Continuous Retrograde Monitoring of the Facial Nerve During Cerebellopontine Angle Surgery: Normative Data

Abstract—An alternative technique for the continuous monitoring of the facial nerve, monopolar recording of facial nerve antidromic potentials (FNAPs), on 10 subjects undergoing retrosigmoid vestibular neurectomy for Meniere's disease is described. To elicit FNAPs bipolar electrical stimulation of the marginalis mandibulae was performed. Stimulus intensity ranged from 0 to 10 mA with a delivery rate of 7/second. Antidromic potentials were recorded with a silver wire monopolar electrode positioned intracranially on the proximal portion (root entry zone) of the acoustic-facial bundle. Bipolar recordings with two silver electrodes were also performed from different nerves in the cerebellopontine angle to define the specific origin of the action potentials. FNAP amplitude increased as a function of stimulus intensity. The average latency was 3.35 milliseconds (range 3.0 to 3.7 ms). Action potentials recorded intracranially during electrical stimulation of the marginal nerve originated specifically from the facial nerve. FNAP recording is therefore a promising technique for the continuous intraoperative monitoring of the facial nerve during cerebellopontine angle surgery. (*Skull Base Surgery*, 6(1):47–51, 1996)

Today, facial nerve (FN) monitoring is routinely employed during cerebellopontine angle surgery and particularly during acoustic tumor removal, where it has been found to significantly improve postoperative facial function.^{1–6} Although motion detector devices have been suggested by some authors^{7,8} for monitoring FN function intraoperatively, electromyographic (EMG) recording from the facial muscles is probably the most commonly used technique. Muscle potentials can be evoked by electrical and/or mechanical stimulation of the facial nerve.^{9,10}

Electrical stimulation yields EMG responses synchronous with the stimuli and is used to identify the FN and assess its function during surgery. To this end, a hand held mono- or bipolar electrical stimulator is used to activate the FN when necessary.⁹

Mechanical stimulation by surgical maneuvers may furnish short bursts of EMG responses or prolonged asynchronous EMG activity ("trains" of responses).⁹ These

responses are currently utilized to perform continuous monitoring of facial function.^{9,10} The EMG activity, as detected visually or by acoustic loudspeaker, alerts the surgeon to the fact that the facial nerve is being damaged and that a change or suspension of surgical maneuvers is necessary. However, this technique presents a number of drawbacks. First, the facial nerve is mechanically sensitive only when it has suffered some degree of injury.¹⁰ Second, using neuromuscular junction blockers, such as atracurium or vecuronium bromide, can make facial muscles unresponsive to mechanical stimulation. A single dose of short- or intermediate-acting relaxant administered at the beginning of the operation may compromise continuous monitoring, while still allowing electrical stimulation of the nerve.¹⁰ Third, EMG monitoring furnishes qualitative information on activation of the FN, but is unable to quantify the degree and mechanism of FN damage. To perform continuous facial nerve monitor-

ing, several alternative methods have been proposed over the past decade, for example, facial brainstem-evoked responses,¹¹ orthodromic (intra/extracranial) facial neurography,¹² and antidromic recording of facial nerve potentials.¹³

Antidromic potentials are of particular interest, as they can explore FN conduction along its entire length, including the intracranial portion before entrance into the brainstem. This technique, proposed by Richmond and Mahla,¹³ consists of electrical stimulation of a peripheral branch of the FN and the intracranial recording of the neural compound action potentials using a bipolar electrode. It is therefore possible to investigate the conduction properties of the facial nerve, identifying the presence of partial or complete conduction block in real time.

The technique, however, is not suitable for continuous monitoring of the FN, owing to major technical difficulties requiring preventive identification of the facial nerve and permanent placement of the bipolar electrode on the nerve. Previous personal experience in intraoperative monitoring has demonstrated that permanent placement of a monopolar electrode in the cerebellopontine angle is quite easy.¹⁴⁻¹⁶ The monopolar recording technique is, in fact, performed successfully in our department and in other institutions¹⁷ to monitor cochlear nerve action potentials during cerebellopontine angle surgery when hearing preservation is indicated.

The specific aim of the present investigation was to extend the technique of direct monopolar recording of action potentials to the monitoring of facial nerve antidromic potentials (FNAPs). The results are described in detail and discussed in two articles. This article, the first, evaluates the specificity of monopolar recording of FNAPs and furnishes normative data. To this end, a group of subjects undergoing vestibular neurectomy (VN) due to Meniere's disease (MD) was investigated. The second article, forthcoming, reports on the application of FNAP recording during acoustic neuroma surgery and investigates its utility in predicting postoperative facial function and in assessing the mechanisms of FN damage.¹⁸

MATERIALS AND METHODS

Ten subjects undergoing VN for MD participated. The patients' ages ranged from 31 to 54 years (mean age 44 years). All operations were performed by the senior author (V.C.) using a retrosigmoid approach.

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 between them was perpendicular to the long axis of the nerve. Biphasic electrical pulses of 50 microseconds duration were delivered seven times per second at an intensity ranging from 1 to 10 mA. Potentials were recorded using a teflon-insulated silver wire monopolar electrode (type Ag

7/10, Merwire Corp.) with approximately 3 millimeters of the distal end uninsulated. The uninsulated portion was bent and embedded with a cotton wick sutured by a 4-0 silk suture.

Vecuronium bromide was used at the beginning of surgery at a dosage of 0.08 mg/kg. The same dosage was repeated according to anesthesiologic needs. The monopolar electrode was placed at the root entry zone of the seventh to eighth cranial nerve complex and was connected up to the negative input of the preamplifier. A positive needle electrode (Type E2, Grass Instruments Co.) placed in front of the contralateral tragus and a ground needle electrode placed halfway between the stimulating and recording electrodes were also employed.

Bipolar recordings from the facial and trigeminal nerves were also performed to rule out the presence of trigeminal-evoked potentials superimposed upon the FNAPs. Two silver electrodes (type Ag 7/10) insulated with teflon up to the exposed ends were utilized for direct bipolar recording. The electrodes were twisted together, inserted in a small polyethylene tube, and fixed to a hand held sharp instrument with adhesive to permit accurate and rapid placement on the nerves. The technique of bipolar recording of action potentials in cerebellopontine angle surgery has been extensively described in previous papers.^{20,21} A compact Amplaid MK15 unit was used for electrical stimulation and recording of potentials. The recorded potentials were filtered through a 30 to 2500 Hz bandpass, amplified (10000 or 20000 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 seconds.

RESULTS

Figure 1 shows typical FNAPs recorded with the monopolar technique from the proximal portion of the acoustic-facial bundle in a subject with MD. Recordings were performed just before VN. Stimulus intensity ranged from 1 to 10 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 latency of the N_1 component, which is an expression of the passage of depolarization under the electrode, was 3.0 milliseconds at all stimulation intensities. As expected, the amplitude increased as a function of stimulus intensity.

The average FNAP threshold was 0.8 mA (range, 0.5 to 1.5 mA). The averaged latency of FNAPs elicited at 5 mA in all investigated subjects was 3.35 milliseconds (range, 3.0 to 3.7).

A series of monopolar recordings obtained before VN from different sites in the cerebellopontine angle, using a 5 mA stimulation intensity, are shown in Figure 2. As expected, recording from the distal portion of the

Figure 1. Intraoperative monopolar recording of FNAPs in a subject undergoing vestibular neurectomy. Stimulus intensity ranging from 1 to 10 mA.

nerve, close to the porus of the IAC, furnished shorter latencies compared with the recordings from the proximal portion of the nerve. Interestingly, potentials could also be recorded when the electrode was not in contact with the acoustic-facial bundle, that is, on the internal auditory canal wall, on the mixed nerves, or on the cerebellum. These potentials were of lower amplitude compared with the potentials recorded directly on the nerve.

Figure 2. Intraoperative monopolar recording of FNAPs from different sites in the CPA in a subject undergoing vestibular neurectomy. Stimulus intensity: 5 mA.

Figure 3 shows a series of recordings obtained just before and immediately after administration of 6 mg of vecuronium bromide to a subject with muscle responses from the mentalis muscle. Two waveforms were recorded: the first was sharper, with a small amplitude and a latency of 3.5 milliseconds, while the second was broader and larger with a latency of 6.5 milliseconds. Immediately after administration of the muscle relaxant the second broad component originating from the muscles disappeared, whereas the first waveform persisted.

Bipolar recording was performed just after VN from the trigeminal and the facial nerves using different stimulus intensities, that is, 1 to 10 mA. Figure 4 shows the FNAPs obtained with bipolar recording from the facial nerve in one of the subjects investigated. Action potentials with a typical biphasic morphology were obtained. Potentials presented a threshold of 1 mA and increased in amplitude as a function of the stimulus intensity. No responses were detected when recording from the trigeminal nerve (Fig. 5).

Bipolar recordings from different sites along the axis of the facial nerve allowed for calculation of the conduction velocity of the nerve. Figure 6 shows two recordings obtained from the distal and the proximal portions of the nerve, approximately 1 cm apart. The difference in latency between the recordings was 0.3 milliseconds, with the distal one presenting the shorter latency. The differences in latency obtained when placing the bipolar electrode on two different levels of the FN is plotted in Figure 7. The latency shift showed a close correlation ($p < 0.001$) with the distance between the electrodes ($r = 0.98$) and the mean conduction velocity was 42 meters per second.

Figure 3. Intraoperative monopolar recording of FNAPs in a subject undergoing vestibular neurectomy before and after administration of 6 mg of vecuronium bromide. The neurogenic response (FNAPs) is indicated by the arrow. Stimulus intensity: 3 mA.

Figure 4. Intraoperative bipolar recording from the facial nerve in response to electrical stimulation of the marginal nerve in a subject undergoing vestibular neurectomy. Stimulus intensity ranging from 1 to 10 mA.

DISCUSSION

Electrical stimulation of the peripheral portion of a nerve activates orthodromic and antidromic responses. Facial nerve antidromic potentials can be recorded using a monopolar electrode placed in the cerebellopontine angle

Figure 5. Intraoperative bipolar recording from the trigeminal nerve in response to electrical stimulation of the marginal nerve in a subject undergoing vestibular neurectomy. Stimulus intensity ranging from 1 to 10 mA.

Figure 6. Intraoperative bipolar recording of FNAPs from the distal and proximal portions of the facial nerve, 9 mm apart. Stimulus intensity: 5 mA.

in contact with or close to the nerve and with the stimulating electrode on the marginal nerve.

Several arguments suggest that these potentials originate specifically from the intracranial portion of the facial nerve. For instance, FNAPs have an average latency of 3.35 milliseconds (range, 3.0–3.7), which is the value expected assuming a conduction velocity of 42 meters per second. In fact, the distance from the site of electrical stimulation to the recording electrode is approximately 15 cm, the extratemporal portion of the facial nerve being 10 cm, the intratemporal portion 2.8 cm, and the intracranial segment 2.2 cm including the internal auditory canal. The FNAP propagation velocity value of 42 meters per second was confirmed in the present investigation by bipolar recordings from different sites in the intracranial portion of the FN. This value closely resembles the findings of Kitani and Yanagihara¹⁹ and of Møller and Jannetta²⁰ who recorded FNAPs from the auditory canal and the auditory nerve, respectively. Bipolar recording is an extremely specific technique currently utilized in our department during cerebellopontine angle surgery for the electrophysiologic identification of the cochlear nerve fibers and their cleavage plane with the surrounding structures.^{21,22} Bipolar recording of FNAPs from the proximal portion of the facial nerve yielded potentials with latencies corresponding to those obtained with monopolar recording. In addition, potentials were detected only when probing the facial nerve and were absent when recording from the trigeminal nerve.

Finally, use of a muscle relaxant abolished a 6.5 millisecond latency response, which can be attributed to activation of facial muscle, while leaving a shorter latency (3.5 milliseconds) response unchanged, a response

Figure 7. Differences in FNAP latency vs distance in bipolar electrode position along the intracranial portion of the facial nerve (18 measurements in 10 subjects using a stimulus intensity of 5 mA).

which was presumably neurogenic. These outcomes suggest a remarkable specificity of antidromic FNAPs, at least for stimulation intensities not exceeding 10 mA. Richmond and Mahla¹³ used a stimulation intensity of 19.9 mA which was probably strong enough to activate also the trigeminal fibers in the area stimulated. The use of bipolar recording of FNAPs was thus necessary to reduce the spread of electrical current and be more selective, ruling out the possible contamination of trigeminal-evoked potentials.

The present study shows that intracranial monopolar recording of FNAPs is highly sensitive and specific in recording the activity of the entire route (extratemporal, intratemporal, and intracranial) of the facial nerve. It provides real-time information about the conduction velocity and integrity of this nerve. The possibility of performing monopolar recording of antidromic FNAPs makes this technique a potentially useful tool in the continuous monitoring of the facial nerve during posterior fossa surgery.

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