

*Original Article***Feasibility of repetitive peripheral magnetic stimulation for dysphagia with reduced hyoid elevation: a report of two cases**

Shino Mori, MD, DMSc,<sup>1</sup> Hitoshi Kagaya, MD, DMSc,<sup>1</sup> Yuki Nagashima, DDS,<sup>1</sup>  
Fumi Toda, MD, DMSc,<sup>1</sup> Ayako Kuwabara, SLHT, MSc,<sup>2</sup> Yoko Masuda, SLHT,<sup>2</sup>  
Yuriko Sato, SLHT, MSc,<sup>2</sup> Mao Ogawa, MD,<sup>1</sup> Tetsuya Tsunoda, MD, DMSc,<sup>1</sup>  
Ryoko Akahori, MD, DMSc,<sup>1</sup> Seiko Shibata, MD, DMSc,<sup>1</sup> Eiichi Saitoh, MD, DMSc<sup>1</sup>

<sup>1</sup>Department of Rehabilitation Medicine I, School of Medicine, Fujita Health University

<sup>2</sup>Department of Rehabilitation, Fujita Health University Hospital

**ABSTRACT**

Mori S, Kagaya H, Nagashima Y, Toda F, Kuwabara A, Masuda Y, Sato Y, Ogawa M, Tsunoda T, Akahori R, Shibata S, Saitoh E. Feasibility of repetitive peripheral magnetic stimulation for dysphagia with reduced hyoid elevation: a report of two cases. *Jpn J Compr Rehabil Sci* 2019; 10: 42–46.

**Objective:** This study aimed to investigate the feasibility of peripheral magnetic stimulation for dysphagia with reduced hyoid elevation.

**Methods:** Two patients with dysphagia with reduced hyoid elevation received two to three sets of magnetic stimulation, each comprising thirty treatments lasting 2 s. This repetitive peripheral magnetic stimulation (rPMS) was performed for at least five days per week for a period of six weeks.

**Results:** Both patients underwent rPMS for six weeks without any complications. After rPMS, the 82-year-old male patient with disuse syndrome after aspiration pneumonia (Case 1) showed improved muscle strength and hyoid elevation distance. The 47-year-old male patient with dermatomyositis (Case 2) demonstrated improved muscle strength and fatigue after rPMS; in addition, his neck stiffness was alleviated, which led to the alleviation of fatigue during meals.

**Conclusion:** Our results suggest that rPMS is a feasible and novel option for the treatment of reduced hyoid elevation.

**Key words:** dysphagia, reduced hyoid elevation, suprahyoid muscles, repetitive peripheral magnetic stimulation

**Introduction**

The effectiveness of neuromuscular electrical stimulation for managing dysphagia has been demonstrated through meta-analyses [1, 2]. In cases with reduced hyoid elevation, electrical stimulation is frequently performed on the suprahyoid muscles to achieve hyoid elevation. However, the use of surface electrodes often simultaneously stimulates the inferior alveolar nerve, which can cause pain [3]. In addition, men receiving electrical stimulation must shave daily to enable electrodes to be attached to their skin, which increases the burden of this procedure. By contrast, a key advantage of magnetic stimulation is that it does not stimulate the nociceptors in the skin because it induces eddy currents within the body through electromagnetic induction, resulting in less pain than that caused by electrical stimulation [4, 5]. Moreover, as magnetic stimulation coils do not necessarily need to be in contact with the skin, patients can be wearing clothes during the procedure. However, these coils are large, making it difficult to apply them to small sites. We developed and used small hyoid elevation magnetic stimulation coils to apply peripheral magnetic stimulation targeting the suprahyoid muscles, which are located anterior to the hyoid; this resulted in significantly greater hyoid elevation compared with electrical stimulation using surface electrodes [3]. Therefore, it appears that PMS for patients with dysphagia is an alternative to electrical stimulation therapy. The objective of the present study was to determine the feasibility of repetitive peripheral magnetic stimulation (rPMS) by administering it to two patients with dysphagia with reduced hyoid elevation.

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Correspondence: Shino Mori, MD, DMSc  
Department of Rehabilitation Medicine I, School of  
Medicine, Fujita Health University  
1–98 Dengakugakubo, Kutsukake, Toyoake, Aichi 470–  
1192, Japan.

E-mail: shino@fujita-hu.ac.jp

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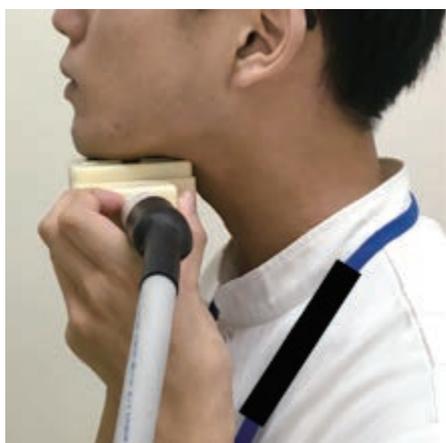
Dr. Kagaya is one of the inventors of the patent-pending new coil for the suprahyoid muscles. The remaining authors have no conflicts of interest in this study.

## Methods

This study was conducted after receiving the approval of the Institutional Review Board at Fujita Health University. Criteria for inclusion in the study were patients with dysphagia with reduced hyoid elevation who were indicated for rPMS of the suprahyoid muscles. Exclusion criteria included the following: patients with a history of epilepsy, with pacemakers, with permanent magnetic materials embedded in the vicinity of the stimulation sites (e.g., cochlear implants), or who were pregnant. In addition to conventional dysphagia rehabilitation, two eligible patients underwent rPMS of the suprahyoid muscles using the Pathleader™ (IFG Corporation, Sendai, Japan) device and specialized magnetic stimulation coils. Among the suprahyoid muscles, the anterior belly of the digastric muscle, and the mylohyoid and geniohyoid muscles are located on either side of the centerline of the mental protuberance of the mandible; therefore, magnetic stimulation coils were held directly above the submental suprahyoid muscles. Stimulation was applied thirty times for 2 s each, which constituted one set; two to three such sets were applied daily for at least five days per week for a period of six weeks (Figure 1). The time required to apply rPMS was brief, requiring approximately 3 min to prepare the device and approximately 2 min to complete one set. The stimulation intensity was set to a level at which suprahyoid movement could be sufficiently observed using X-ray fluoroscopy without causing pain.

### Case 1

Case 1 included an 82-year-old male with disuse syndrome after aspiration pneumonia. The patient had a history of right internal capsule stroke, which occurred two years prior to the study; prostate cancer;



**Figure 1.** A specially designed coil to stimulate the suprahyoid muscles. The coil was placed on the submental area to stimulate the suprahyoid muscles.

and sleep apnea syndrome as comorbidities. He had left hemiplegia and dysphagia as post-stroke sequelae. With regard to the activities of daily living (ADLs) before admission, he could move using a cane and orthosis under supervision and was able to chew and swallow rice porridge and independently ingest nectar-thick fluids with 1% water while in a seated position. The dysphagia severity scale (DSS) [6] score was 3 (water aspiration).

The patient was hospitalized after establishing a diagnosis of aspiration pneumonia. A videofluoroscopic examination of swallowing (VF) performed on day 11 of his hospital stay, after his general condition had stabilized, indicated reduced hyoid elevation, upper esophageal sphincter opening dysfunction, and a large amount of pharyngeal residue. In addition, the patient presented with tongue movement, bolus formation, laryngeal closure, and pharyngeal contraction dysfunctions; and decreased expiratory force. The patient had a DSS score of 3 and was able to ingest rice porridge (granular) and honey-thick fluids with 2% water when reclining at a 60° angle. To manage the dysphagia, the patient underwent a range of motion exercises for the lips, tongue, cheeks, and neck; tongue-pressure resistance exercises; tongue holding exercises; supraglottic swallowing; respiratory muscle training; and the Shaker exercise [7]. However, the patient was unable to perform the standard Shaker exercise as he easily experienced fatigue and instead performed repeated head raising exercises at a rate of five per set (total five sets per day). After providing written informed consent, the patient started rPMS therapy on day 23 of his hospital stay. At this point, he was clear and lucid with good cognitive function but had decreased muscle strength owing to disuse and reduced stamina. He was mobile, albeit with the use of a wheelchair, and required the maximum level of assistance.

Fluoroscopy was used to measure hyoid movement. We designated the line from the upper anterior corner of the third cervical vertebral body to the lower anterior corner of the fifth cervical vertebral body as the y-axis and the line perpendicularly crossing the y-axis as the x-axis. These axes were used to assess the distances of anterior hyoid movement and hyoid elevation as a result of magnetic stimulation using the ImageJ analysis software (National Institutes of Health, Bethesda, MD, USA). We measured the maximum anterior movement distance and the elevation distance of the hyoid when the patient swallowed 4 mL of 1% nectar-thick fluid before and after the rPMS treatment. Neck flexion muscle strength in the seated and supine positions was measured using the  $\mu$ Tas F-1™ hand-held dynamometer (Anima Corporation, Tokyo, Japan). Jaw-opening muscle strength was measured in the seated position with maximally opened mouth using the KT2014™ force measurement device (Livet Inc., Tokyo, Japan) [8]. All

muscle strength measurements were performed three times each, and the maximum value was used for assessment.

### Case 2

Case 2 included a 47-year-old male with dermatomyositis and no noteworthy medical history or comorbidities. Before admission, the patient could independently perform all ADL and did not have dysphagia.

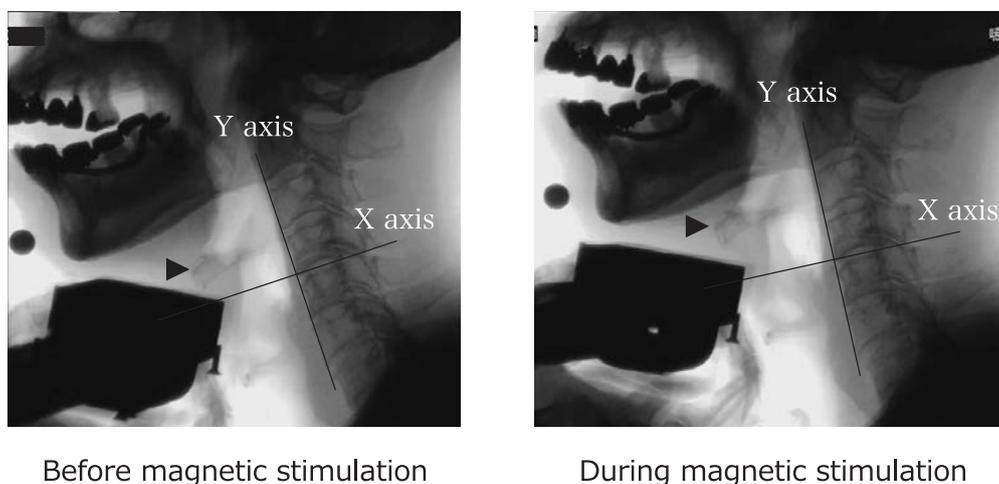
Approximately one month prior to hospital admission, the patient began primarily experiencing proximal muscle weakness and pain; dysphagia onset occurred approximately one week prior to hospital admission. He was diagnosed with dermatomyositis and admitted to another medical department, where steroid pulse therapy was initiated. Immediately thereafter, he underwent VF examination and was found to have a DSS score of 2 (food aspiration); he was diagnosed with marked pharyngeal contraction and hyoid elevation disorder, and upon swallowing 4 mL+ of 1% nectar-thick fluid, a large amount of pharyngeal residue was observed. A blood test conducted four months after admission indicated no disease activity, and a VF examination performed on day 110 of his hospital stay indicated a DSS score of 6 (minimum problems). However, muscle weakness persisted, and the patient continued to present large amounts of pharyngeal residue as a result of remnant reduced hyoid elevation. Therefore, he needed to swallow several times per mouthful, resulting in extreme fatigue during meals. The patient had good cognitive function and provided written informed consent to start rPMS. At the start of the stimulation, his swallowing function was limited by reduced hyoid and larynx elevation as well as upper esophageal sphincter opening, laryngeal closing, and pharyngeal contraction dysfunctions. He underwent a range of motion exercises for the lips, tongue, cheeks, and neck; tongue-pressure resistance exercises; tongue

holding exercises; supraglottic swallowing, and the Shaker exercise [7]. However, he was unable to perform the standard Shaker exercise owing to the significant physical burden of the activity, which resulted in fatigue. Instead, he performed head elevation maintenance training for only 10 s per exercise at a frequency of two to three times per day. Following the training, he sometimes experienced worsened stiffness of the sternocleidomastoid and other muscles in the neck.

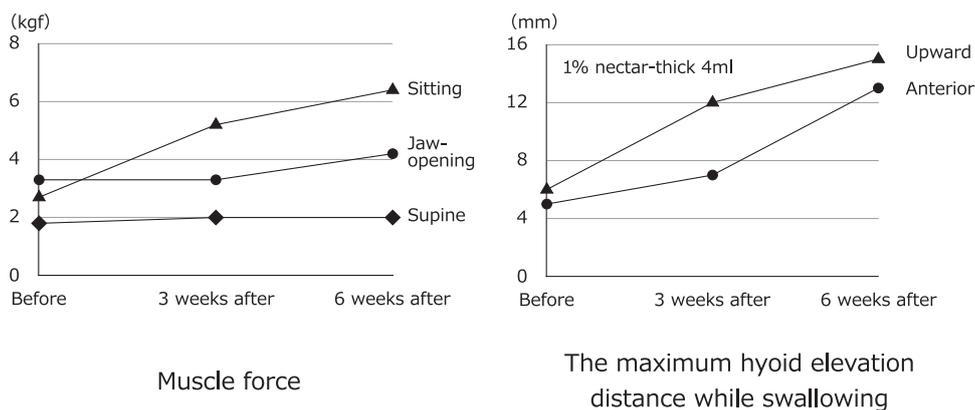
The anterior elevation of the hyoid and jaw-opening muscle strength [8] were measured using similar methods to those described for Case 1. Electromyography during neck flexion in a supine position was performed to assess muscle fatigue. Using an MQ16™ electromyograph (Kissei Comtec Co., Ltd., Matsumoto, Japan) at a sampling frequency of 1,000 Hz and a frequency band of 20–500 Hz, we calculated the rate of change in the median frequency (MF rate) for the suprahyoid and infrahyoid muscles. MF rate measurements provide negative values that declined with an increase in muscle fatigue and approached zero with a decrease in muscle fatigue [9].

### Results

In Case 1, magnetic stimulation resulted in 5.0 and 11.5 mm of anterior and upward hyoid movement, respectively (Figure 2). No pain was reported during treatment [numerical rating scale (NRS)=0]. The patient was able to undergo all the repetitions of magnetic stimulation designed to reduce the patient burden, and was able to complete the six-week regimen of rPMS without any complications. Both muscle strength and maximum hyoid elevation distance while swallowing 4 mL of 1% nectar-thick fluid improved during the course of stimulation (Figure 3). Although the DSS score of 3 remained unchanged after six weeks of stimulation, the patient was able to take meals at a reclining angle of 70° and could ingest



**Figure 2.** Magnetic stimulation of suprahyoid muscles under fluoroscopy (Case 1). Suprahyoid muscles contracted and the hyoid bone was elevated during magnetic stimulation.



**Figure 3.** Changes in muscle force and the maximum hyoid elevation distance during swallowing (Case 1).

Both neck flexion muscle strength in the seated and supine positions, and jaw-opening muscle strength increased. The maximum hyoid elevation distance while swallowing 4 mL of 1% nectar-thick fluid improved during the course of rPMS.

granular rice porridge and nectar-thick fluids with 1.5% water.

In Case 2, magnetic stimulation resulted in 2.9 and 4.2 mm of anterior and upward hyoid movement, respectively, at the start of the stimulation. The patient reported no pain during rPMS (NRS=0) and no fatigue after training. Thus, he was able to complete the six-week rPMS without any complications. Blood tests and clinical examination indicated no recurrence of disease activity. Jaw-opening muscle strength was 1.7 kgf at the start, 5.6 kgf after three weeks, and 7.5 kgf after six weeks of rPMS, indicating progressive improvement. MF rates were  $-3.03$  at the start and  $-1.45$  after six weeks of rPMS for the suprahyoid muscles (Figure 4) and  $-0.73$  at the start and  $-0.76$  after six weeks of rPMS for the infrahyoid muscles; fatigue declined substantially in the rPMS-targeted suprahyoid muscles. The patient was able to maintain neck flexion while in the supine position for 10 s at the

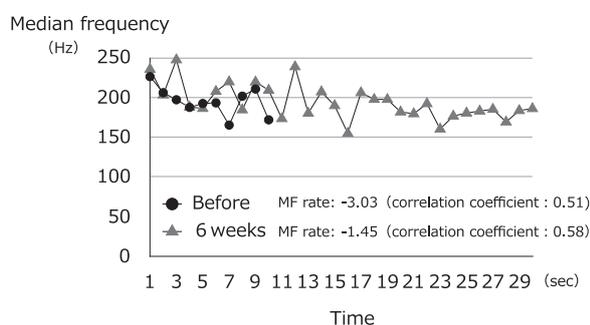
start of rPMS, which improved to 30 s after six weeks; the patient reported alleviated neck stiffness following magnetic stimulation and stated that fatigue upon eating was most directly reduced after the stimulation.

**Discussion**

The patient in Case 1 presented with dysphagia as a post-stroke sequela and muscle weakness resulting from disuse following aspiration pneumonia, which exacerbated his dysphagia. During the six-week rPMS, he experienced no pain or discomfort and was able to undergo the planned number of treatments without any complications. The comparison of pre- and post-stimulation measurements indicated that muscle strength and maximum hyoid elevation distance had increased. As a result, the patient was able to change his position while eating and drink fluids of reduced viscosity.

The patient in Case 2 had dysphagia associated with dermatomyositis. Approximately four months after starting treatment for his primary illness, rPMS was initiated as it was confirmed that there was no disease activity. No recurrence of disease activity was noted after initiating rPMS, suggesting its safety in patients with myopathy. At the start of the stimulation, the patient showed marked remnant muscle weakness, and despite a normal regimen including indirect swallowing therapy, his training load could not be increased. He reported no post-training fatigue during the six-week rPMS; indeed, he reported alleviated neck stiffness and was therefore able to eat with minimal fatigue immediately after the stimulation. rPMS led to increased muscle strength and reduced muscle fatigue.

As the Shaker exercise is effective in strengthening the suprahyoid muscles and as rPMS facilitates hyoid elevation, these interventions are expected to



**Figure 4.** Muscle fatigue analysis by electromyography for the suprahyoid muscles (Case 2).

MF rates were increased after six weeks of rPMS, suggesting improvement in muscle fatigue. The patient was able to maintain neck flexion while in the supine position for 10 s at the start of rPMS, which improved to 30 s after six weeks.

strengthen this muscle group. The present study included two patients who underwent rPMS and demonstrated its safety as an alternative for those who are unable to perform the conventional Shaker exercise. We identified patients with dysphagia with reduced hyoid elevation as an indication for rPMS. At present, we are not considering restricting this therapy to targeted diseases. The main objective of the therapy is to strengthen the anterior belly of the digastric muscle, and the mylohyoid and geniohyoid muscles. The greater the muscle strength gained through electrical stimulation, the greater the muscle strength improvement effect [10]. We therefore expected rPMS to have a similar effect. As the direct assessment of suprahyoid muscle strength can be challenging, we obtained proxy measurements of the neck flexion muscle and jaw-opening strength. Based on our investigations in two patients, we expect that rPMS can increase hyoid movement distance during swallowing and alleviate muscle fatigue. As rPMS does not require laborious procedures, such as the need to attach surface electrodes for electrical stimulation, the preparation time is shorter with limited associated pain. The time required for thirty sessions of stimulation, assuming 2 s for on and off times each, is 2 min; in addition, device preparation requires only about 3 min, suggesting that rPMS can easily be combined with other swallowing rehabilitation therapies. However, the optimal number of stimulations per day and period required to obtain therapeutic efficacy are currently unknown. In addition, as the magnetic stimulation coil needs to be maintained at a consistent size, patients with a shorter distance between the tip of their chin and the hyoid may not experience sufficient hyoid elevation. Finally, as the patients in this report were concurrently undergoing other therapies, we were unable to isolate the extent of the effect of rPMS. Although we demonstrated the feasibility of rPMS as a novel dysphagia therapy, randomized controlled trials are warranted to obtain sufficient evidence regarding its efficacy.

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