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Abstract

1. After spinal transection at the medulla-spinal junction the thoracic respiratory movements no longer appear in the adult animals, nevertheless the sporadic spike discharges can be recorded from the intercostal muscles. 2. Both in the acute and chronic experiments the spinal cord is transected at the two levels of Th7 and Thl1 respectively and all the dorsal rootlets coming into that part of the cord lying between the transections are severed. The sporadic spike discharges with irregular intervals varying about 0.5 to 3.0 sec. can be recorded from intercostal muscles in the 8th to 10th segments of the spinal cord isolated. There can never be found any reflex influence of the skin stimulation upon the discharges, which also disappear provided the intercostal nerves innervating the muscles are severed. 3. From these results it may be concluded that the spinal cord is endowed with an ability to initiate the impulses autochthonously to excite the intercostal muscles, even though it is only poorly developed in the adult animals.

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AUTOMATIC ACTIVITIES OF THE SPINAL CORD CONCERNED WITH THE RESPIRATORY MOVEMENTS

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It is a question of a long standing whether or not there exists in the spinal cord a center, where the respiratory impulses can be originated spontaneously. The results obtained up to the present time by some investigators (ROKITANSKY[4], SCHROFF[6], LANGENDORFF[2] and MARCKWALD[3]) show that the respiratory movements of the thorax in infant or newborn animals still persist even after the spinal cord is transected at medullo-spinal junction, however, such a persistent respiration can not be observed in adult animals.

Recently KOTANI[1] reported the presence of some sporadic spike discharges in the intercostal muscles even in spinalized adult animals, although no recognizable contraction seems to take place. This, however, can not be at once be construed as sporadic spikes to originate autochthonously in the spinal cord itself, since these are likely to be provoked reflexively by stimuli of peripheral sources (i. e., skin, muscle, joint and so on). The following results may offer a clue to a better understanding of the point at issue.

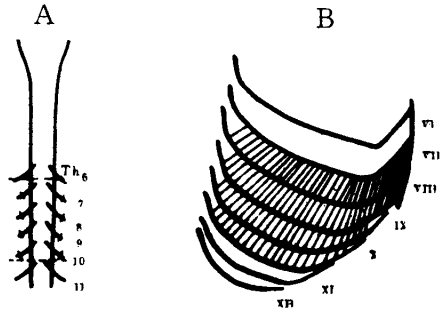
METHODS

As experimental animals newborn and adult dogs, cats and rabbits are used. Each newborn animal, less than 2 days old, is decapitated without any anesthetics and the change of respiratory movements both in the thorax and in the nostrils or larynx are observed or recorded on the smoked surface of the drum of a kymograph by clipping the skin of the regions concerned.

In adult cats and dogs the spinal cord is on the one hand exposed by laminectomy under local anesthesia with 1% solution of xylocaine. In one series of experiments the cord is then transected at the medullo-spinal junction. In another series of experiments the spinal cord is at first transected at the level between Th_6 and Th_7 rostrally as well as between Th_{10} and Th_{11} caudally, and then all the dorsal rootlets coming into that part of the cord lying between the level of transections are severed bilaterally (Fig. 1A).

Expecting to be able to determine whether or not the isolated spinal cord, thus prepared, has an ability to excite automatically, electromyograms are taken

Fig. 1. Schematic drawing for the explanation of partial isolation of the spinal cord.



A : Thoracic part isolated from the rest of the spinal cord of the dog ; all the dorsal roots of that part are severed. B : Part shadowed by slanting lines in the right thoracic wall corresponds to the isolated part of the spinal cord.

from the intercostal muscles in the intercostal spaces (Fig. 1B) which correspond to the isolated part of the cord. Details for the recording of electromyogram are described in the previous paper[7].

Considering some possible influence of acute injuries upon the spinal cord activity, a series of experiments is also carried out on the animal whose spinal cord has been isolated aseptically about 10 to 14 days before the experiments.

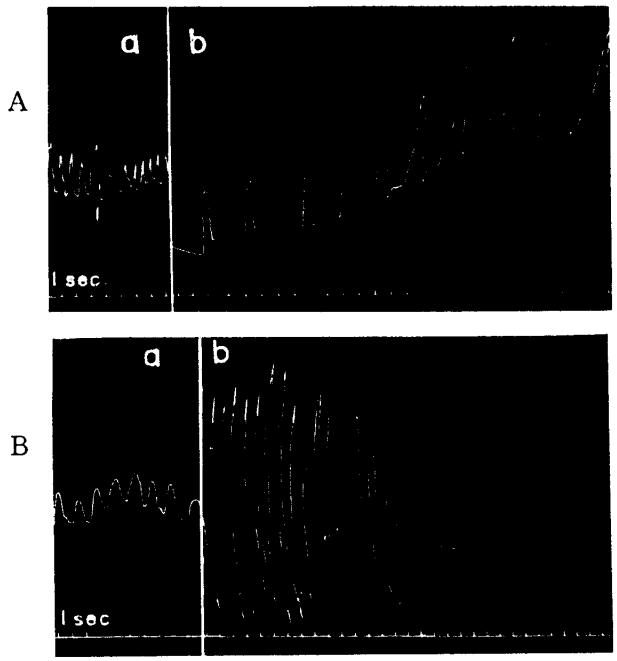
RESULTS AND DISCUSSION

A. *Effects of decapitation upon the respiratory movements in the newborn or infant animals.*

Respiratory movements both in the nostrils or larynx and thorax are abruptly interrupted for about 5 to 30 seconds when the animal is decapitated. Then abrupt, short-lasting opening of the mouth coincidentally with the opening of nostrils and caudal shifting of larynx occurs recurrently. In the thorax and extremities, which have already lost their nervous connections to the respiratory centers involved in the brain stem, there also recurrently occur convulsive movements whose rhythm is, however, different from that of the movements observed in the neck and head. Concordant with these movements of thorax there is noted a remarkable widening and narrowing of intercostal spaces, therefore they can undoubtedly be conceived as respiratory movements. The movements are in general more vigorous but less frequent than those observed before the decapitation (Fig. 2 A and B). Some 20 to 30 seconds later the movements rapidly begin to wane until they finally disappear. On the other hand, electromyograms of the intercostal muscles exhibit bursts of impulses with the rhythm of thoracic movements as shown in Fig. 3.

The results described above may suggest the presence of automaticity in the spinal cord, at least in newborn or infant animals.

Fig. 2. Changes of the respiratory movements produced by decapitation in two rabbits.



A and B show the breathings before and after the decapitation respectively. After decapitation, an increased amplitude of the movements both in A and B, however, a decreased frequency in A, and no remarkable change in B are noticed. Inspiration upwards.

Fig. 3. Electromyogram led from the intercartilaginous muscles of a decapitated newborn rabbit.

There are observed three burst of impulses corresponding to the phasic thoracic movements.

B. Effects of transection of the spinal cord at the medullo-spinal junction upon the respiratory movements in the adult animals.

When the spinal cord is transected at the medullo-spinal junction, the rhythmical opening of the nostrils and contraction of the laryngeal muscles per-

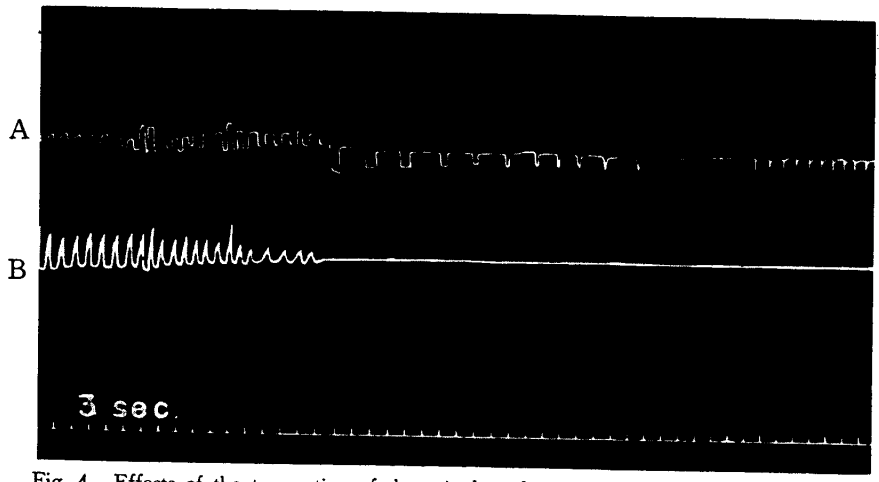
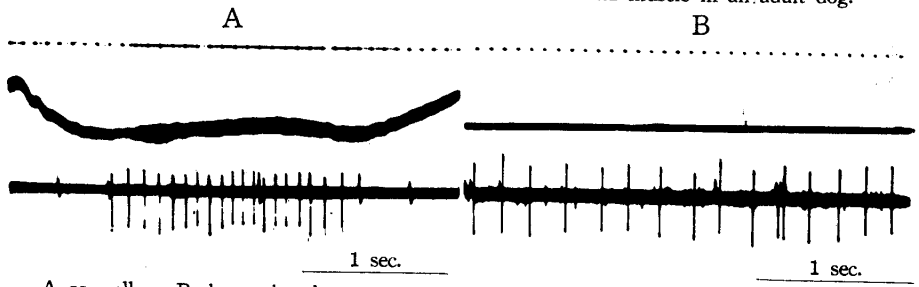


Fig. 4. Effects of the transection of the spinal cord at the medullo-spinal junction upon the respiratory movements both in the nostril (upper trace) and in the thorax (lower trace) in an adult dog. During the period as indicated by a straight line the transection is performed. The movements do not stop in the nostril but these stop in the thorax instantaneously. Inspiration downwards in A and upwards in B.

sist. These movements are, however, remarkably reduced in frequency and prolonged in duration, waning gradually until they completely disappear, soon afterwards giving place to a sequence of another type of respiratory movements, gaspings (Fig. 4 A). On the other hand the thoracic respiratory movements abruptly cease and no longer reappear (Fig. 4 B). Nevertheless the electromyogram reveals that a few impulses are discharged sporadically (Fig. 5).

Fig. 5. Electromyogram led from the internal intercostal muscle in an adult dog.



A as well as B shows the electromyogram before and after the spinal transection at the medullo-spinal junction. The thorax is apparently quiet after the transection, nevertheless spikes are discharged sporadically. Upper trace indicates the thoracic movements, expiration downwards.

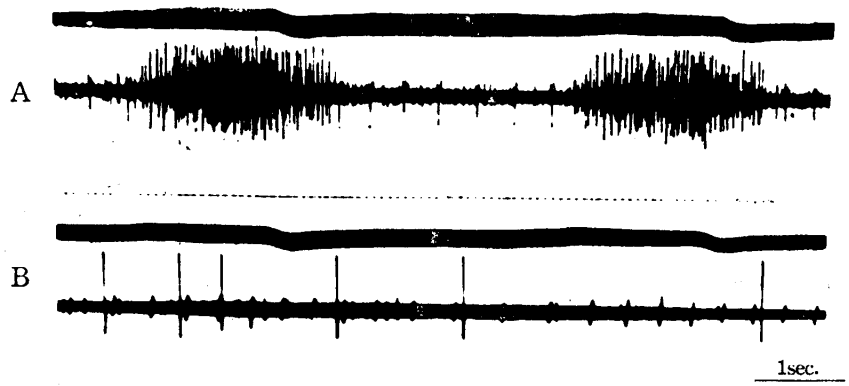
C. *Electrical activities of intercostal muscles in the animal with acutely isolated spinal cord.*

In the animal in which a part of the spinal cord lying between Th_7 to

Th_{10} is isolated by rostral and caudal spinal transections and by complete severance of all the dorsal rootlets the electrical activities of intercostal muscles are recorded from each intercostal space corresponding to the isolated spinal cord segment respectively.

In the 7th intercostal space there can be observed, unexpectedly, the bursts consisting of a few impulses recurring with respiratory rhythm, although the spinal segment corresponding to the region must be involved within the isolated part of the spinal cord. The phenomenon naturally suggests that a minute number of motor nerve fibers coming from the 6th thoracic segment, whose connection with the normal respiratory centers is kept intact, distribute to the intercostal space mentioned above via the 7th intercostal nerve. On the other hand, in the 8th to 10th intercostal spaces the spikes are discharged sporadically with intervals varying from 0.15 to 3.0 seconds without showing any respiratory change (Fig. 6 B).

Fig. 6. Electromyograms led from the intercostal muscles in the intercostal spaces which correspond to the isolated part of the spinal cord.



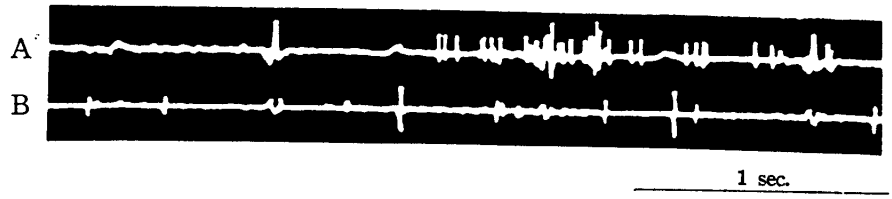
Cat, 1 day old. A : Respiratory bursts of action potentials led from the intercartilaginous muscles in the 6th intercostal space (control). B : Spontaneously produced action potentials led from the intercartilaginous muscles in the 8th intercostal space.

D. *Electrical activities of intercostal muscles in the animal with chronically isolated spinal cord.*

In another series of experiments the isolation of a part of the spinal cord has been carried out 10 to 14 days before the experiments for the purpose of excluding a possibility of such spike discharges as above described from originating in the sites suffering from injury produced by the operative procedure, that is, spinal transection and dorsal root severance.

The results are similar to those obtained in the acute experiments, that is, the sporadic spike discharges are recorded from the intercostal muscles in the 8th

Fig. 7. Action potentials led from the intercostal muscles in the intercostal spaces which correspond to the isolated part of the spinal cord.



Cat, adult. The isolation of the spinal cord has been carried out 14 days before the experiment. A : A burst of respiratory action potentials led from the intercartilaginous muscles in the 6th intercostal space (control). B : Spontaneously produced action potentials led from the intercartilaginous muscles in the 8th intercostal space.

to 10th intercostal spaces, as shown in Fig. 7 B. The discharges are free from the reflex inhibitory influence of skin pinching[7] and disappear totally provided the intercostal nerves innervating the muscles are cut. This suggests that the spike discharges are produced by impulses which spontaneously originate in the spinal cord isolated.

SUMMARY

1. After spinal transection at the medullo-spinal junction the thoracic respiratory movements no longer appear in the adult animals, nevertheless the sporadic spike discharges can be recorded from the intercostal muscles.

2. Both in the acute and chronic experiments the spinal cord is transected at the two levels of Th7 and Th11 respectively and all the dorsal rootlets coming into that part of the cord lying between the transections are severed. The sporadic spike discharges with irregular intervals varying about 0.5 to 3.0 sec. can be recorded from intercostal muscles in the 8th to 10th segments of the spinal cord isolated. There can never be found any reflex influence of the skin stimulation upon the discharges, which also disappear provided the intercostal nerves innervating the muscles are severed.

3. From these results it may be concluded that the spinal cord is endowed with an ability to initiate the impulses autochthonously to excite the intercostal muscles, even though it is only poorly developed in the adult animals.

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