Atti Accademia Nazionale dei Lincei

Classe Scienze Fisiche Matematiche Naturali

Rendiconti

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Effects of dorsal roots section in the cervical spinal cord on the activity of the diaphragm in rabbits

Atti della Accademia Nazionale dei Lincei. Classe di Scienze Fisiche, Matematiche e Naturali. Rendiconti, Serie 8, Vol. **46** (1969), n.4, p. 481–485.

Accademia Nazionale dei Lincei

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Atti della Accademia Nazionale dei Lincei. Classe di Scienze Fisiche, Matematiche e Naturali. Rendiconti, Accademia Nazionale dei Lincei, 1969.

Fisiologia. — *Effects of dorsal roots section in the cervical spinal cord on the activity of the diaphragm in rabbits* (*). Nota di GIUSEPPE SANT'AMBROGIO (**), presentata (***) dal Socio R. MARGARIA.

RIASSUNTO. — È stato studiato l'effetto della sezione delle radici dorsali nel midollo cervicale sulla forza di contrazione del diaframma in conigli spinalizzati al primo segmento toracico. Dopo chiusura della trachea a vari volumi polmonari, si sono misurate le pressioni massime raggiunte durante gli sforzi inspiratori. Nessuna differenza significativa è stata rilevata prima e dopo la rizotomia dorsale.

Anche la attività riflessa, mediata dai nervi vaghi (Hering–Breuer), modifica l'attività del diaframma in maniera equivalente sia prima che dopo rizotomia dorsale.

Complessivamente si può concludere che la abolizione del ' input ' afferente diaframmatico è trascurabile nella sua capacità di variare l'attività di questo muscolo.

INTRODUCTION.

The section of the dorsal roots causes a sudden withdrawal of the habitual afferent inflow to the alpha motoneurones from muscle spindle afferents, which is an important factor for the maintenance of their excitability. The impairment which follows dorsal rhizotomy is well established for the limb muscles (5, for reference) and for the intercostals [6], but conflicting results have been reported for the diaphragm [5, 7]. The proprioceptive innervation of the diaphragm appears to be peculiar: the muscle spindles are scanty and this should involve a lack of facilitatory influences on the excitability of the phrenic motoneurones, on the other hand the prevailing number of Golgi tendon organs [2] indicates a possible prevalence of the inhibitory influences. Both in cats and in rabbits [1, 6] the prevalence of the inhibitory influences has been shown. In this work in order to evaluate quantitatively the influence of the proprioceptive inflow from the diaphragm on the activity of this muscle the pressure-volume relationship before and after cutting the dorsal roots has been investigated by measuring the pressure developed during static inspiratory efforts with the trachea clamped at various lung volumes. Also the strength of the Hering-Breuer reflexes before and after severance of the dorsal roots has been analyzed.

METHODS.

Rabbits anaesthetized with a mixture of urethane and pentobarbitone sodium (initial dose 2.5 ml/kg body weight of a solution containing 218 mg urethane and 7.5 mg pentobarbitone sodium per ml) have been used. For the pressure-

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(**) L'autore ringrazia la sig.ra P. Fiocchi per l'assistenza tecnica.

(***) Nella seduta del 19 aprile 1969.

volume relationship experiments the animals were vagotomized. A metal cannula was placed in the trachea 1 cm below the larynx. With the animal in a prone position, the neck muscles were separated by a midline incision and the vertebrae exposed. The vertebral laminae were cut and the spinal cord exposed, the dura cut along the midline. The section of the dorsal roots (C_3, C_4, C_5, C_6) was done intradurally, each individual root being reached by lifting the dural margin on its side. The intrapulmonary pressure was recorded through a Sanborn strain gauge during maximal inspiratory efforts immediately before and after rhyzotomy. Lung volumes above and below the F.R.C. value were obtained by injecting or withdrawing volumes of air through a syringe connected to one side of the tracheal cannula.

In the experiments aimed to test the strength of the Hering-Breuer reflexes a couple of silver electrodes was placed in the sternal portion of the diaphragm reached through a midline incision of the upper part of the abdominal wall. As an index of the strength of the Hering-Breuer reflexes has been taken the ratio between the duration of the eletromyographic discharge from the diaphragm during the first breath after tracheal occlusion and that of a normal breath.

Results and discussion.

Dorsal roots section and pressure developed during static inspiratory efforts at various lung volumes.—These experiments have been carried out on four rabbits spinalized at the level of the first thoracic segment and vagotomized. In fig. 1 is shown a trial performed in one rabbit and the results of all experiments are given in Table I.

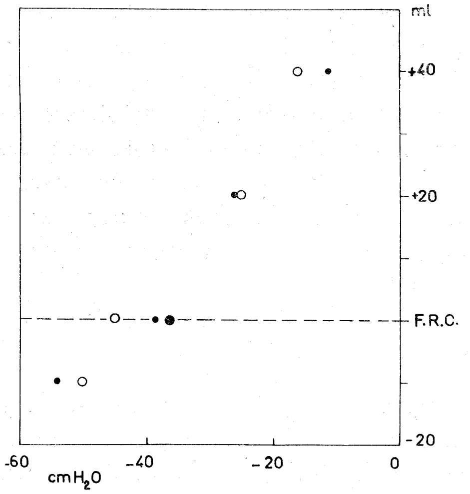

Fig. 1. – Pressure-volume relationship during maximal inspiratory efforts obtained in the rabbit n° 2 of Table I.

The rabbit has been spinalized at the first thoracic level, and vagotomized. Efforts before (●) and after (○) posterior thizotomy in the cervical cord (C_3, C_4, C_5 and C_6).

TABLE I.

Intratracheal pressure at different lung volume above (+) *and below* (—) FRC (*volume at the end of a normal expiration*). *The pressures are in* cm H_2O.

	Rabbit n° 1		Rabbit n° 2		Rabbit n° 3		Rabbit n° 4	
	Intratracheal pressure cm H_2O		Intratracheal pressure cm H_2O		Intratracheal pressure cm H_2O		Intratracheal pressure cm H_2O	
ml	Before	After	Before	After	Before	After	Before	After
—10	—20	—22 —22	—54	—50	—	—	—31	—32
F.R.C.	—15 —19	—15 —16	—36 —28	—36 —45	—55 —56	—53 —61	—28 —30	—28 —28
+20	— 8 —10	—8 —9	—26	—25	—38	—44	—20	—21
+40	—4.0 —4.5	—3.5 —5.0	—12	—16	—23	—26	—12	—15

The pressure developed during the static inspiratory efforts decreases as the volume of the respiratory system becomes larger [4], as expected according to the tension-length diagram of the skeletal muscles. The dorsal rhizotomy does not change the pressure developed by the contracting diaphragm: Euler and Fritts [4] in intact cats found, on the contrary, a decrease of the inspiratory efforts after cervical and thoracic dorsal rhizotomy. This decrease in strength developed in the inspiratory muscles in non-spinalized animals should therefore be attributed to a functional impairment of the inspiratory muscles depending from neuromeres below T_1. This hypothesis is supported also by the observation that the section of the dorsal thoracic roots abolishes the activity of the corresponding intercostal muscle [6].

These results suggest a lack of a proprioceptive drive for the phrenic motoneurones in accordance with previous observations [7].

The numerous Golgi tendon organs present in the diaphragm [2] should involve a predominance of inhibitory influences and this has been shown in previous experiments [1, 6]. This does not appear in these experiments possibly because the anaesthesia, which was necessarily deep, abolished this autogenetic inhibition [6].

Hering-Breuer reflexes before and after severance of the dorsal spinal roots.—The first breath after a tracheal occlusion lasts longer than the previous ones; this effect is due to the prevention of the increased discharge of pulmonary stretch receptors which occurs during a normal inspiration with increasing lung volume (8 for reference). As an index of the strength of the

Hering-Breuer reflex it has been used the ratio between the duration of the electromyographic discharge from the diaphragm during tracheal occlusion and that during a normal breath. These experiments have been performed on three rabbits spinalized at the first thoracic level. In fig. 2 is shown

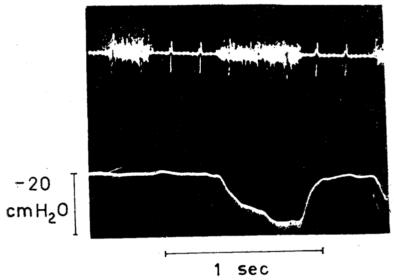

Fig. 2. – Top tracing = diaphragm electromyogram; bottom tracing = intratracheal pressure. During tracheal occlusion the inspiratory discharge lasts longer than in a normal breath; the strength of the Hering–Breuer reflex has been measured as the ratio between the duration of the inspiratory activity during tracheal occlusion and during a normal breath. The rabbit has been spinalized at the first thoracic level.

a trial performed in one experiment and all the data are collected in the Table II. These results indicate that the afferent inflow through the cervical spinal roots, containing fibres coming from the diaphragm, does not vary the strength of the vagal respiratory reflexes.

TABLE II.

Strength of the Hering-Breuer reflexes before and after posterior rhizotomy, as given by the ratio between the duration of the inspiratory discharges during tracheal occlusion and in the normal breath before and after posterior rhizotomy.

RABBITS		Inspiratory activity during tracheal occlusion / Inspiratory activity during a normal breath	
		Before	After
n° 1		1.70 1.78 1.65	1.50 1.78 1.52 1.50
	Avg.	1.70	1.57
n° 2		1.83 1.58 1.85 1.87 1.92	1.72 1.82 1.81 1.76 1.69
	Avg.	1.81	1.76
n° 3		1.66 1.66 1.69	1.69 1.64 1.77
	Avg.	1.67	1.70
n° 4		2.00 1.75	1.85 2.000
	Avg.	1.87	1.93

On the whole it may be concluded that the net effect of abolishing the afferent inflow from the diaphragm is negligible in its capacity of varying the activity of this muscle.

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