Preservation of facial function during removal of acoustic neuromas

Use of monopolar constant-voltage stimulation and EMG

AAGE R. MOLLER, PH.D., AND PETER J. JANNETTA, M.D.

Department of Neurological Surgery, Presbyterian-University Hospital, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

The authors describe a modification in the way the facial nerve is stimulated electrically during operations to remove medium and large-sized (> 2 cm) acoustic tumors. This consists of monopolar stimulation with low internal impedance. Proper use of this modified stimulation technique together with acoustic monitoring of the electromyographic responses of facial muscles helps to preserve facial nerve function in patients undergoing these operations, and also decreases the duration of the operation.

KEY WORDS • acoustic tumor • facial nerve • nerve stimulation • intraoperative stimulation

It is standard practice to stimulate the facial nerve electrically during operations for removal of acoustic neuromas in order to identify the nerve and to monitor the effects of surgical manipulations on facial nerve function. A variety of different stimulation techniques are in use, but most often the stimuli consist of rectangular pulses lasting about 1 msec and produced by a constant-current source. The current delivered is varied according to need. The responses to stimulation (contractions of facial muscles) are often monitored by an assistant (frequently the anesthetist) who observes the patient's face.

Several investigators have described improvements in this technique. Delgado, et al., devised a method of recording the electromyographic (EMG) responses of facial muscles following electrical stimulation of the facial nerve. These investigators photographed the EMG recordings for the purpose of detecting small changes that might occur during the operation and that would indicate deterioration of facial nerve function. Sugita and Kobayashi recognized advantages in monitoring facial muscle contractions acoustically. However, since the electrical stimulus produces a loud acoustic artifact, making it difficult to hear the EMG responses of the facial muscles, these authors recorded muscle movements rather than EMG responses by placing accelerometers over the patient's facial muscles. They then presented the output, amplified, through a loudspeaker.

Stimulators designed for use on the facial nerve have traditionally been of the constant-current type. Such stimulation is advantageous when electrode impedance is likely to vary, since it will drive approximately the same current through the tissue independent of the electrode impedance. However, in operations for removal of acoustic tumors, there is often a variable degree of shunting of the stimulating electrode from tumor tissue and, particularly, from cerebrospinal fluid (CSF). When the electrode is covered with CSF, a large part of the current delivered by a constant-current source will be diverted by the CSF and, since the total current is constant, less current will flow through the neural tissue. A larger total current through the electrode is needed to stimulate the nerve compared to a situation with less shunting. The result is that the output of the stimulator has to be adjusted frequently in order to maintain a stimulus current that exceeds the threshold of the nerve. Since the degree of shunting varies rapidly, it is not always possible to make proper adjustments, and the result is that the current through the nerve tissue may increase to levels that can damage the nerve. Our own experience in the use of bipolar constant-current stimulation confirms this fact. For these reasons we have chosen a means of stimulation with a
low impedance. While the total output current associated with such a stimulation will vary with the degree of shunting, the current through any one part of the tissue will remain relatively constant. This can be seen by recalling Ohm's law, which states that the current through a resistor is determined by the voltage across the resistor and its resistance. Our experience with such a monopolar low-impedance source confirms its superiority over a constant-current source.

Previously, the main purpose of stimulating the facial nerve during the operation was to identify the nerve and to check its integrity. In addition to this, we use stimulation to identify regions of the tumor that are free of facial nerve tissue so that excision is performed without risk of facial nerve damage. When stimulation is to be used for identification of regions of the tumor where there is no facial nerve present, the adjustment of the stimulus current in the case of a constant-current type of stimulator becomes even more difficult because of the unknown degree of shunting. In this paper we show that using monopolar stimulation with low internal impedance has several advantages over using bipolar constant-current stimulation.

**Materials and Methods**

**Description of Stimulator**

We use a Grass Type SD9 facial nerve stimulator* that provides rectangular pulses of 150-μsec duration at a rate of 10 pulses/sec, and that has an output impedance of about 1000 ohms, thus supplying a nearly constant voltage. We also use a monopolar hand-held stimulator, the active part of which is a wire electrode consisting of a 5-cm long annealed copper wire, 0.5 mm in diameter, that is silver-plated. This wire, which is fixed to the tip of an insulated handle, can easily be bent to produce the shape that is most practical (Fig. 1). This active electrode is connected to the negative (cathode) terminal of the stimulator, and the indifferent electrode is a hypodermic needle placed in muscles of the wound. The impedance of the electrode is about 5000 ohms. The stimulator is set to deliver between 0.5 and 0.7 V.

The electrical activity (EMG response) of the facial muscles is recorded from two needle electrodes (Grass Type E2 subcutaneous platinum needles), one placed in the orbicularis oculi muscle and the other in the orbicularis oris muscle. The ground electrode is placed on the forehead. The potentials from these two electrodes are amplified differentially using a Grass P511J amplifier equipped with a current-limiting probe. The potentials are displayed on an oscilloscope, and are made audible through a loudspeaker using an audio-amplifier. In order to avoid interference with the muscle action potentials by stimulus artifacts, the potentials that are led to the audio-monitor are passed through an electronic gate that is kept closed during the time the electrical stimulation is applied and opened just before the response is expected. The stimulator is triggered by an external timer that also activates the pulse generator which supplies the control voltage for the gate used to suppress the stimulus artifact (Fig. 2).

**Operative Procedure**

Patients are placed in the lateral decubitus position and are operated on under endotracheal anesthesia, without the use of any long-lasting muscle relaxants. A retromastoid approach is used, as for hemifacial spasm procedures.\(^3,4\) When the tumor has been exposed by elevation of the cerebellum, the stimulator is then used to identify areas of the tumor where there is no risk of damaging the facial nerve. This is done by mapping regions of the tumor where no response can be elicited. Large fragments of the tumor from these regions are then removed without risk to the facial nerve. Excision is carried out by grasping the tumor with forceps and cutting it with scissors. If hemostasis is required, coag-
Intraoperative facial nerve monitoring

![Block diagram of the recording and stimulation set-up.](image)

**Fig. 2.** Block diagram of the recording and stimulation set-up. EXT.SYNC. = external synchronization; CRO = cathode ray oscilloscope; FET = field effect transistor.

The fact that the stimulator is used to identify the nerve and map its location within the tumor. In cases where the tumor is adherent to the nerve, we have found it valuable to monitor the activity of the facial muscles by listening to the amplified potentials (EMG responses) recorded from the facial muscles without any electrical stimulation. A certain degree of mechanical manipulation of the nerve will stimulate the nerve and give rise to muscle activity that can be monitored by the sound produced. This provides valuable feedback to the surgeon. Vigorous manipulation of the nerve will give rise to sustained periodic activity of the facial muscles. We consider that to be an indication of a possible risk of permanent injury to the nerve.

**Results**

We have used the technique described to monitor facial nerve function in 10 patients operated on for removal of medium and large-sized (greater than 2 cm in diameter) tumors of the acoustic nerve. Our experience is that the stimulation described is superior to conventional constant-current stimulation in several ways. We have found that the threshold level at which the nerve is stimulated shows little dependence upon the degree of shunting from CSF or other factors. This makes it possible to keep the same output setting of the stimulator while the stimulus is used for identification of regions where there is no nerve or for identification of the nerve. The possibility of identifying areas of the tumor where there are no portions of the facial nerve present has made it possible to remove large parts of the tumor without risking damage to the facial nerve. The reduction in the duration of the operation is substantial, in some cases by as much as a factor of two. None of the patients has suffered permanent loss of facial function and none had any facial muscle weakness immediately following the operation, although one patient developed a delayed facial paresis on the 2nd postoperative day which improved rapidly thereafter.

**Discussion**

We see four advantages to using the method of monitoring facial nerve function described here instead of the previously used techniques. 1) A constant-voltage source will deliver approximately the same current through any given part of the tissue, independent of shunting. Thus, the stimulation voltage rarely needs to be adjusted, which decreases the risk of damaging the nerve by over-stimulation. Constant-current stimulation requires adjustment of the current with changes in the degree of shunting by brain tissue and CSF, and needs to be adjusted according to the degree of shunting. 2) Through monopolar stimulation it is possible to map regions of the tumor that do not contain facial nerve tissue. Bipolar stimulation is dependent on the

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† Cavitron ultrasonic aspirator manufactured by Cavitron, Cooper Medical, 88 Hamilton Avenue, Stamford, Connecticut.
orientation of the bipolar electrode with regard to the nerve, and it may not stimulate the nerve if the anode instead of the cathode is placed on the nerve and, therefore, gives a false impression that there are no parts of the facial nerve within the region that is tested. 3) Monitoring of facial muscle contractions via EMG through a loudspeaker is superior to having an assistant observe the patient's face. It provides a faster feedback to the surgeon and gives greater certainty as to which muscle responses are monitored. 4) By continuously monitoring the facial muscles with EMG, the surgeon can tell immediately when the facial nerve has been manipulated excessively or damaged. This technique appears to us to ensure facial nerve preservation while permitting rapid and safe removal of tumor bulk.

References

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Address reprint requests to: Aage R. Møller, Ph.D., Department of Neurological Surgery, Room 9402, Presbyterian-University Hospital, University of Pittsburgh School of Medicine, 230 Lothrop Street, Pittsburgh, Pennsylvania 15213.