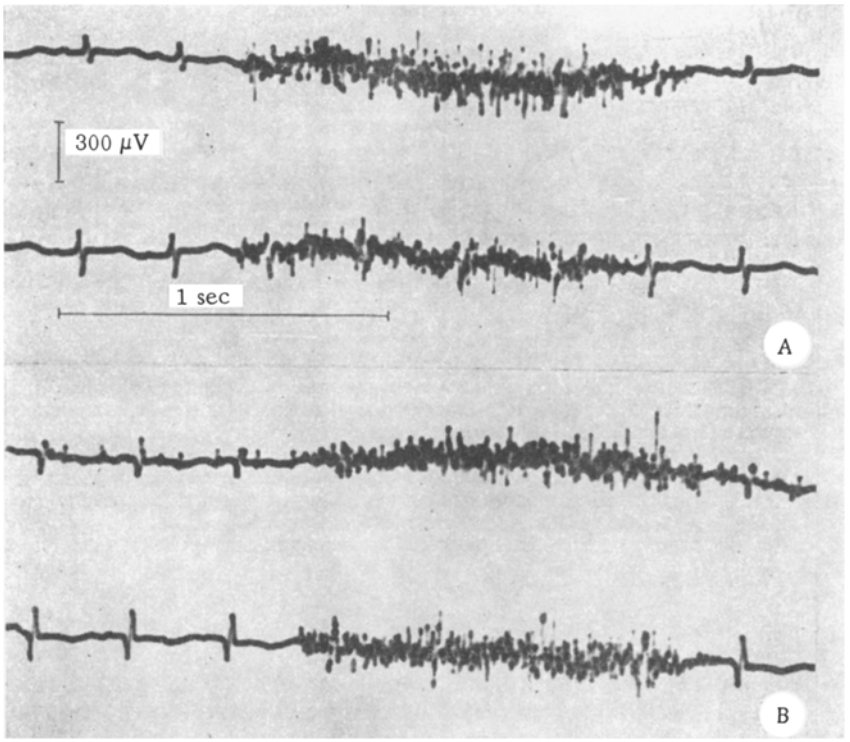

Fig. 1. Electromyogram of leaflets of diaphragm before and after unilateral division of the posterior roots at the level C_5-C_7 on the left side. Above – electromyogram of the left diaphragm; below – of the right diaphragm. A) Initial activity (2 h 30 min after laminectomy); B) immediately after division of the roots – reduction of the amplitude of impulses on the deafferented side, enhancement on the intact side.

Unilateral division of the dorsal roots at the level C_5-C_7 in 12 animals caused a reduction of electrical activity of the leaflet of the diaphragm on the operated side, while in 2 there was no change. None of the cats showed any increased electrical activity on the operated side (Fig. 1). After division of the roots, activity gradually returned. In 4 animals, after 2 h electrical activity had completely recovered; in 8 it had recovered to $\frac{2}{3}$ of the original level 1-1$\frac{1}{2}$ h after the operation.

On the opposite side (where the roots were not divided) in 10 cats the activity of the leaflet of the diaphragm showed no change, in 4 it was enhanced. Therefore division of the posterior roots at the level C_5-C_7 caused a maintained reduction in amplitude of the activity of the leaflet of the diaphragm on the operated side, but activity of the opposite leaflet either showed no change, or was enhanced.

Unilateral division of the dorsal roots at the level T_2-T_8 reduced or abolished electrical activity of the intercostal muscles on that side (Fig. 2). During the period of observation (from 13 to 20 h) electrical activity in 3 of the animals did not recover, and in 2 it recovered to $\frac{1}{3}$ of the original value.

On the opposite side (where the dorsal roots were not divided), in 4 animals either there was no change in the activity of the intercostal muscles or else it was enhanced, and in 1 it fell considerably. These results indicate that division of the dorsal roots at the level T_2-T_8 greatly reduced the electrical activity of the intercostal muscles.

Therefore electromyographic recording revealed a marked reduction of activity in all the animals on the operated side. This result indicates the part played in respiration by afferent pathways running along sensory spinal nerves and connecting with motoneurones of the respiratory muscles. Evidently, the afferent link in the regulation of respiratory movements is not restricted to the vagus nerve, but involves also afferent fibers entering the spinal cord at the level of the motoneurones of the respiratory muscles. This spinal afferent supply appears to be of greater significance for thoracic than for diaphragmatic respiration: division of the corresponding posterior roots caused less permanent change in the electrical activity of the diaphragm than of the intercostal muscles. The diaphragm is the principal respiratory muscle, and it appears to enjoy a greater degree of independence.

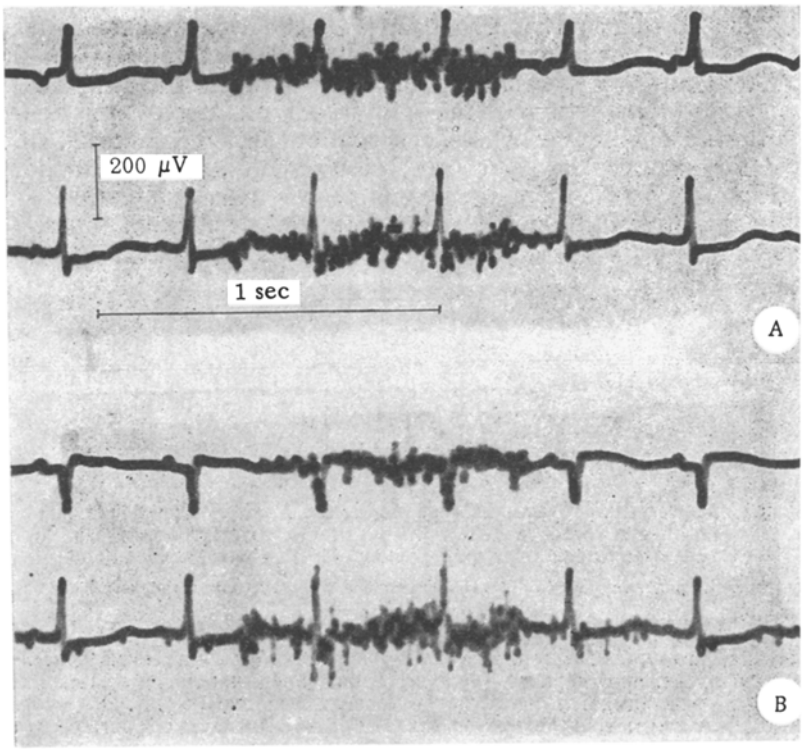

Fig. 2. Electromyogram of the intercostal muscles before and after unilateral division of the posterior roots at the level T_2-T_8 on the left side. Above – electromyogram of the left intercostal muscles; below – of the same muscles on the right side. A) Initial level (3 h after laminectomy); B) immediately after division of the posterior roots, reduction in amplitude of impulses on the deafferented side.

SUMMARY

Division of the dorsal roots at the level C_5-C_7 caused a transitory reduction of electrical activity of the diaphragm on the same side. Division of the posterior roots of the level T_2-T_8 caused a disappearance or a marked reduction of the activity of the intercostal muscles on that side which was maintained the whole observation period (up to 24 h).

Evidently, in respiratory control, besides afferent impulses spreading to the respiratory center via the vagus nerves, other impulses must spread from the respiratory muscles along the posterior roots.

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