Continuous Retrograde Monitoring of the Facial Nerve: Preliminary Experience During Acoustic Neuroma Surgery

Abstract—Continuous electromyographical (EMG) monitoring of the facial nerve is widely used during acoustic tumor surgery. Mechanical stimulation of the facial nerve is capable of eliciting synchronous and asynchronous EMG responses alerting the surgeon to damaging maneuvers performed on the nerve. Mechanical stimulation, however, elicits EMG responses only when the nerve has been injured by the underlying pathology or previous surgical maneuvers, and the technique is sensitive to administration of muscular blockers. In addition, EMG is unable to furnish quantitative information about the damage. The present paper illustrates an alternative technique for intraoperative facial nerve monitoring, that is, the recording of facial nerve antidromic potentials (FNAPs).

Eleven subjects operated on by acoustic neuroma surgery via a retrosigmoid approach (tumor sizes ranging from 12 to 28 mm) participated in the investigation. Bipolar electrical stimulation of the marginalis mandibulae was performed to elicit FNAPs. Stimulus intensity ranged from 2 to 6 mA with a delivery rate of 7/second. A silver-wire electrode positioned on the proximal portion of the acoustic-facial bundle was used to record action potentials. Changes in latency and amplitude of FNAPs were analyzed as a function of the main surgical steps. FNAP monitoring provided quantitative real-time information about damaging maneuvers performed on the nerve and allowed prediction of postoperative facial function. (*Skull Base Surgery*, 6(2):77–81, 1996)

Facial nerve (FN) monitoring during acoustic neuroma surgery has reduced the prevalence of postoperative facial dysfunction.^{1–6} Facial electromyography (EMG) is probably the most popular technique utilized to detect facial muscle activity in response to electrical or mechanical intracranial stimulation of the facial nerve.^{7–12} EMG activity in response to mechanical stimulation of the FN, as detected visually or revealed by an acoustic feedback system, alerts the surgeon to the fact that the nerve is being damaged and that either a change or a suspension of surgical maneuvers is necessary.

Continuous monitoring of mechanically-evoked EMG potentials, however, presents a number of drawbacks. First, only an injured FN is mechanically sensitive.⁹ Second, the use of endplate blockers, such as atracurium or

vecuronium bromide, which allow electrical stimulation of the nerve, can make facial muscle irresponsive to mechanical stimulation. Reversal of the effect of the endplate blocker after a single dose of short- or intermediate-acting relaxant administered at the beginning of the operation is often variable and, consequently, it is difficult to judge the muscle response.⁹ Third, continuous EMG monitoring furnishes qualitative information on facial function but is unable to quantify the degree and mechanisms of FN damage.

In a companion paper¹³ we reported that the technique of direct monopolar recording of FN antidromic potentials (FNAPs) from the exposed intracanal portion of the seventh cranial nerve can offer an alternative method for continuous monitoring of the FN. FNAP re-

cording has proved sensitive to activation of a peripheral branch of the FN and is extremely specific.¹³

The present paper extends our previous experience and specifically evaluates the utility, advantages, and limitations of FNAP recording during acoustic neuroma surgery in terms of: (a) assessing the mechanisms of FN damage intraoperatively, (b) preventing postoperative FN dysfunction, and (c) predicting postoperative facial function.

MATERIALS AND METHODS

Eleven subjects with acoustic neuromas participated in the investigation. Subjects ranged in age from 25 to 64 years (mean, 49 years). Six were male and five were female. The tumors presented both intrameatal and extrameatal spread, and the maximum diameter, as evaluated according to Fischer et al,¹⁴ ranged from 12 to 28 mm. All subjects presented a Grade 1 facial function preoperatively, according to the House and Brackmann scale.¹⁵

All operations were performed by the senior author (V.C.) using a retrosigmoid approach. Surgical techniques have been extensively described in a previous paper.¹⁶

A pair of platinum needle electrodes (type E2, Grass Instruments) were used to stimulate the marginal branch of the FN ipsilateral to the side operated on. Electrodes were placed 1 cm apart so that the imaginary line passing through the tips was perpendicular to the long axis of the nerve. Electrical biphasic pulses of 50 microsecond duration were delivered seven times per second at an intensity ranging from 2 to 6 mA. Potentials were recorded using a teflon-insulated silver wire monopolar electrode (type Ag 7/10, Merwire Corp.) with approximately 3 mm of the distal end uninsulated. The uninsulated portion was bent and embedded in a cotton wick sutured by a 4-0 silk suture. Anesthesia was performed using vecuronium bromide at the beginning of surgery at a dosage of 0.08 mg/kg. The same dosage was repeated when needed.

The monopolar electrode was placed at the root entry zone of the seventh to eighth cranial nerve complex (Fig. 1) and was connected to the negative input of the preamplifier. A positive needle electrode (Type E2, Grass Instruments Co.) was placed in front of the contralateral tragus and a ground needle electrode halfway between the stimulating and recording electrodes. A compact Amplaid MK15 unit was used for electrical stimulation and recording of potentials. The recorded potentials were filtered (30 to 2500 Hz), amplified (10 000 or 20 000 $\times$), averaged, and viewed on a monitor. Each average contained 100 to 300 repetitions and was completed in a time window of 14 to 42 milliseconds. To facilitate comparative analysis of surgical actions, electrophysiologic findings, and postoperative FN function, surgical maneuvers were divided into the various steps listed in Figures 2 through 5.

RESULTS

Figure 2 shows a series of FNAPs obtained in a subject undergoing retrosigmoid removal of a 15-mm left acoustic neuroma using a stimulation intensity of 3 mA. Triphasic responses, which are typical of action potentials recorded with the monopolar technique, were obtained. They were characterized by a first positive peak (P_1), a negative peak (N_1), and a second positive peak (P_2). The FNAPs were stable throughout surgery. Dissection of the FN from the tumor was easily accomplished in this patient, and the postoperative facial function was Grade 1 both at discharge and 6 months later.

Figure 3 shows a series of recordings in a subject with a 22-mm acoustic neuroma. Stimulation at 4 mA was used to elicit reliable responses. A progressive reduction in amplitude and latency shift was observed. Dissection of the tumor from the FN and traction of the FN during the maneuvers performed to remove the tumor produced the

Figure 1. Monopolar silver wire electrode placed close to the root entry zone of the acoustic facial bundle to record FNAPs in a patient with a left acoustic neuroma.

Figure 2. Intraoperative monopolar recording of FNAPs in a subject undergoing retrosigmoid removal of a 15-mm AN. Stimulus intensity: 3 mA.

Figure 3. Intraoperative monopolar recording of FNAPs in a subject undergoing retrosigmoid removal of a 22-mm AN. Stimulus intensity: 4 mA.

largest latency modifications. The patient presented Grade 4 facial function at discharge and Grade 3 at 6 months.

The FNAPs shown in Figure 4 indicate progressive deterioration in latency and amplitude, with subsequent loss of potentials, as a result of traction of the FN and intracranial tumor resection in the internal auditory canal, in a subject with a 25-mm acoustic neuroma in the right ear. The FN was particularly involved in the tumor, and on completion of surgery only a portion of the nerve was preserved. Dissection of the tumor from the nerve caused the disappearance of potentials. Facial function was Grade 6 both at discharge and at 6 months.

At 6 months, postoperative facial function in the patients investigated was as follows: Grade 1 in three patients, Grade 2 in four patients, Grade 3 in two patients, Grade 4 in one patient, and Grade 6 in one patient. Figure 5 shows the individual latency shifts of the N_1 component of the FNAPs as a function of surgical steps. A large individual variability in FNAP changes was observed. Traction of the FN and tumor dissection in the internal auditory canal caused the largest N_1 latency shift in most of the patients.

Table 1 summarizes the changes in intraoperative FNAPs and compares them with postoperative (6 months) facial function. Subjects with postoperative facial dysfunction (Grades 3 or greater) presented the largest modi-

Figure 4. Intraoperative monopolar recording of FNAPs in a subject undergoing retrosigmoid removal of a 25-mm AN. Stimulus intensity: 5 mA.

Figure 5. Individual changes in N_1 latency as a function of surgical steps.

fications in latency and amplitude of the N_1 component of the FNAPs.

DISCUSSION

Direct recording of evoked compound action potentials from the exposed seventh and eighth cranial nerves during posterior fossa surgery provides the surgeon with real-time information on the conductive efficiency of the nerve. This recording method is extensively used in our department to monitor auditory function during cerebellopontine angle surgery. It has proved useful for decreasing the hearing loss caused by traumatic or ischemic injury to the cochlea or cochlear nerve, for identifying surgical maneuvers that are critical to hearing function, and for predicting postoperative hearing.¹⁷⁻¹⁹ In addition, analysis of the waveform has yielded useful information on the mechanism of the damage.¹⁷⁻¹⁹

The monopolar FNAP recording technique described in this paper is original, quite easy to perform, and allows recording of potentials even though the electrode is not in close contact with the FN because of the spread of electrical activity from the nerve. This may prove useful when monitoring FNAPs during removal of middle- and large-sized tumors in which the FN has yet to be identified.

The method presented here also has the advantage of providing precise quantitative information on a broad

spectrum of changes in the status of the nerve. It is well known that the classic detection of EMG activity after mechanical stimulation of the FN yields only qualitative information on the presence of neural damage.

The practical impact of this method in acoustic tumor surgery needs to be demonstrated in a large number of subjects monitored with this method versus subjects monitored by EMG recording. Obviously, FNAP recording is no substitute for the EMG technique, since the latter is essential in the anatomic identification of the FN by electrical stimulation. The FNAP recording technique, however, offers the unique possibility of effective continuous monitoring of the FN. In fact, the recording of mechanically-induced EMG activity is marred by disadvantages such as low sensitivity, the impossibility of monitoring facial function when neuromuscular blockers are administered, and the absence of quantitative information on the conduction properties of the FN.⁹

FNAP monitoring of the FN has a number of advantages over the EMG technique. First, facial function can be monitored even when the anesthesiologic protocol includes endplate blockers. Anesthesiologists are often reluctant to maintain anesthesia without muscle relaxants, particularly during long-lasting, delicate surgical procedures. FNAP recording affords a more comfortable maintenance of anesthesia with the use of intermediate-acting muscle relaxants because they fully suppress patient movement, assist ventilation, and allow the use of a smaller amount of anesthetics. Second, real-time information on the pathophysiologic status of the FN can be obtained when recording FNAPs. These potentials have a broad amplitude and furnish reliable responses after the averaging of only a few recordings (15 to 30) in a time window of 2 to 4 seconds. Third, the activity of the entire route (extratemporal, intratemporal, and intracranial) of the FN can be explored. It is therefore possible to identify the site of conduction block in the cerebellopontine angle by comparing the latency and the morphology of the responses at different levels along the intracranial portion of the facial nerve. Other authors²⁰ have attempted to achieve the same objective using electrical stimulation of the FN in conjunction with EMG recording from the facial muscles. Direct recording of the FN affords the advantage of furnishing a more precise estimate of conduction properties of the facial nerve (Colletti et al, in preparation). Fourth, FNAPs effectively allow continuous monitoring of FN function. "Continuous" EMG monitoring depends on the mechanical stimulation of the FN, and therefore other types of injury, for example, ischemic, might not be detected. Finally, analysis of the modifications of FNAP waveforms and latencies during surgery may furnish useful information on the mechanism of the iatrogenic damage, enabling the surgeon to modify and refine surgical technique.

It is well known that a decreased action potential amplitude is related to the overall number of functioning neural fibers. A partial neural conduction block is usually

Table 1. Intraoperative FNAP Changes versus Postoperative Facial Function

FN Function at 6 Months	N_1 Latency Shift (ms)		N_1 Amplitude Decrease (%)	
	Median	Range	Median	Range
Grades 1-2 (n = 7)	0.3	0-0.7	18	0-35
Grades 3-4 (n = 4)	1.0	0.5-loss	40	20-loss

characterized by a relative increase in the first positive peak (P_1) compared with the negative peak (N_1). The former is generated by the depolarization coming close to the recording electrode and the latter by the passage of the depolarization under the electrode. A complete conduction block may be characterized by permanence of only the P_1 component. Increased potential latency may be due both to a partial block or to slowed conduction along the nerve.

In the present investigation, intraoperative FNAP changes enabled the surgeon to identify the surgical steps which cause damage and to temporarily suspend or modify surgical maneuvers to permit regression of the damage. In addition, severe modifications of FNAPs were associated with unsatisfactory facial function at 6 months.

On the basis of these outcomes, FNAP recording is a promising intraoperative monitoring technique which may prove useful for predicting FN damage. Yet, owing to the small number of subjects, the present investigation does not provide any detailed information on the value of FNAP recording in preventing FN damage. To this end, a longitudinal study in a larger series of patients is in progress in our department with the specific aim of comparing postoperative FN results in subjects undergoing acoustic neuroma surgery (1) without any form of FN monitoring, (2) with continuous EMG monitoring, and (3) with FNAP monitoring.

REFERENCES

1. Harner SG, Daube JR, Ebersold MJ: Improved preservation of facial nerve function with use of electrical monitoring during removal of acoustic neuromas. *Mayo Clin Proc* 62:92-102, 1987
2. Harner SG, Daube JR, Beatty CW, Ebersold MJ: Intraoperative monitoring of the facial nerve. *Laryngoscope* 98:209-212, 1988
3. Leonetti JP, Brackmann DE, Prass RL: Improved preservation of facial nerve function in the infratemporal approach to the skull base. *Otolaryngol Head Neck Surg* 101:74-78, 1989
4. Niparko JK, Kileny PR, Kemink JL, Lee HM, Graham MD: Neurophysiological intraoperative monitoring. II. Facial nerve function. *Am J Otol* 10:55-61, 1989
5. Kwartler JA, Luxford WN, Atkins J, Shelton C: Facial nerve monitoring in acoustic tumor surgery. American Neurotologic Society Meeting. Palm Beach, Florida. April 1990. Abstract.
6. Dickens JR, Graham SS: A comparison of facial nerve monitoring systems in cerebello-pontine angle surgery. *Am J Otol* 12:1-6, 1991
7. Colletti V, Fiorino FG, Carner M: La conservazione dell'udito nella chirurgia del neurinoma dell'acustico. CRS Amplifon, Milan, 1994.
8. Møller AR, Jannetta PJ: Preservation of facial function during removal of acoustic neuromas. Use of monopolar constant-voltage stimulation and EMG. *J Neurosurg* 61:757-760, 1984
9. Møller AR: Evoked potentials in intraoperative monitoring. Baltimore: Williams & Wilkins, 1988.
10. Kartush J, Niparko J, Bledsoe S: Intraoperative facial monitoring: comparison of stimulating electrodes. *Laryngoscope* 95:1536-1540, 1985
11. Prass R, Luders H: Constant current versus constant voltage stimulation. *J Neurosurg* 62:622-623, 1985
12. Prass RL, Luders H: (Acoustic loudspeaker) facial electromyography monitoring: Evoked electromyographic activity during acoustic tumor resection. *Neurosurgery* 19:392-400, 1986
13. Colletti V, Fiorino FG: Continuous retrograde monitoring of the facial nerve during cerebellopontine angle surgery: Normative data. *Skull Base Surg* 6:47-51, 1996
14. Fischer G, Fischer C, Bremond J: Hearing preservation in acoustic neurinoma surgery. *J Neurosurg* 76:910-917, 1992
15. House JW, Brackmann DE: Facial nerve grading system. *Otolaryngol Head Neck Surg* 93:146-150, 1985
16. Colletti V, Benecke JE: Colour atlas of micro oto neurosurgical procedures. Berlin, Springer Verlag, 1989.
17. Colletti V, Fiorino FG, Carner M: Investigation on electrophysiology and morphology of the human eighth nerve. *Revue de Laryngologie (Bordeaux)* 114:107-111, 1993
18. Colletti V, Bricolo A, Fiorino FG, Bruni L: Changes in directly recorded cochlear nerve compound action potentials (CNAPs) during acoustic tumor surgery. *Skull Base Surg* 4:1-9, 1994
19. Colletti V, Fiorino FG: Vulnerability of hearing function during acoustic neuroma surgery. *Acta Otolaryngol (Stockholm)* 114: 264-270, 1994
20. Beck DL, Atkins JS, Benecke JE, Brackmann DE: Intraoperative facial nerve monitoring: Prognostic aspects during acoustic tumor removal. *Otolaryngol Head Neck Surg* 104:780-782, 1991