# Coordination of the Levator Veli Palatini and Intrinsic Laryngeal Muscles: An Evoked Electromyographic Study in the Dog

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**Fourteen dogs anesthetized with sodium pentobarbital were used as experimental animals in an electromyographic study of the functional relationships among the levator veli palatini and the intrinsic laryngeal muscles. The following results were obtained:**

**1. A single pulse stimulation to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve evoked ipsilateral reflexes from the levator veli palatini and laryngeal adductor muscles. The laryngeal abductor muscle, however, did not respond to this stimulation.**
**2. A repetitive pulse stimulation (3–5 Hz) to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve decreased the level of amplitude of the respiratory discharge from the laryngeal abductor muscle.**
**3. The reflex discharges in the levator veli palatini muscle were decreased when the respiratory discharges in the laryngeal abductor muscle were enhanced.**

**The present study indicates that there are relationships between the palatal and glottal movements and that the coordinate actions in these regions are influenced by two types of relationships among the palatal and laryngeal muscles. One is the relationship between the levator veli palatini and laryngeal adductor muscles, and the other is that between the levator veli palatini and laryngeal abductor muscle.**

Velar movement is one of the most important components of swallowing and phonation. In swallowing and vomiting, both the velopharynx and the glottis are closed. During normal inspiration, both the velopharynx and glottis are open. Iwashita (1965) and Fritzell et al (1976) studied the relationship between velar and glottal movements. However, questions remain unanswered.

This study was designed to investigate the functional relations among the levator veli palatini and the intrinsic laryngeal muscles, which are associated with velar and glottal movements, respectively. Electromyographic analysis of the levator and intrinsic laryngeal muscle activities in the dog was carried out in conjunction with electrical stimulation of the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve.

## MATERIALS AND METHODS

Fourteen adult dogs weighing 7.0 to 9.0 kg were used. Anesthesia was induced by intraperitoneal injection of 35 mg per kilogram body weight of sodium pentobarbital, and it was maintained by repeated intravenous injections of sodium pentobarbital.

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After tracheostomy in each animal, the respective left unilateral pharyngeal branches of the glossopharyngeal nerve, levator veli palatini muscle, intrinsic laryngeal muscles, and internal intercostal muscle were exposed without their sustaining any damage. This procedure is described next.

After mandibulectomy at the left molar portion, including disarticulation, the carotid artery and hypoglossal nerve were separated from the hypopharyngeal muscle so as to expose the pharyngeal branches of the glossopharyngeal nerve and dissect it free. Then the medial pterygoid muscle was rotated to the lateral side and the pterygopharyngeal muscle was excised, allowing exposure of the levator veli palatini muscle.

Among the intrinsic laryngeal muscles, the following muscles were studied, the cricothyroid muscle, the thyroarytenoid, lateral cricoarytenoid, interarytenoid (the laryngeal adductors), and the posterior cricoarytenoid muscle (the only laryngeal abductor).

The sternothyroid muscle was cut at its attachment to the thyroid cartilage and retracted down so as to expose the cricothyroid muscle. After experimental analysis of the cricothyroid muscle, an incision was made in the thyroid cartilage about 3 mm to the left of the midline, and the left part was resected with the left cricothyroid muscle. With this operation, the thyroarytenoid, lateral cricoarytenoid, interarytenoid and posterior cricoarytenoid muscles were exposed. A skin incision between the fifth and sixth rib was made. One part of the rectus abdominus was cut, and the internal intercostal muscle was exposed.

Bipolar platinum electrodes (polar distance, 1 mm; diameter 200 $\mu$m) were placed on the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve, and the surrounding tissues were covered with paraffin cotton to prevent spread of electrical current.

In one series of experiments, a single pulse stimulation (square wave stimulus of 0.1 msec duration) was applied to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve using a stimulator (Electronic stimulator SEN-3101, Nihon Koden Kogyo Co., Japan), and the activities in the levator and intrinsic laryngeal muscles were recorded by means of two platinumiridium needles, 50 $\mu$m in diameter and insulated with isonel except at the tip. Responses were amplified (Biophysial Amplifier AVB-9 Nihon Koden Kogyo Co., Japan) and displayed on an oscilloscope (Universal Dual-Beam Oscilloscope VC-9 Nihon Koden Kogyo Co., Japan), and selected responses were photographed (RLG-6101, Nihon Koden Kogyo Co., Japan).

In a second series of experiments, analysis was carried out on the effects of repetitive pulse stimulation of the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve on the respiratory activities in the intrinsic laryngeal muscles. The stimuli with a frequency of 3 to 5 per second and of 5 V amplitude, were applied to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve, and the activities of the levator veli palatini and intrinsic laryngeal muscles were recorded. In order to compare these activities with the respiratory phase, recording electrodes were also placed at the internal intercostal muscle. The activities of the levator veli palatini, the intrinsic laryngeal muscles and the internal intercostal muscle were amplified (Bioelectric Amplifier AB-621G Nihon Koden Kogyo Co., Japan) and displayed (Photocorder Type 2932 Yokokawa Electric Works Ltd., Japan) (Fig. 1).

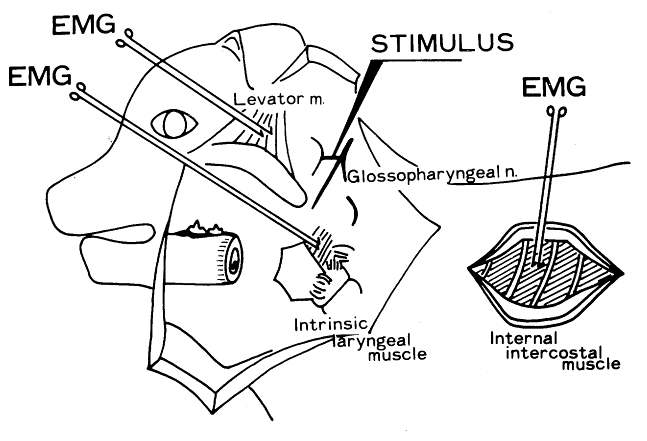


**FIGURE 1 Schema of the experiment. The stimulus was applied to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve. The activities in the levator veli palatini, intrinsic laryngeal, and internal intercostal muscles were recorded.**

## RESULTS

### Responses of the Levator Veli Palatini and Intrinsic Laryngeal Muscles Elicited by a Single Pulse Stimulation of the Afferent Fibers of the Pharyngeal Branches of the Glossopharyngeal Nerve

The experiments comprised studies of reflex responses obtained from the levator veli palatini and the various intrinsic laryngeal muscles after ipsilateral stimulation of the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve.

A single pulse stimulation applied to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve evoked reflex responses in the levator veli palatini, cricothyroid, thyroarytenoid, lateral cricoarytenoid, and interarytenoid muscles (Fig. 2). The latency of those responses ranged from 10 to 15 msec in the levator veli palatini and cricothyroid muscles, from 15 to 20 msec in the thyroarytenoid muscle, and from 20 to 25 msec in the lateral cricoarytenoid and interarytenoid muscles. The latencies observed in the latter two were longer than those observed in the other muscles. The size of the amplitude of evoked reflex responses obtained by the maximum stimulus strength was from 50 to 1,200 $\mu$v in the levator veli palatini muscle, from 200 to 1,500 $\mu$v in the cricothyroid muscle, from 200 to 5,000 $\mu$v in the thyroarytenoid muscle, and from 50 to 120 $\mu$v in the lateral cricoarytenoid and interarytenoid muscles. In the lateral cricoarytenoid and interarytenoid muscles, the reflex responses were smaller in size than those in the other muscles in each animal. No reflex responses were obtained in the ipsilateral posterior cricoarytenoid muscle regardless of stimulus strength (Fig. 2).

### Effects of the Repetitive Pulse Stimulation of the Afferent Fibers of the Pharyngeal Branches of the Glossopharyngeal Nerve on the Respiratory Activities in the Intrinsic Laryngeal Muscles

The respiratory discharges of the levator veli palatini and intrinsic laryngeal muscles at rest were investigated. In the cricothyroid muscle, respiratory discharges were observed during inspiration and expiration (Fig. 3). In the lateral cricoarytenoid and interarytenoid muscles, the respiratory discharges were observed only in the expiratory phase. In the posterior cricoarytenoid muscle, the respiratory discharges increased cyclically with inspiration (Fig. 4). No respiratory discharges were evident in the levator veli palatini or thyroarytenoid muscles.

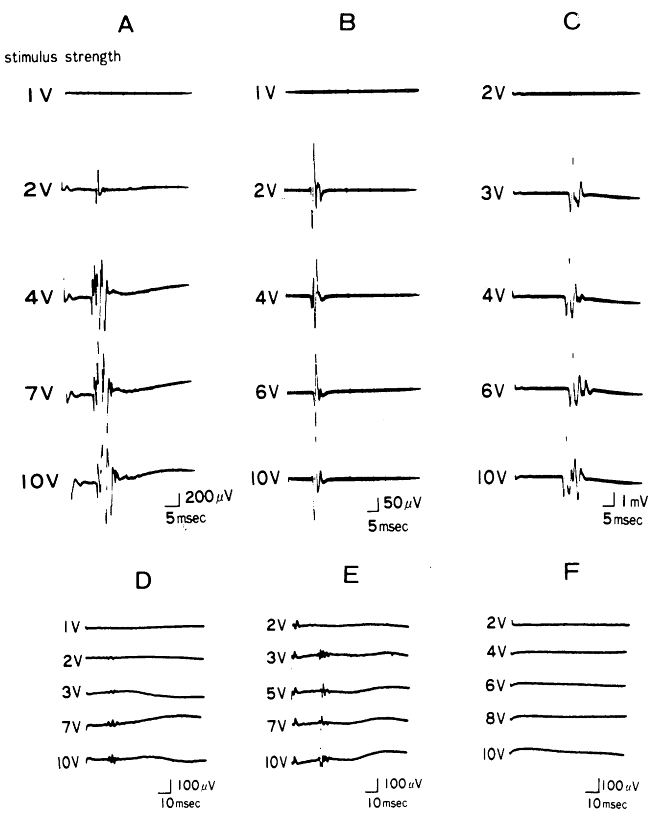


**FIGURE 2** Effects of single pulse stimulation of afferent fibers of pharyngeal branches of glossopharyngeal nerve. Ipsilateral reflex responses in the levator veli palatini and laryngeal adductors were obtained. No reflex response was obtained in the posterior cricoarytenoid muscle (the laryngeal abductor). *A*, levator veli palatini muscle; *B*, cricothyroid muscle; *C*, thyroarytenoid muscle; *D*, lateral cricoarytenoid muscle; *E*, interarytenoid muscle; *F*, posterior cricoarytenoid muscle.

When the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve were repetitively stimulated at stimulus frequencies of 3 to 5 per second, each stimulus evoked a reflex response in the levator veli palatini and thyroarytenoid muscles. In the cricothyroid muscle, both reflex discharges and respiratory discharges were observed (Fig. 3). In the lateral cricoarytenoid and interarytenoid muscles, reflex responses were elicited with single pulse stimulation, but not with repetitive pulse stimulation. Markedly enhanced respiratory discharges were observed (Fig. 4). In contrast, in the posterior cricoarytenoid muscle, the respiratory discharges were decreased with repetitive pulse stimulation (Fig. 4).

Figure 5 shows the respiratory discharges recorded in the internal intercostal muscle. No effect was noted on the amplitude of the respiratory discharges in the internal intercostal muscle with repetitive pulse stimulation.

Figure 6 shows the relation between the reflex responses in the levator veli palatini muscle and respiratory discharges in the posterior cricoarytenoid muscle during prolonged repetitive pulse stimulation. A decrease in the reflex discharges in the levator veli palatini muscle was observed to be coincidental with an increase in the respiratory discharges in the posterior cricoarytenoid muscle.

## Discussion

These results indicate that muscles in the soft palate and larynx can be classified functionally into two types, one in which activities are enhanced by stimulation of afferent fibers of the pharyngeal branches of the glossopharyngeal nerve and the other in which activities are inhibited by such stimulation. The levator veli palatini, cricothyroid, thyroarytenoid, lateral cricoarytenoid, and interarytenoid muscles are enhanced by stimulation, whereas the posterior cricoarytenoid muscle is inhibited.

Single pulse stimulation elicited reflex responses in the levator veli palatini, cricothyroid, thyroarytenoid, lateral cricoarytenoid and interarytenoid muscles. The latencies of these responses ranged from 10 to 15 msec in the levator veli palatini and cricothyroid muscles, from 15 to 20 msec in the thyroarytenoid muscle, and from 20 to 25 msec in the lateral cricoarytenoid and interarytenoid muscles. These latencies show that the reflexes were multisynaptic. The latency in the cricothyroid muscle was the shortest among the intrinsic laryngeal muscles. This muscle is innervated by the external branch of the superior laryngeal nerve, and the other intrinsic laryngeal muscles are innervated by the much longer recurrent nerve. Measurement in this study of the lengths of these nerves from the

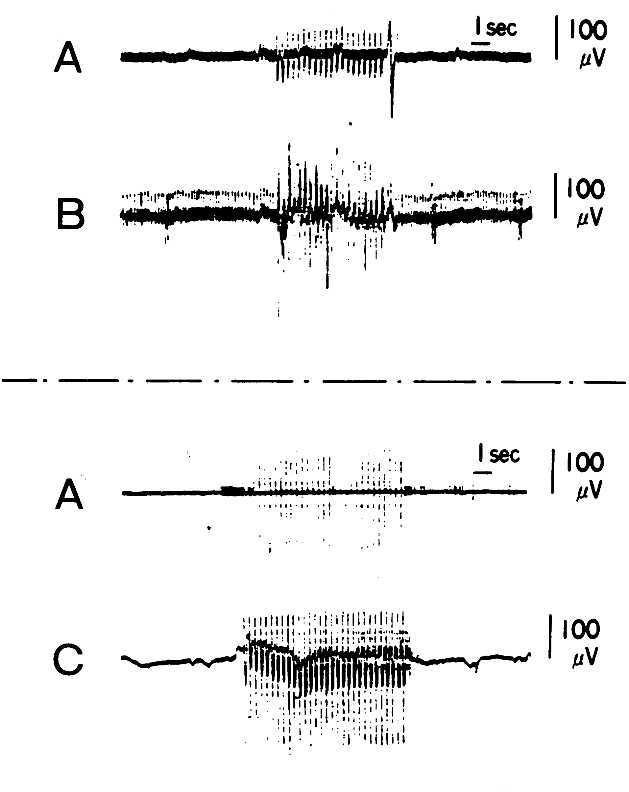


**FIGURE 3 Effects of repetitive pulse stimulation of afferent fibers of pharyngeal branches of glossopharyngeal nerve on activities in levator veli palatini, cricothyroid, and thyroarytenoid muscles. Each stimulus elicited reflex responses in each of the three muscles. *A*, levator veli palatini muscle; *B*, cricothyroid muscle; *C*, thyroarytenoid muscle.**

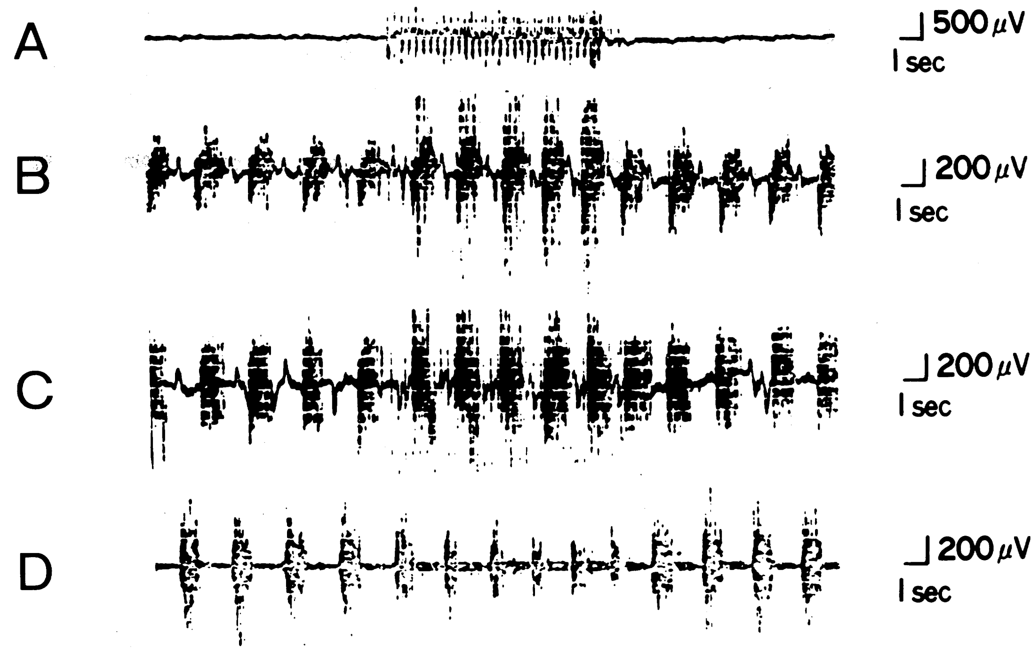


**FIGURE 4** Effects of repetitive pulse stimulation of afferent fibers of the pharyngeal branches of the glossopharyngeal nerve on respiratory activities in intrinsic laryngeal muscles. Comparison with the non-stimulus phase revealed that the repetitive pulse stimulation enhanced the lateral cricoarytenoid and interarytenoid activities three times and one-and-a-half times, respectively, but reduced posterior cricoarytenoid activities by one half. *A*, levator veli palatini muscle; *B*, lateral cricoarytenoid muscle; *C*, interarytenoid muscle; *D*, posterior cricoarytenoid muscle.

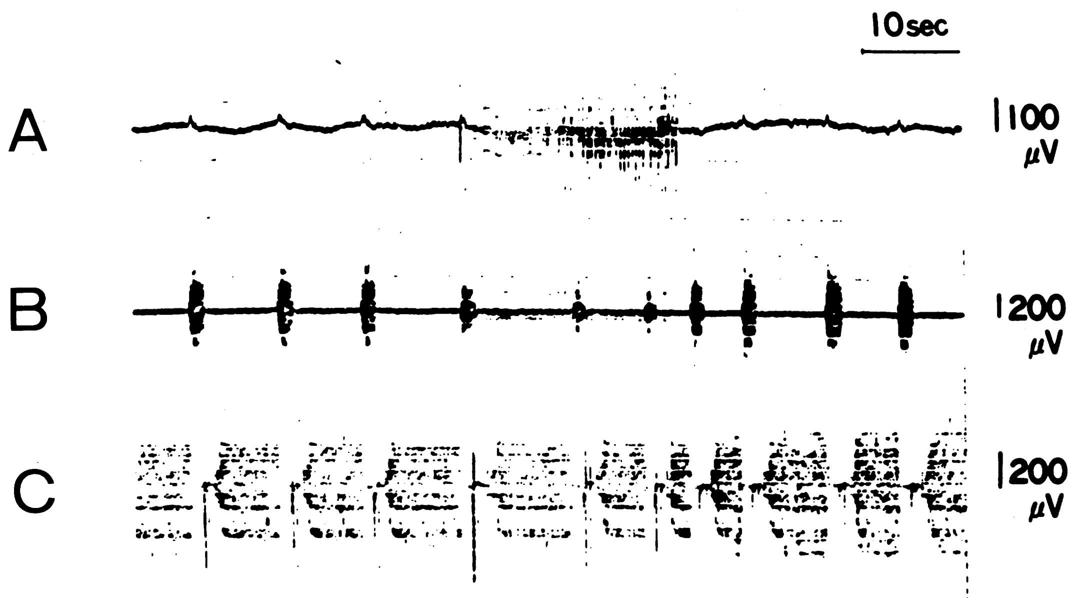


**FIGURE 5** Effects of repetitive pulse stimulation of afferent fibers of the pharyngeal branches of the glossopharyngeal nerve on respiratory activities in posterior cricoarytenoid and internal intercostal muscles. The respiratory discharges in the posterior cricoarytenoid muscle were decreased, but no influence in the amplitude of the activities of the internal intercostal muscle was observed. *A*, levator veli palatini muscle; *B*, posterior cricoarytenoid muscle; *C*, internal intercostal muscle.

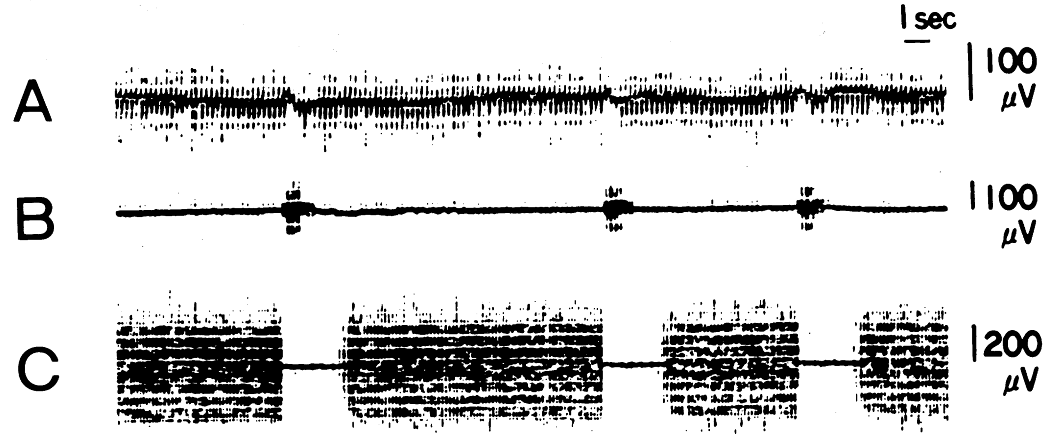


**FIGURE 6 Activities in levator, posterior cricoarytenoid and internal intercostal muscles during prolonged repetitive pulse stimulation. The levator activities were reduced when the posterior cricoarytenoid activities were enhanced. *A*, levator veli palatini muscle; *B*, posterior cricoarytenoid muscle; *C*, internal intercostal muscle.**

jugular foramen to each muscle showed that the external branch of the left superior laryngeal nerve is 30 cm shorter than the left recurrent nerve. Nevertheless, in spite of the same recurrent nerve innervation, the latencies in the lateral cricoarytenoid and interarytenoid muscles were clearly longer than the latency in the thyroarytenoid muscle. The reflex responses in the lateral cricoarytenoid and interarytenoid muscles were of lower amplitude and showed higher levels of stimulus threshold than those in the thyroarytenoid muscle. These results support the hypothesis that there are more synapses in the reflex arc of the lateral cricoarytenoid and interarytenoid muscles than in the thyroarytenoid muscle.

The intrinsic laryngeal muscles show a rhythmical movement synchronized with respiration, aside from that of glottal closure for protection (Green and Neil, 1955; Pressman and Kelemen, 1955; Proctor, 1964). In this study, respiratory discharges in the cricothyroid muscle during expiratory and inspiratory phases, in the lateral cricoarytenoid and interarytenoid muscles only during the expiratory phase, and in the posterior cricoarytenoid muscle only during the inspiratory phase were also present during the expiratory phase in the internal intercostal muscle. Doty and Bosma, (1956) reported observing the respiratory activities in the cricothyroid and thyroarytenoid muscles, but in this study, respiratory activity of the thyroarytenoid muscle was not evident.

Continuous activity of the levator veli palatini muscle is necessary to compare the activities of the levator and intrinsic laryngeal muscles. Accordingly, stimuli with a low frequency of 3 to 5 Hz were applied to the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve during a certain period of time (more than 5 sec), and the activities in the levator veli palatini muscle continued during that period. Thus, a comparison of the activities in the levator veli palatini and intrinsic laryngeal muscles was carried out. A frequency greater than 10 Hz was inappropriate for this experiment, since such a frequency immediately attenuated the reflex activities in the levator muscle.

When the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve were repetitively stimulated (3 to 5 Hz), each stimulus evoked a reflex response in the levator veli palatini, cricothyroid, and thyroarytenoid muscles. In the lateral cricoarytenoid and interarytenoid muscles, no reflex response was elicited by repetitive pulse stimulation, although single pulse stimulation did evoke a response. It seems justifiable to presume that, in the lateral cricoarytenoid and interarytenoid muscles, because the reflex connections are more complicated than those in the other muscles, as mentioned above, the repetitive pulse stimulation caused a complete "frequency-dependent attenuation" (Suzuki and Sasaki, 1977) of the reflex. The repetitive pulse stimulation enhancement of the respiratory discharges in the lateral cricoarytenoid and interarytenoid muscles may possibly result from the residual excitatory postsynaptic potential (EPSP) under the level of threshold. It is considered that the residual EPSP, which was attenuated by the repetitive pulse stimulation (Curtis and Eccles, 1960), facilitated the respiratory discharges in those muscles.

The inhibitory effect was observed only in the posterior cricoarytenoid muscle. Repetitive pulse stimulation decreased the respiratory discharges in the posterior cricoarytenoid muscle, but did not decrease respiratory discharges in the internal intercostal muscles. This may indicate that the repetitive pulse stimulation of the afferent fibers of the pharyngeal branches of the glossopharyngeal nerve inhibited not respiration but the activities in the posterior cricoarytenoid muscle. These movements are different from those seen in deglutition, because the respiratory activities in each muscle would become silent in deglutition (Doty and Bosma, 1956).

Figure 6 shows the interaction between the levator and posterior cricoarytenoid activities, that is, the reflex activities in the levator veli palatini muscle are inhibited when the activities in the posterior cricoarytenoid muscle are enhanced.

In anatomical and functional studies of the larynx, it has been clarified that the cricothyroid, thyroarytenoid, lateral cricoarytenoid and interarytenoid muscles are laryngeal adductors and that only the posterior cricoarytenoid muscle is a laryngeal abductor (Miller, 1979; Martensson, 1963; Martensson and Skoglund, 1964; Proctor, 1964). With regard to these functional features, the results of the present study indicate that the increase in activity in laryngeal adductors and decrease in activity in the laryngeal abductor are coincident with activity enhancement in the levator veli palatini muscle and that a decrease in the levator activity is coincident with the enhancement of activity in the laryngeal abductor.

Consequently, it is suggested that velar-laryngeal coordination comprises two aspects. One is the coordination between the levator veli palatini muscle and the laryngeal adductors, and the other is that between the levator veli palatini muscle and the laryngeal abductor.

In the present study, it has been clarified that there are relationships between the soft palate and the larynx with respect to reflex control synchronized by input from the glossopharyngeal nerve. This laryngeal and palatal regulation may be needed in such reflex mechanisms as swallowing and vomiting. In speech articulation, an important role would be played by this velar-laryngeal coordination under the influence of the sensations from oral and pharyngeal areas. An understanding of these physiological mechanisms of the articulatory organs is considered very important in providing treatment to patients with cleft palate and other speech disorders.

## References


CURTIS DR, ECCLES JC. Synaptic action during and after repetitive stimulation. J Physiol 1960; 150:374.

DOTY RW, BOSMA JF. An electromyographic analysis of reflex deglutition. J Neurophysiol 1956; 19:44.

FRITZELL B, KOTBY MN. Observation on thyroarytenoid and palatal levator activation for speech. Folia Phoniat 1976; 28:1.

GREEN JH, NEIL E. Respiratory function of the laryngeal muscles. J Physiol 1955; 129:131.

IWASHITA A. Electromyographic study on the articulation mechanism of Japanese speech sounds (Japanese text). Pract Otol Kyoto 1965; 58:712.

MARTENSSON A. Reflex responses and recurrent discharges evoked by stimulation of laryngeal nerves. Acta Physiol Scand 1963; 57:248.

MARTENSSON A, SKOGLUND CR. Contraction properties of intrinsic laryngeal muscles. Acta Physiol Scand 1964; 60:318.

MILLER ME. Muscles. In: Evans HE, Christensen GC, eds. Anatomy of the dog. Philadelphia: WB Saunders, 1979.

PRESSMAN JJ, KELEMEN G. Physiology of the larynx. Physiol Rev 1955; 35:506.

PROCTOR DF. Physiology of the upper airway. In: Fenn WO, Rahn H, eds. Respiration. 1 In: Handbook of physiology. Washington, D.C.: American Physiological Society, 1964.

SUZUKI M, SASAKI CT. Effect of various sensory stimuli on reflex laryngeal adduction. Ann Otol 1977; 86:30.