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Abstracts

Functional electrical stimulation (FES) has been debated as an innovative treatment in the management of patients with laryngeal paralysis. In this study, we examined whether FES to the paralyzed laryngeal adductor muscles improve the voice sounds impaired by unilateral laryngeal paralysis. We confirmed that the FES to the paralyzed thyroarytenoid muscle (TA) induced the adduction of vocal fold in decerebrate cats. Electrical stimulation delivered to periaqueductal grey induced vocalization in the cats with unilateral laryngeal paralysis. We estimated the changes in duration of voice sounds, subglottic pressure and quality of voice during vocalization with or without FES to the paralyzed TA muscle. The duration of voice sounds prolonged by delivering the FES to paralyzed laryngeal adductor TA muscle. The subglottic pressure increased during vocalization with FES. The intensity of voice sounds increased and the quality of voice sounds improved by the FES. These results suggested that the FES to paralyzed adductor TA muscle could be expected to improve the quality of voice sounds in the animals with unilateral laryngeal paralysis. This study indicates the possibility that FES to the paralyzed laryngeal adductor muscles is accepted as a new therapy for patients of unilateral laryngeal paralysis.

Key words: functional electrical stimulation, unilateral laryngeal paralysis, laryngeal adductor muscle, vocalization, cat.

1.Background

Functional electrical stimulation (FES) has been proposed as a potential therapy for restoring function of a denervated muscle system. In the field of otolaryngology, FES has been debated as an innovative treatment in the management of patients with laryngeal paralysis. Numerous studies in acute and chronic animal models have demonstrated that FES restores mobility of the paralyzed laryngeal muscles [1-5]. In recent study, FES to the paralyzed posterior cricoarytenoid muscles of human larynx have induced vocal fold abduction and restored ventilation through the glottis in case of bilateral laryngeal paralysis [6]. On the other hand, laryngeal paralysis disturbs not only opening the glottis but also closing the glottis. We have intended to establish the new therapy for impaired voice caused by unilateral recurrent laryngeal nerve paralysis.

In this study, we examined whether FES to the paralyzed laryngeal adductor muscles improve the voice sounds impaired by unilateral laryngeal paralysis.

2. Methods

Data of this study were obtained from 2 adult cats. About 1 month before the experiment, the left recurrent laryngeal nerve of the cat was resected. Just before the experiments, we confirmed that their voice sounds were getting weaker and more breathy during spontaneous vocalization. The cats were anesthetized with halothane/ nitrous oxide by way of nasal intubation. Both carotid arteries were ligated and surgical decerebration was performed at the level of precollicular-postmammillary level. After the surgical procedure including decerebration, the anesthesia was discontinued. Electrical stimulation (20-50 μA, 0.2 msec, 50 Hz) delivered to periaqueductal grey (PAG) induced

vocalization in unanesthetized cats. To adduct the paralyzed left vocal fold, we implanted a pair of thin (50 μm) stainless wire electrodes into the paralyzed (left) thyroarytenoid muscle (TA). We confirmed directly using a rigid laryngoscope that the FES (2-5 mA, 0.2 msec, 30 Hz) to the paralyzed TA induced the adduction of vocal fold. Electromyograms (EMGs) were recorded using a pair of thin stainless wire electrodes implanted into each muscle. EMGs were recorded from the intact (right) TA, diaphragm (DIA) and external oblique abdominal muscle (EA). Change in subglottic pressure during vocalization was also recorded using a micro-tip catheter pressure transducer placed in the trachea. To evaluate quality of voice, voice sounds were recorded using digital audio tape recorder. After the experiment, voice sounds were analyzed using computer software for sound analysis (Sound Scope).

3. Results

Repetitive electrical stimulation delivered to the PAG was able to induce vocalization in the animal with unilateral recurrent nerve palsy. During the PAG stimulation period, inspiration and vocalization were induced alternately with reciprocal activation of DIA and TA. Increase of the subglottic pressure and production of voice sounds were observed during vocalization (Figure-1A). Besides the PAG stimulation, FES was delivered to paralyzed TA of the same animal simultaneously (Figure-1B).

Average of the duration of TA activity during vocalization without FES was 2.50 $\pm$ 0.16 sec (n=10), and that with FES was 5.1 $\pm$ 1.00 sec (n=10). Namely, duration of TA activation significantly prolonged during vocalization with FES (p=0.008). However,

duration of DIA activation did not change whether the FES was delivered or not. These results indicated that vocal fold adduction induced by the FES prolonged voice duration time without increasing the activity of inspiratory muscle.

Average of the peak positive subglottic pressure during vocalization without FES was 12.6 ± 1.14 cmH2O (n=10), and that with FES was 18.0 ± 2.84 cmH2O (n=10). Namely, the peak positive subglottic pressure significantly increased during vocalization with FES (p=0.008). These results indicated that vocal fold adduction induced by the FES was able to increase subglottic pressure effectively so as to improve the voice sounds.

The amplitude of recorded voice sound also increased during vocalization with the FES. The breathy voice sound by recurrent laryngeal palsy was improved perceptually by FES. And the quality of voice sounds evaluated by the sonagram was also improved during vocalization with FES. These results suggested that the FES to paralyzed adductor TA muscle could be expected to improve not only the EMG activities of vocalization but also the quality of voice sounds in the animals with unilateral laryngeal paralysis.

4. Summary and Conclusions

It is well known that unilateral laryngeal paralysis induces hoarseness or aspiration risk. Conventional treatment for unilateral laryngeal paralysis is intracordal injection or thyroplasty. In this study, we examined whether FES to the paralyzed laryngeal adductor muscles improve the voice sounds impaired by unilateral laryngeal paralysis. By delivering the FES to paralyzed laryngeal adductor TA muscle; 1) the duration of voice sounds prolonged, 2) the positive subglottic pressure during vocalization

increased, 3) the intensity of voice sounds increased and the quality of voice sounds improved. Our results indicate the possibility that FES to the paralyzed laryngeal adductor muscles is accepted as a new therapy for unilateral laryngeal paralysis of human larynx.

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Figure legends

Figure 1.

Most representative changes in muscle activities, subglottic pressure and voice sounds during vocalization with functional electrical stimulation (FES) to paralyzed laryngeal adductor muscle. A: Induced vocalization without the FES. The stimulus period of periaqueductal gray (PAG) is indicated by the solid line at the bottom of the figure. B: Induced vocalization with the FES. The period of FES is indicated by the solid line at the top of the figure. TA (right), right side (intact side) of the thyroarytenoid muscle; DIA, diaphragm; EA, the external oblique abdominal muscle; SP, subglottic pressure.

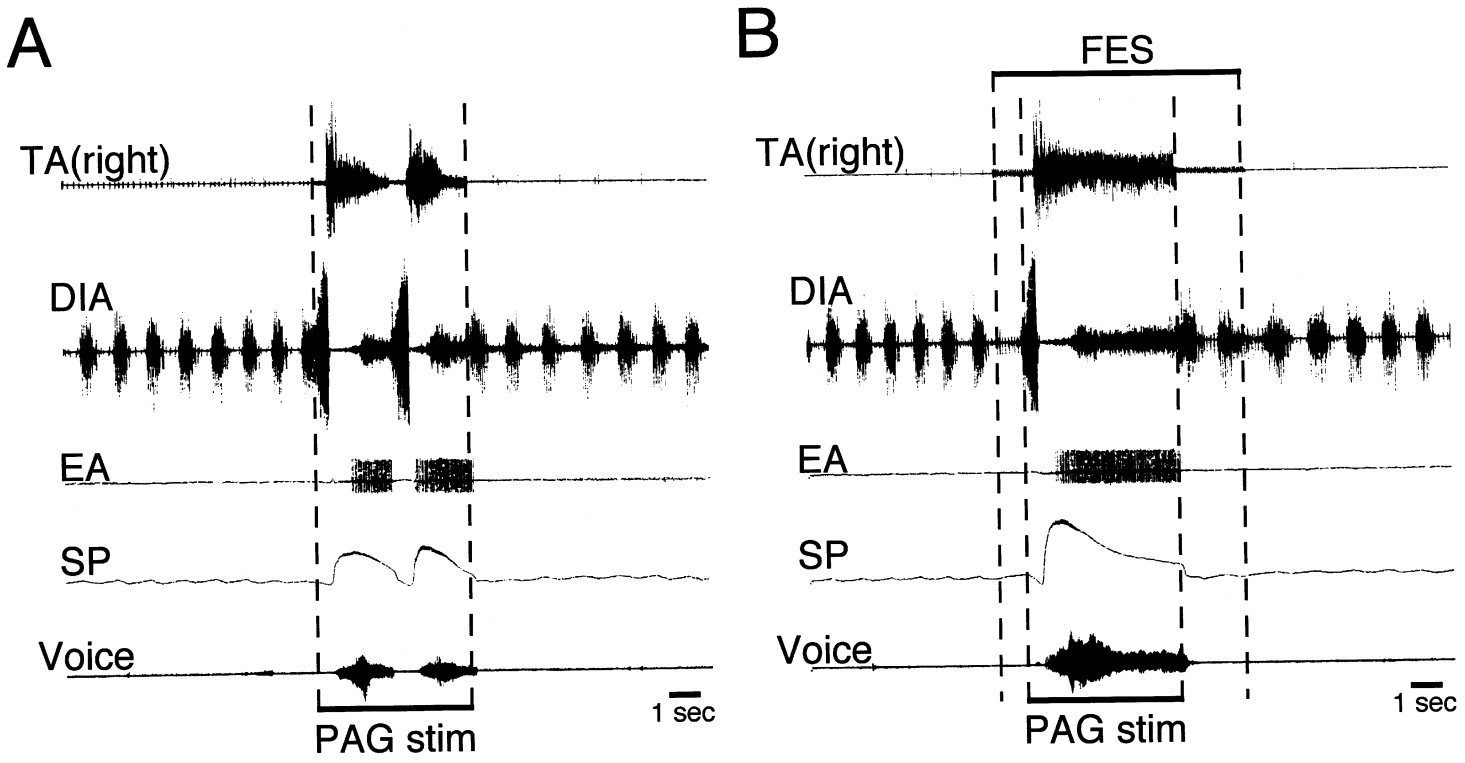

Figure 1

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