Intramedullar Stimulation of the Facial and Hypoglossal Nerves: Estimation of the Stimulated Site

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Aim. To determine the stimulation site of both facial and hypoglossal nerves after transcranial magnetic stimulation.

Methods. After surgical exposure of the brainstem in 22 patients with intrinsically pontine (n=9) or medullary (n=13) tumors, the facial colliculus and the hypoglossal triangle were electrically stimulated. The EMG responses were recorded with flexible wire electrodes from the orbicularis oculi/orbicularis oris muscles, and genioglossal muscles. Patients had no preoperative deficits of the nerves.

Results. The EMG mean latencies of the unaffected facial nerve were 5.2±0.6 ms for the orbicularis oculi, and 5.2±0.5 ms for the orbicularis oris muscle. After the stimulation of 18 possibly affected facial nerves, the EMG mean latencies were 5.3±0.3 ms for the orbicularis oculi (p=0.539, unpaired Student’s t-test), and 5.4±0.2 ms for the orbicularis oris (p=0.122). The EMG mean latency of the unaffected hypoglossal nerve was 4.1±0.6 ms for the genioglossal muscle. After the stimulation of 26 possibly affected hypoglossal nerves, the EMG mean latency for the genioglossal muscle was 5.3±0.3 ms. There was a significant difference (p<0.001) in latency for genioglossal EMG responses between the patients with pontine and those with medullary tumors.

Conclusion. Shorter EMG mean latencies of unaffected facial nerves obtained after direct stimulation of the facial colliculi confirm that magnetic stimulation is most likely to occur closer to the nerve’s exit from the brainstem than to its entrance into the internal auditory meatus. The hypoglossal nerve seems to have the site of excitation at the axon hillock of the hypoglossal motor neurons.

Key words: brain stem neoplasms; brain stem; cranial nerves; facial nerve; hypoglossal nerve; intraoperative monitoring
pa tients with medullary tu mors served as “a con trol” for the fa cial nerve, and the pa tients with pontine tu mors served as “a con trol” for the hypoglossal nerve.

Method

Monopolar stim u la tion tech nique we used has been de scribed pre viously (11,12). Stim u la tion and record ing pro ce dure was per formed with an Axon Sen ti nel-4 evoked po ten tial sys tem (Axon Sys tems Inc., Hauppauge, NY, USA). Briefly, af ter sur ge cal ex po sure of the floor of fourth ven tri cle, the sur ge cal stim u la tion at the fa cial nerve was per formed with a hand-held monopolar-stimulating electrode (Xomed No. 82-25100, di am e ter 0.75 mm), which served as a cath ode. An N-spiral ne er elec trode (Nicolet, Mad i son, WI, USA) at Fz point (ac cord ing to the 10-20 in ter na tional elec tro en ceph a log ra phy sys tem) served as an an ode. One to two sec ond trains of stim uli of 0.2 ms du ra tion were de livered at 4 Hz. The stim u la tion was per formed us ing the un par ed Stu dent’s t-test, with p<0.05 con sid ered sig nif i cant.

Results

In all pa tients, elec tri cal stim u la tion at the facial colliculus and/or hypoglossal tri an gle on the floor of the fourth ven tri cle re sulted in se lec tive EMG re spon ses re corded from the ipsilateral fa cial and tongue mus cles (Figs. 1 and 2). The EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles, 5.2±0.6 ms for the oribula rius ocu li mus cles, and 5.4±0.5 ms for the oribula rius oris mus cle. The EMG mean la ten cies of the un af fected fa cial nerve, obtained in 13 pa tients with medullary tu mors, were 5.2±0.6 ms for the oribula rius ocu li mus cles, and 5.4±0.5 ms for the oribula rius oris mus cles. They were not sig nif i cantly lon ger than the un af fected fa cial nerve EMG la ten cies (p=0.122, re spec tively). Af ter the stim u la tion of 26 po si bly af fected fa cial nerves, the EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles – sig nif i cantly lon ger (p<0.001) than the un af fected fa cial nerve EMG la ten cies (p=0.539 and p=0.122, re spec tively). Af ter the stim u la tion of 26 po si bly af fected fa cial nerves, the EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles – sig nif i cantly lon ger (p<0.001) than the un af fected fa cial nerve EMG la ten cies (p=0.539 and p=0.122, re spec tively). Af ter the stim u la tion of 26 po si bly af fected fa cial nerves, the EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles – sig nif i cantly lon ger (p<0.001) than the un af fected fa cial nerve EMG la ten cies (p=0.539 and p=0.122, re spec tively). Af ter the stim u la tion of 26 po si bly af fected fa cial nerves, the EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles – sig nif i cantly lon ger (p<0.001) than the un af fected fa cial nerve EMG la ten cies (p=0.539 and p=0.122, re spec tively). Af ter the stim u la tion of 26 po si bly af fected fa cial nerves, the EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles – sig nif i cantly lon ger (p<0.001) than the un af fected fa cial nerve EMG la ten cies (p=0.539 and p=0.122, re spec tively). Af ter the stim u la tion of 26 po si bly af fected fa cial nerves, the EMG mean la ten cies were 5.3±0.3 ms for the genioglossal mus cles – sig nif i cantly lon ger (p<0.001) than the un af fected fa cial nerve EMG la ten cies (p=0.539 and p=0.122, re spec tively).

Table 1. Age, sex, and tumor location in study participants (N=22)

<table>
<thead>
<tr>
<th>Clinical parameter</th>
<th>Tumor location</th>
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</thead>
<tbody>
<tr>
<td>Age (years, mean±SD)</td>
<td>medulla pons</td>
</tr>
<tr>
<td>Sex (women/men)</td>
<td>19.2±14.9/7.4±4.3</td>
</tr>
<tr>
<td>Tumor location (No.)</td>
<td>9/4</td>
</tr>
</tbody>
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Figure 1. Schematic pre sen ta tion of stim u la tion of facial colliculi in the pa tient with a medullary gan glioma (large dark area), to gether with an orig inal re cord ing of elec tri cal ac tiv ity from orbula rius ocu li mus cles.

Figure 2. Schematic pre sen ta tion of stim u la tion of hypoglossal tri an gle in pa tient with a pontine anaplastic astrocytoma (large dark area), to gether with an orig inal re cord ing of elec tri cal ac tiv ity from genioglossal mus cles. The small dots rep re sent the site where elec tri cal stim u la tion elicited re spon ses, which were re corded from the right or left orbula rius ocu li mus cles ipsilat eral to the stim u la tion site. Rt – right, Lt – left.
supramaximal had little or no effect on its latency (Fig. 3).

**Discussion**

During the resection of brainstem tumors, the intracranial part of the facial and hypoglossal nerves is usually accessible to direct electrical stimulation. We believe that it is possible to stimulate area on the small ably small and well-localized area by use of a small-tip electrode and low current (7,11). Electrical stimulation may also cause an over flow of current through the cerebrospinal fluid, which may lead to false identification of the stimulus latency (15). In our study, however, the stimulus latency of the facial colliculus evoked a facial EMG response, whereas the stimulus latency of the part just next to the facial colliculus did not. These findings indicate that the applied stimulus current did not spread significantly and that the localizing value of this method is in de tecting the facial colliculus was reliable. Furthermore, once the hypoglossal tri an gle is identified on the floor of the fourth ventricle, the stimulus latency of the hypoglossal nerve resulted in a superficial EMG response of the genioglossal muscle.

The site of impulse generation at transcerebral magnetic stimulation of the facial nerve can be determined by comparing the latencies of EMG responses to a magnetic stimulus and to those elicited by direct stimulation on the floor of the fourth ventricle. The mean latency of 5.2±0.6 ms for orbicularis oculi was within the range of 4.9-5.4 ms in health vol unteers. The authors did not use the latency values due to a small num ber of sub jects. The authors inferred from anatomic and localization studies that the stimulus latency was closer to the exit zone than to the entry point in the internal auditory meatus.

Our results also confirm the findings by Möller and Janetta (17), who measured the mean latency of 4.5±0.3 ms in orbicularis oculi muscle in patients undergoing surgery for hemifacial spasm. Bearing in mind that the sites of stimulation were not the same (facial colliculus in our case vs. root exit zone – the distance about 15-20 mm; Dr. F. Epstein, personal communication, September 1994) the latency should be increased up to 0.4 ms. With this adjustment, our finding with direct electrical stimulation of the facial nerve suggests that the magnetic coil most probably stimulate the facial nerve near the brainstem. In contrast, Murray et al (2), Schriefer et al (3), Rössler et al (4), Schmid et al (5,6), and Rimpiläinen et al (7) suggested the labyrinthine segment of the facial nerve as the most likely latency of the facial nerve stimulation. Why is the facial nerve not activated by the magnetic field (8). We observed little to no effect on evoked muscle response latency (ver tal dot line). Sin gle reponses are shown. Stim. – stimulus intensity.

The mean latency of the EMG responses in the facial musc lles was prac tically the same in both groups of pa tients (pontine vs. midbrain tumor). Pontine tumors tend to grow more intrinsically and expand circumferentially, pushing fewer surrounding structures, in cluding the facial nerve more distally in the bony canal? The bony covering of the facial nerve significantly increases the local extracellular resistance, thereby reducing current density in duced by the magnetic field (8). We observed little to no change in the latency of re sponse to increased stimulus intensity from submaximal to close to supramaximal (Fig. 3). Furthermore, the fact that the potent volatile anesthetic isoflurane does not suppress the motor re sponse to the stimulus latency of the floor of the fourth ventricle (16,18) in dogs of a postynaptic axonal or spinal re sponses.

The mean latency of the EMG responses in the facial muscles was practically the same in both groups of patients (pontine vs. midbrain tumors). Pontine tumors tend to grow more in two partially cally and ex pand circumferentially, pushing fewer surrounding structures, in cluding the facial nerve more distally in the bony canal. The bony covering of the facial nerve significantly increases the local extracellular resistance, thereby reducing current density induced by the magnetic field (8). We observed little to no change in the latency of re sponse to increased stimulus intensity from submaximal to close to supramaximal (Fig. 3). Furthermore, the fact that the potent volatile anesthetic isoflurane does not suppress the motor re sponse to the stimulus latency of the floor of the fourth ventricle (16,18) in dogs of a postynaptic axonal or spinal re sponses.

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(β < 20%). We were not able to in clude a larger num ber of pa tients in the study, as the brain stem tu mor sur gery in volves high mor tal ity (23–25).

The mean la ten cy of EMG re spon ses after the stimu lation of the un af fect ed hy po glossal nerve of 4.1 ± 0.6 ms for the geni oglossal mus cle dif fers from the la ten cy of 4.9 ms ob tained af ter mag netic stimu lation of the in tracranial seg ment of the hy po glossal nerve (10). The stimu lat ing tech nique used in this inves ti gation dif fers, how ever, from that de scribed by Muel bacher and col leagues (10). The au thors did not use mean la ten cy val ues. They agreed that their meth od was not re liable for in tracranial stim u la tion of the hy po glossal nerve be cause a clear-cut re sponse was rare. The sig nif i cant dif fer ence be tween the two groups of pa tients (pon tine vs. med ul lary tu mors) in the mean la ten cy of EMG re spon ses for the geni oglossal mus cle may be due to the fact that med ul lary tu mors tend to grow ex op hy tically and com press the lower cra nial mo tor nu clei (20).

Ac ti va tion at the mo tor nu ron seems to de ter mine the im pulse gen er a tion site of the hy po glossal nerve fi bers. Se lec tive con di tions of stimu lation used in our study led us to be lie ve that the bare mem brane of the ax on hill ock was the most likely site of ac ti va tion, sim i lar ly as with the F waves (19).

In con clu sion, this study of elec tri cal stim u la tion of the fa ci al and hy po glossal nerves on the sur gical ex posed site of the fourth ver tex in pa tients is an orig i nal ad ap tation to a prob lem pre vi ously in ves ti gated with mag netic stimu la tion with quite con tro ver sial in ter pre ta tion of the site of stim u la tion. The re sul ts of our study in fer that mag netic stimu lation with quite con tro ver sial in ter pre ta tion of the site of stimu la tion and com pression op er a tions. Neu rology 1985;35:969-74.

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References


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