Pharyngeal Motor Evoked Potential Monitoring During Skull Base Surgery Predicts Postoperative Recovery from Swallowing Dysfunction

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■ OBJECTIVE: **Monitoring pharyngeal motor evoked potential (PhMEP) with a modified endotracheal tube is useful for predicting postoperative swallowing dysfunction. However, the relationship between intraoperative PhMEP findings and recovery from postoperative swallowing dysfunction has not been clarified. The aim of this study was to determine whether PhMEP monitoring predicts swallowing dysfunction not only immediately after surgery but also in the postoperative recovery period.**

■ METHODS: **We analyzed PhMEPs in 36 patients during treatment for skull base tumors. Recovery from postoperative swallowing dysfunction was evaluated when oral intake was started postsurgery and drip or tube feeding was discontinued. The correlation between the final to baseline PhMEP ratio and postoperative recovery times from swallowing dysfunction was examined.**

■ RESULTS: **The PhMEP ratio significantly correlated with postoperative swallowing function immediately after surgery ($P < 0.001$). The period before starting oral intake in patients with a PhMEP ratio >50% (mean ± standard deviation [SD], 3.8 ± 4.3 days) was shorter than those with a PhMEP ratio ≤50% (mean ± SD, 14.7 ± 11.8 days; $P < 0.01$). Drip or tube feeding was removed from patients with a PhMEP ratio >50% significantly earlier (mean ± SD, 13.7 ± 19.2 days) than those with a PhMEP ratio ≤50% (mean ± SD, 38.3 ± 27.3 days; $P < 0.05$). Both univariate and multivariate analysis showed that only the PhMEP ratio was predictive of early recovery from swallowing dysfunction.**

■ CONCLUSIONS: **PhMEP monitoring allowed us to predict not only immediate swallowing dysfunction but also recovery from the dysfunction in the postsurgery period.**

INTRODUCTION

Intraoperative monitoring of swallowing function is important in patients undergoing skull base surgery when the glossopharyngeal and vagus nerves are involved in the tumor. Motor function of these nerves can be monitored using needle electrodes placed in the vocal cords or pharyngeal wall, as well as surface electrodes on an endotracheal tube adhering to the vocal cords (1, 7, 8, 11, 12). However, these devices are usually used for recording compound muscle action potentials obtained from direct electrical stimulation of the glossopharyngeal and vagus nerves during intraoperative neurophysiologic monitoring.

Recently, we have demonstrated that monitoring pharyngeal motor evoked potential (PhMEP) using a modified endotracheal tube placed on the posterior pharyngeal muscles can be useful in predicting postoperative swallowing function during skull base surgery (3, 4). Patients with reduced PhMEP amplitude after tumor resection often experience deteriorated swallowing function immediately after surgery compared with those with preserved PhMEP amplitude. However, the correlation between intraoperative PhMEP findings and the postoperative course of swallowing function is not clear. The aim of this study was to determine whether PhMEP monitoring predicts outcomes of swallowing function not only immediately after surgery but also in the period of recovery from swallowing dysfunction.

Key words
- Glossopharyngeal nerve
- Pharyngeal motor evoked potential
- Skull base tumor
- Swallowing dysfunction
- Transcranial electrical stimulation
- Vagus nerve

Abbreviations and Acronyms
CMAP: Compound muscle action potentials
PhMEP: Pharyngeal motor evoked potential
SD: Standard deviation

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CLINICAL MATERIALS AND METHODS

Patients

We assessed data from 38 consecutive patients with skull base tumors treated surgically at the University of Niigata from February to October 2013, in whom PhMEP monitoring was performed. Two patients had severe preoperative swallowing dysfunction and were excluded. Therefore, the study included 36 patients (15 males and 21 females). Twenty-one of the 36 patients described here were included in a previous study (3) and 15 new patients were added. The cranial base tumors were as follows: jugular foramen schwannoma (12 patients), petroclival meningioma (6 patients), vestibular schwannoma (5 patients), brainstem tumor (4 patients), cerebellar tumor (3 patients), foramen magnum meningioma (3 patients), cerebellopontine angle meningioma (2 patients), and hypoglossal schwannoma (1 patient). Preoperative magnetic resonance imaging showed that all the tumors involved the lower cranial nerves.

Swallowing Function

Swallowing function was evaluated preoperatively and immediately after surgery according to a 3-grade scale (normal, 0 points; mild dysfunction, 1 point; severe dysfunction, 2 points). Mild dysfunction was defined as a sensation of difficult swallowing, although the ability to swallow food and liquid was retained without the need for tube feeding. Severe dysfunction was defined as swallowing disturbance that necessitated tube feeding.

Recovery from postoperative swallowing dysfunction was evaluated as 2 variables: 1) the period when oral intake was started after surgery; 2) the period when drip or tube feeding was discontinued, that is, the period when foods and liquids taken only orally were sufficient.

Intraoperative Monitoring

We monitored the glossopharyngeal and vagus nerves by intraoperatively recording compound muscle action potentials (CMAPs) and PhMEP. We used bipolar stimulators for CMAP monitoring. Current was delivered using a 0.2-millisecond pulse duration and a 1/second pulse frequency; the stimulus intensity was 1.0 mA. CMAPs from the posterior pharyngeal wall were recorded at paired contacts with PhMEPs with the largest amplitude following transcranial electrical stimulation. We exclusively used CMAP monitoring to identify the course of nerves with severely distorted anatomy.

Intraoperative PhMEP monitoring has been described in detail previously (3, 4). A modified endotracheal tube with adhesive surface electrodes was used until April 2011 (4). Since May 2011, a new device with 4 contacts adhering to the surface of the cuff of the endotracheal tube was introduced for PhMEP monitoring (4). After induction of anesthesia with a short-acting agent for neuromuscular blockade, neuroanesthesia was maintained by intravenous infusion of propofol and fentanyl. Constant voltage stimuli consisting of 5 rectangular pulses with 1-millisecond interstimulus intervals were generated with a D185 stimulator (Digitimer Ltd, Welwyn Garden City, United Kingdom). Corkscrew electrodes were placed at positions C3 or C4 and Cz to evoke the PhMEPs. The cathode was always positioned at Cz and the anode on the contralateral side. Intraoperative monitoring was based on the PhMEP with the largest amplitude among the responses obtained from the 2-paired contacts. A Viking monitoring system (Nicolet Biomedical, Inc., Madison, Wisconsin, USA) was used. The bandpass filter was set at 200 to 3000 Hz. The PhMEP amplitude was defined as the range between the maximum positive and negative peaks of the polyphasic waveform. The applied stimulus was adjusted to supramaximal intensity.

The highest value obtained before the microsurgical procedure was taken as the baseline response. PhMEPs were usually recorded every 10 minutes with measurements repeated twice to confirm reproducibility. During removal of tumors adjacent to the glossopharyngeal or vagus nerve, PhMEPs were recorded every 1 to 5 minutes. If the PhMEP amplitude decreased to $<50\%$ of the baseline amplitude during resection, the surgeon assumed that the procedure would damage the glossopharyngeal or vagus nerve and temporarily abandoned the resection or manipulated other lesions more distal to the nerve.

Statistical Analysis

The ratios of final PhMEP amplitude (at dural closure) to baseline PhMEP amplitude (shown as percentages) were used for the evaluations. For statistical analysis, patients were divided into 2 groups according to the PhMEP ratio: $\leq 50\%$ and $>50\%$. Surgery-induced changes in swallowing function were evaluated as the postoperative score minus the preoperative score. The χ^2 test was used to compare scores between the 2 groups and Spearman correlation coefficients were used to examine the relationship between the PhMEP ratio and the time required to restart oral intake or exclusive oral intake. Mann-Whitney U tests were performed to compare differences between the 2 groups in these periods. Patient age, sex, approach side of operation (left or right), presence of preoperative swallowing dysfunction, pathology (jugular foramen schwannoma or not), and PhMEP ratio ($\leq 50\%$ or $>50\%$) were tested as independent factors in predicting postoperative recovery from swallowing dysfunction using univariate and multivariate logistic regression analyses. $P < 0.05$ was considered significant.

RESULTS

Swallowing Function Immediately After Surgery

Seven of the 36 patients had mild preoperative dysfunction (1 point); all of them reported mild swallowing dysfunction but had no objective palsy of the glossopharyngeal or vagus nerve. Five of the 7 patients had jugular foramen schwannomas, 1 had a foramen magnum meningioma, and 1 had a petroclival meningioma. Magnetic resonance imaging revealed that all 7 patients had tumors affecting the lower cranial nerves. In 3 of the patients, their immediate postoperative swallowing function deteriorated from mild (1 point) to severe dysfunction (2 points). The other 4 patients showed no changes. Fifteen of the 29 patients who had normal swallowing function preoperatively developed swallowing disturbance postoperatively (mild, 6 patients; severe, 9 patients). The changes in pre-versus postoperative swallowing function grade were 0 in 18, 1 in 9, and 2 in 9 patients.

Recovery from Swallowing Dysfunction

The period between surgery to starting oral intake ranged from 1 to 39 days (mean $\pm$ standard deviation [SD] 7.1 $\pm$ 9.0 days). The