Pergamon

Brain Research Bulletin, Vol. 35, No. 3, pp. 233–236, 1994
Copyright © 1994 Elsevier Science Ltd
Printed in the USA. All rights reserved
0361-9230/94 $6.00 + .00

0361-9230(94)E0106-5

Role of Proprioceptors in the Mylohyoid Muscle

KIYOFUMI FURUSAWA,* MINORU YAMAOKA,*[1] KATSUHIKO FUJIMOTO*
AND TOSHIFUMI KUMAI†

**Oral and Maxillofacial Surgery Department II, and †Department of Oral Physiology, Matsumoto Dental College, Shiojiri, Nagano 399-07 Japan*

Received 27 August 1993; Accepted April 1994

FURUSAWA, K., M. YAMAOKA, K. FUJIMOTO AND T. KUMAI. *Role of proprioceptors in the mylohyoid muscle.* BRAIN RES BULL **35**(3) 233–236, 1994.—Afferent discharges of the mylohyoid muscle branch during respiration were studied electrophysiologically in the rat. Afferent discharges from the mylohyoid muscle branch of the mylohyoid nerve were found to be synchronized with respiration. Stretching of the mylohyoid muscle elicited afferent discharges of the mylohyoid muscle branch, suggesting that lengthening of the mylohyoid muscle caused electrical activity in the proprioceptors. When the central cut end of the mylohyoid muscle branch was stimulated electrically, reflex discharges were recorded from the EMG lead at the sternohyoid muscle where it is innervated by the cervical nerve. The latency between the electrical stimulation and the action potential in the sternohyoid muscle was 3–4 ms. Therefore, the mylohyoid muscle branch may transmit information to the sternohyoid muscle regarding the stretching actions of the mylohyoid muscle resulting from movements of the hyoid bone.

Mylohyoid muscle   Mylohyoid nerve   Sternohyoid muscle   Upper airway   Reflexes

BY elevating the hyoid bone, the mylohyoid muscle raises the floor of the mouth and the base of the tongue and, thus, is directly involved in the act of swallowing (6). The hyoid bone is held in place by the sternohyoid, omohyoid, thyrohyoid, middle constrictor of the pharynx, stylohyoid, digastric tendon, mylohyoid, and genioglossus muscles, and it is freely movable (6). The geniohyoid and the sternohyoid muscles show a change in length during rebreathing of CO_2 (15). The average rates of movement of the geniohyoid, thyrohyoid, and sternohyoid muscles increase with progressive hypercapnia (14). Therefore, it has been suggested that the hyoid arch and the geniohyoid and sternohyoid muscles can affect the upper airway patency (14,15). On the other hand, the activity of the mylohyoid muscle is characterized by bursts during the expiratory phase and increase in peak activity during hypercapnia or hypoxia (13); the extent of this activity, which is inhibited during the inspiratory phase in progressive asphyxia, declines steadily in comparison with the expiratory level as the apnea progresses (3). Furthermore, there may be an interrelationship between the activities of the suprahyoid and infrahyoid muscles, because the mylohyoid (7,16) and the sternohyoid (10) muscles possess muscle spindles. The purpose of this study was to investigate the participation of the mylohyoid muscle in breathing and how it affects the sternohyoid muscle.

METHOD

Seventeen Wistar rats (200–250 g) aged 8–10 weeks were anesthetized with sodium thiopental (0.1–0.15mg/g) and were thereafter maintained under anesthesia without tracheal cannulation at body temperature of 37–38°C. Heart rate was stable, and the spontaneous respiratory rate was sufficient to maintain the $tcPO_2$ between 45 and 55 mmHg and the $tcPCO_2$ between 50 and 53 mmHg with ambient temperature room air. A transcutaneous blood gas analyzer was utilized to continuously measure the $tcPO_2$ and $tcPCO_2$. Each rat was placed on a table with its dorsal side down, and its jaw was fixed rigidly with clamps. The procedures described below were conducted under an operating microscope. A skin incision was made over the masseter muscle. The mylohyoid nerve was identified near the molar region of the lower border of the mandible, and the mylohyoid muscle branch was exposed. The sternohyoid muscle was exposed with a vertical skin incision over the clavicle bone in preparation for EMG recording with a bipolar tungsten electrode.

In preparation for recording of the afferent single unit discharges caused by respiration (Fig. 1, S.R.), the peripheral cut ends of the mylohyoid muscle branch were dissected into several viable fibers with forceps. Each dissected fiber was placed on a fine blunt tungsten hook electrode (resistance >2 MΩ). For respiratory airflow measurements (Fig. 1, R.C.), a mask was applied to the mouth and connected to a differential transducer (AK-601, Nihon Kohden) in reference to the atmosphere. The mylohyoid muscle was stretched intermittently at a load of less than 1 g with a thread attached from the body of the hyoid bone to a transducer (Fig. 1, stretch). The traction did not change the head position. The amplitudes of the neural discharges and EMG activities were amplified by a high-input impedance preamplifier and main am-

---

[1] To whom requests for reprints should be addressed.

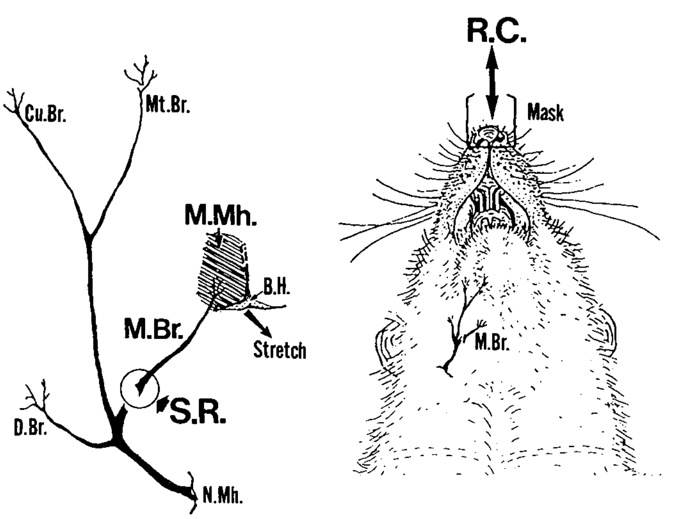

FIG. 1. A schematic illustration of the mylohyoid nerve and its branches to the submandibular region. M.Mh., mylohyoid muscle; M.Br., branch innervating mylohyoid muscle; S.R., spike recording of single unit afferent discharges from the peripheral cut end of M.Br; R.C., respiratory curve; B.H., hyoid bone; N.Mh., mylohyoid nerve; Cu.Br., intracutaneous branch; Mt.Br., branch innervating the mandibular transverse muscle; D.Br., branch innervating the digastric muscle.

plifier (AVH-10, Nihon Kohden). The impulses, together with either the airflow measurements during respiration or the stretching load, were displayed on an oscilloscope (VC-10, Nihon Kohden), and these data were stored on a magnetic tape recorder at the speed of 38 cm/s (MR-30, TEAC).

The central cut end of the mylohyoid muscle branch was mounted on a pair of silver wire electrodes for electrical stimulation (Fig. 2, E.S.) In the examination of the effects of electrical stimulation of the mylohyoid muscle branch on the EMG activities of the sternohyoid muscle, the applied electrical stimulation was a rectangular pulse with a duration of 0.1 ms and with the current varied from 1 to 5 mA.

RESULTS

Afferent discharges were recorded successfully from 22 proprioceptive units in the mylohyoid muscle branch of the mylohyoid nerve ($n = 7$). Fifteen units (68%) responded only to hyoid arch traction, and the remaining seven units (32%) were excited by both stretching of the hyoid bone and expiration. The instantaneous frequencies in the spike train recorded during respiration through the mask are shown in Fig. 3. Distinct increase in frequency during expiration and decrease during inspiration were seen, and both showed similar patterns (Table 1). Hyoid arch traction was then applied during recording from the same seven units to investigate the cause of the afferent discharges of the mylohyoid muscle during respiration. There was a clear relationship between the afferent discharges and the stretching load on the hyoid bone (Fig. 4). The number of spikes increased in parallel with increase of the load, causing them to deflect in the direction of the mylohyoid muscle fiber.

The EMG responses of the sternohyoid muscle reflexively produced by graded electrical stimulation of the central cut end of the mylohyoid muscle branch were then studied in 10 rats (Fig.

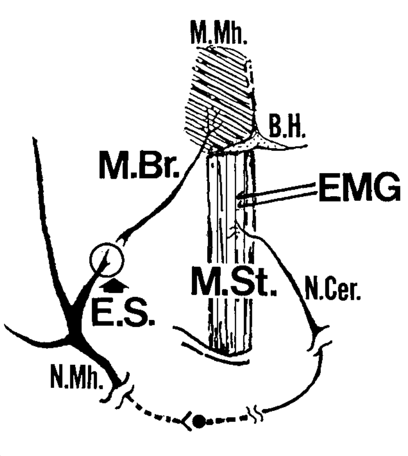

FIG. 2. A schematic illustration of a reflex arc between the mylohyoid muscle branch and the sternohyoid muscle through the cervical nerves. E.S., electrical stimulation; N.Cer., cervical nerve; M.St., sternohyoid muscle. The other abbreviations are defined in Fig. 1.

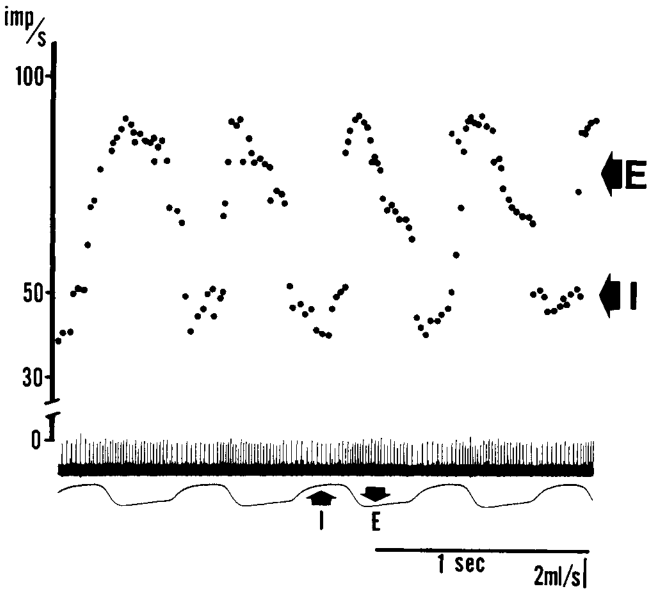

FIG. 3. Instantaneous frequencies in the spike train of a single proprioceptive unit in the mylohyoid muscle branch during respiration. Discharge frequencies varied as a function of inspiration and expiration. Note that the afferent discharge instantaneous frequencies were decreased during inspiration. imp/s, instantaneous frequencies; I, inspiration; E, expiration.

TABLE 1

INSTANTANEOUS FREQUENCY (IMP/S) OF UNITS (N = 7) MODULATED BY RESPIRATION

Unit	Mean maximum (exp)	Mean maximum (insp)
1	87 ± 6	42 ± 5
2	64 ± 8	37 ± 11
3	73 ± 7	40 ± 8
4	94 ± 14	48 ±6
5	70 ± 9	25 ± 5
6	88 ± 6	36 ± 8
7	68 ± 11	27 ± 4

Mean ± SD for ten respiration cycles.

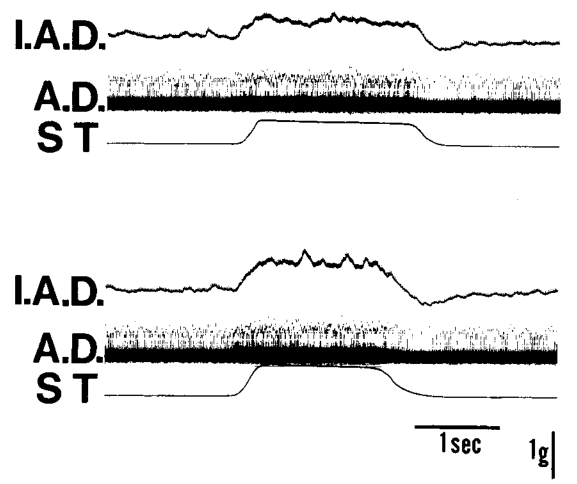

FIG. 4. Effects of stretching of the mylohyoid muscle in the same unit as shown in Fig. 3 during application of traction to the hyoid bone. I.A.D., integrated afferent discharge; A.D., afferent discharge; ST, stretching load.

5). The EMG response of the sternohyoid muscle showed incremental increase in amplitude as intensity of electrical stimulation was increased. The peak heights of amplitude were measured and expressed as a percentage of their value at 5 mA electrical stimulation (Fig. 6). The EMG amplitude reached a plateau level at 4 mA intensity of electrical stimulation. The latency between the stimulation and the reflex potential decreased with increasing intensity of electrical stimulation and reached a constant level at 4 mA intensity (Fig. 7).

FIG. 5. EMG responses reflexively produced in the sternohyoid muscle by graded electrical stimuli applied to the central cut end of the mylohyoid muscle branch. Increases of the amplitude of the EMG signal and decreases of latency were seen in parallel with the magnitude of the stimulus current. The arrow indicates the stimulus onset.

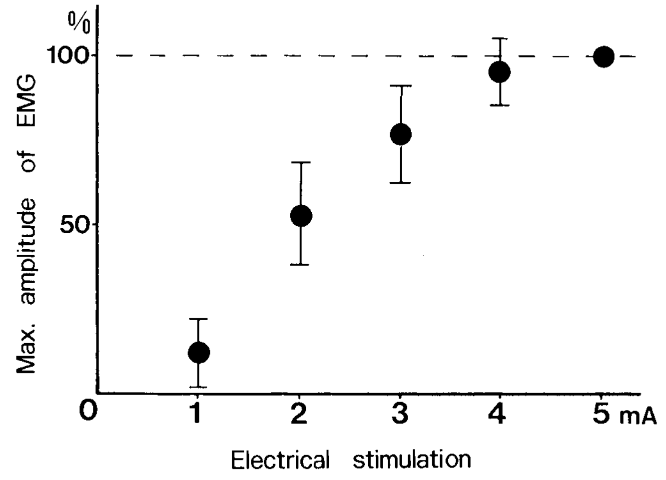

FIG. 6. Effect of intensity of electrical stimulation on the amplitudes of reflex potentials evoked in the sternohyoid muscle after electrical stimulation of the mylohyoid muscle branch. The maximum amplitude is expressed as a percentage of that at 5 mA of electrical stimulation. Each bar indicates 1 SD.

DISCUSSION

Inconsistent findings have been reported regarding the role of the sternohyoid muscle in respiration (1,2). Sternohyoid muscle respiratory activity is not consistent when partial airway obstruction and hypoxia are induced (4). The sternohyoid muscle shows a progressive increase in electromyographic activity with airway occlusion (11), and it has been recognized that this muscle contributes to maintenance upper airway patency (9,11,12). These finding are consistent with our finding that the EMG activities of the sternohyoid muscle are related to the respiratory cycle. Phasic inspiratory contraction of the sternohyoid and sternothyroid muscles may function to resist pharyngeal airway collapse due to negative intraluminal pressures (11).

The activity of the genioglossus muscle is increased by negative pressure and decreased by positive pressure, and cyclic pressure changes applied to the isolated upper airway have been found to increase the activity of this muscle (8). The vector sum

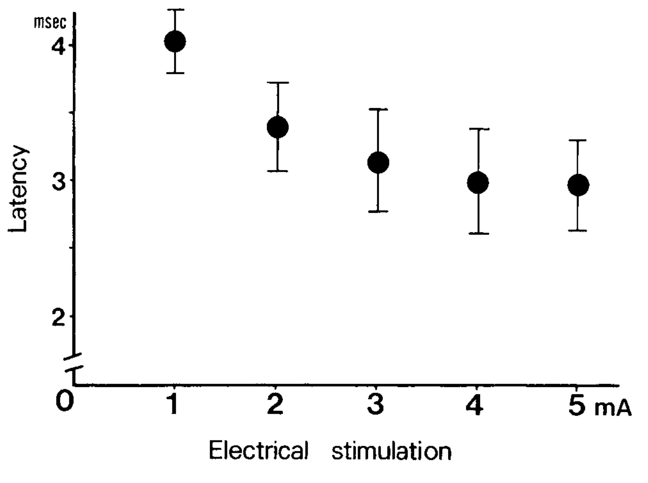

FIG. 7. Effect of intensity of electrical stimulation on the latency of reflex potentials evoked in the sternohyoid muscle after electrical stimulation of the mylohyoid muscle branch. Each bar indicates 1 SD.

of cephalad and caudad forces results from a combination of forces produced by the genioglossus, the geniohyoid muscles, and the thyrohyoid and the sternohyoid muscles, and upper airway patency depends on the position of the hyoid arch and the level of hyoid muscle activity (14). The upper airway is maximally open during inspiration, and the laryngeal lumen is not restricted in any way during expiration (12).

On the other hand, a respiratory-modulated trigeminal (mylohyoid branch) discharge is characterized by a diminution of neural activity during inspiration and a peak during expiration; in hypercapnia or hypoxia, peak activity increases, and its time of occurrence changes to late inspiration (13). The mylohyoid muscle activity, which is inhibited during the inspiratory phase in progressive asphyxia, declines steadily from its expiratory level as apnea progresses (3). Our findings indicate that the instantaneous frequency of some units in the mylohyoid muscle branch is decreased during the inspiratory phase. The mylohyoid muscle may be affected by reduction of upper airway patency due to the high level of $PaCO_2$ or the increase of airflow resistance due to application of a mask to the rat in the supine position. In the present study, the afferent discharge in the mylohyoid muscle branch was active during respiration, suggesting that the mylohyoid muscle is stretched because the muscle spindles are involved in mylohyoid muscle activity (7,16). Our findings support the proposition that the presence of hyoid muscle electrical activity does not necessarily indicate muscle shortening, as described previously (15). The afferent fibers of the mylohyoid muscle branch were activated by respiration, which elicited a response from the same units as did stretching of the mylohyoid muscle, indicating that the muscle spindles were stimulated by respiratory activities. It is reasonable to assume that there is an interrelationship between the mylohyoid and the sternohyoid muscles during respiration. We investigated the influence on the proprioceptors of the mylohyoid muscle of a single electrical shock to the central cut end of the mylohyoid muscle branch. However, electrical stimulation of the mylohyoid muscle branch may excite modalities of afferents other than proprioceptors. We previously found that HRP-labeled primary afferent neurons of the mylohyoid muscle branch are detected only in the trigeminal mesencephalic nucleus (5). This result indicates that the mylohyoid muscle branch contains afferent fibers innervating presumed muscle spindles.

The sternohyoid muscle, which is innervated by the C_1, C_2, and C_3 segments of the motoneurons (10), showed excitability in response to electrical stimulation of the mylohyoid muscle branch, and graded electrical stimulation of the mylohyoid muscle branch produced EMG reflex potentials in the sternohyoid muscle with amplitude which increased and central latency, which decreased with stimulation intensity. This finding indicates that there is a reflex arc between the afferent fibers from the mylohyoid and sternohyoid muscles, the pathway of which is the cervical nerve that conveys the mylohyoid muscle branch stimulation, and that there are functional connections between the trigeminal and the cervical nerves in the central nervous system of the rat.

REFERENCES

1. Andrew, B. L. The respiratory displacement of the larynx: A study of the innervation of accessory respiratory muscles. J. Physiol. 130:474–487; 1955.
2. Armstrong, B. W.; Smith, D. J. Function of certain neck muscles during the respiratory cycle. Am. J. Physiol. 182:599–600; 1955.
3. Davis, P. J.; Macefield, G.; Nail, B. S. Respiratory muscle activity during asphyxic apnoea and opisthotonus in the rabbit. Respir. Physiol. 65:285–294; 1986.
4. Ellenbogen, B. G.; Gerber, T. G.; Coon, R. L.; Toohill, R. J. Accessory muscle activity and respiration. Otolaryngol. Head Neck Surg. 89:370–375; 1981.
5. Furusawa, K.; Yasuda, K.; Yamaoka, M. Central projections of the afferent fibers innervating muscle spindles of the mylohyoid muscle in the rat. (in preparation).
6. Hollinshead, W. H., ed. Anatomy for surgeons, vol. 1. In: *The Head and Neck,* 2nd ed. Hagerstown: Harper & Row; 1968:413–417.
7. Lennartsson, B. Muscle spindles in the human anterior digastric muscle. Acta Odontol. Scand. 37:329–333; 1979.
8. Mathew, O. P.; Abu-Osba, Y. K.; Thach, B. T. Influence of upper airway pressure changes on genioglossus muscle respiratory activity. J. Appl. Physiol. 52:438–444; 1982.
9. Megirian, D.; Hinrichsen, C. F. L.; Sherrey, J. H. Respiratory roles of genioglossus, sternothyroid, and sternohyoid muscles during sleep. Exp. Neurol. 90:118–128; 1985.
10. Müntener, M.; Gottschall, J.; Neuhuber, W.; Mysicka, A.; Zenker, W. The ansa cervicalis and the infrahyoid muscles of the rat. I. Anatomy; distribution, number and diameter of fiber types; motor units. Anat. Embryol. 159:49–57; 1980.
11. Roberts, J. L.; Reed, W. R.; Thach, B. T. Pharyngeal airway-stabilizing function of sternohyoid and sternothyroid muscles in the rabbit. J. Appl. Physiol. 57:1790–1795; 1984.
12. Sherrey, J. H.; Pollard, M. J.; Megirian, D. Respiratory functions of the inferior pharyngeal constrictor and sternohyoid muscles during sleep. Exp. Neurol. 92:267–277; 1986.
13. St. John, W. M.; Bledsoe, T. A. Comparison of respiratory-related trigeminal, hypoglossal and phrenic activities. Respir. Physiol. 62:61–78; 1985.
14. Van de Graaff, W. B.; Gottfried, S. B.; Mitra, J.; van Lunteren, E.; Cherniack, N. S.; Strohl, K. P. Respiratory function of hyoid muscles and hyoid arch. J. Appl. Physiol. 57:197–204; 1984.
15. van Lunteren, E.; Haxhiu, M. A.; Cherniack, N. S. Mechanical function of hyoid muscles during spontaneous breathing in cats. J. Appl. Physiol. 62:582–590; 1987.
16. Yamaoka, M.; Furusawa, K.; Fujimoto, K.; Iguchi, K.; Kumai, T. Muscle spindles in the mylohyoid muscle of rats. Int. J. Oral Maxillofac. Surg. 21:309–312; 1992.