Electroneurography: Electrical Evaluation of the Facial Nerve

Douglas L. Beck*
James E. Benecke†

Abstract
This article provides an introduction, anatomic considerations, and description of technique for the performance of electroneurography. Two case studies are provided as illustrations.

Key Words: Electroneurography (ENoG), evoked electromyography (EEMG), facial nerve, paralysis

Electroneurography is used to determine the physiologic status of the facial nerve. The term electroneurography (ENoG) refers to the electrical stimulation of the facial nerve. Another term used to describe the same test is evoked electromyography (EEMG). This term refers to the motoric response resulting from electrical stimulation of the facial nerve.

ENoG is easily accomplished in the office and requires no anesthesia. It is noninvasive, quick, efficient, and highly reliable. ENoG is an objective measure of facial nerve function and is interpreted within the context of the clinical presentation and the patient’s relevant history.

The purpose of ENoG testing is to quantify the percentage of facial nerve fibers that are electrically stimulable. The patient serves as the control because the weak side is compared to the normal side. ENoG accurately approximates the percentage of functioning nerve fibers based on the amplitude of the motoric response. ENoG helps the physician to differentiate between facial nerve diagnoses, and to implement an effective management strategy designed to facilitate facial motion as soon as possible (Hughes, 1990).

The facial nerve is familiar to the audiologist as it is a prominent factor in the impedance audiometry reflex arc. A loud sound presented to either ear elicits a bilateral acoustic reflex, which is measured and can contribute to the differential diagnosis.

The reflex arc is dependent on the patient’s hearing, auditory nerve, brain stem, and facial nerve for the normally present stapedial muscle contraction. With normal hearing and a facial nerve lesion peripheral to the stapedial branch of the facial nerve, the reflex will be normal even though the patient’s face may be paralyzed (Moller, 1987).

In otology, neurotology, and otolaryngology, patients present with facial nerve injury, weakness, or paralysis. A paralyzed face is debilitating (Pulec, 1974; Luxford and Brackman, 1985). Diagnosis and treatment of facial nerve disorders are most successful when approached in a timely manner.

Bell’s palsy is only one possibility in the differential diagnosis of facial paralysis. Other causes include: temporal bone fracture, facial nerve neuroma, herpes zoster oticus, otitis media, mastoiditis, chickenpox, mumps, cholesteatoma, glomus jugulare, meningioma, and iatrogenic paralysis.
WHEN TO TEST

The timing of the test relative to the onset of facial paralysis is important (Gantz, 1984). There is only a small window of opportunity during which the ENoG offers reliable and useful information.

The test must not be performed too early or too late. Wallerian degeneration of the facial nerve requires 72 hours to completely deactivate the nerve (Gantz, 1987). Testing prior to completion of Wallerian degeneration may lead to an incorrect (usually overly optimistic) conclusion.

An ENoG on the first day following onset of facial paralysis is likely to show a high percentage of intact fibers, despite total facial paralysis. In this situation, the ENoG quantifies the insult before total damage has been done. It is likely that an ENoG performed on the second or third day would show further deterioration. A test after 72 hours would be more representative of the complete injury. Similarly, testing after 21 days is of limited use. Even a good (50%) ENoG obtained after the 3-week window offers questionable prognostic information.

ENoG protocol requires a timely, repeatable test, and an immediate report to the treating physician. The audiologist and physician must work quickly to test, interpret, and manage the patient with a facial nerve disorder.

REPORT GUIDELINES

Although the audiologist does not make the diagnosis or surgical decisions, these decisions are often based on the information provided via the ENoG report. It is important to be aware of the information that our medical colleagues need to appropriately and effectively manage the patient.

In reporting the ENoG result, the quantity of electrically stimulable fibers of the paralyzed side, as a percentage of the normal side is provided.

When comparing both sides of the face, most normal adults produce ENoGs that are within 20 percent of each other.

For example, suppose a patient is referred for an ENoG evaluation, 1 week post onset of left facial paralysis. The ENoG reveals the healthy (normal) response to be 3500 microvolts and the paralyzed side to be 700 microvolts. This is reported as “Left = 20% Right.” The left side ENoG amplitude was determined to be 20 percent of the right side. An alternative notation would be that the left side is 80 percent denervated.

In the above example, the test may be repeated 4 or 5 days later. The second test reveals if the nerve has remained stable, is more stimulable, or less stimulable. If the second test shows that the weak side has decreased in function to less than 10 percent of the healthy side, this is a “red flag.” The physician must be notified immediately. It has been shown that a quickly scheduled facial nerve decompression, on an appropriate patient, is of far greater benefit than the identical procedure performed at a later date (Fisch, 1974). If the ENoG shows that a higher percentage of fibers are stimulable (e.g., 1750 microvolts, or 50%), a good prognosis is anticipated and the patient is followed.

ENoGs may be ordered every 4 or 5 days until a plateau is seen, voluntary motion is initiated, or as ordered by the physician. It is important to follow these patients to resolution.

FACIAL NERVE GRATING SCALE

Attempts to categorize facial nerve function have varied greatly. In essence, normal facial motion is defined by voluntary control of all the muscle groups on the ipsilateral side of the face. Facial paralysis is the total inability to control muscles on the ipsilateral face. Facial weakness refers to the degrees of disability between normal motion and paralysis. Although these three basic categories give a gross impression of facial nerve disorder, they are inexact categorizations and should not be used.

The House-Brackmann (HB) facial nerve grading system (House and Brackmann, 1985) is an effective and efficient tool used to describe facial presentations (Table 1).

TYPES OF FACIAL NERVE INJURY

Different types of facial nerve injury are consistent with various ENoG results. Professor Ugo Fisch has provided extensive analysis and descriptions of these injuries (Fig. 1) (Fisch, 1980).

Neurapraxia describes a paralysis without peripheral degeneration. It is usually reversible. Neurapraxia is the phenomenon associated with Bell’s palsy.

Axonotmesis describes an inner nerve disorder. Individual inner nerve fibers are damaged extensively and complete peripheral degeneration occurs. The outer casing (epineurium)
Table 1  Facial Nerve Grading System

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal</td>
<td>Normal facial function in all areas</td>
</tr>
<tr>
<td>II</td>
<td>Mild dysfunction</td>
<td>Gross: slight weakness noticeable on close inspection; may have very slight synkinesis At rest: normal symmetry and tone Motion Forehead: moderate to good function Eye: complete closure with minimum effort Mouth: slight asymmetry</td>
</tr>
<tr>
<td>III</td>
<td>Moderate dysfunction</td>
<td>Gross: obvious but not disfiguring difference between two sides; noticeable but not severe synkinesis, contracture, and/or hemifacial spasm At rest: normal symmetry and tone Motion Forehead: slight to moderate movement Eye: complete closure with effort Mouth: slightly weak with maximum effort</td>
</tr>
<tr>
<td>IV</td>
<td>Moderately severe dysfunction</td>
<td>Gross: obvious weakness and/or disfiguring asymmetry At rest: normal symmetry and tone Motion Forehead: none Eye: incomplete closure</td>
</tr>
<tr>
<td>V</td>
<td>Severe dysfunction</td>
<td>Gross: only barely perceptible motion At rest: asymmetry Motion Forehead: none Eye: incomplete closure Mouth: slight movement</td>
</tr>
<tr>
<td>VI</td>
<td>Total paralysis</td>
<td>No movement</td>
</tr>
</tbody>
</table>


remains intact and may serve as a conduit for regenerating fibers. Recovery can be expected and may lead to a good quality outcome.

**Neurotmesis** is a total separation of the nerve. These are complete anatomic separations and the prognosis is poor.

ENoG can detect neurapraxia. ENoG cannot differentiate between axonotmesis and neurotmesis.

**PATIENT PREPARATION**

Before testing, the patient is informed as to the nature of the test. The test is described in detail to the patient and a demonstration of the electrical stimulation may be offered (the first author has stimulated his own facial nerve hundreds of times by way of demonstration).

If the patient has a pacemaker or any medical condition that may contraindicate an electrical test, the appropriate medical personnel must be consulted, and a written authorization obtained. We do not know of any patient being harmed by ENoG testing.

**STIMULATION PARAMETERS**

The stimulation system is electrically calibrated to present an electrical stimulus of known parameters. As the goal here is to assure that all viable neural fibers are being electrically stimulated, the stimulation protocol is often approached by a "stimulate, evaluate, increase, repeat" paradigm. If the evaluation phase reveals a plateau in the response amplitude (defined as no further increase in response amplitude with an increase in stimulation current), a 10 to 20 percent increase in current is applied and used as the final stimulation level.

In our practice, when testing most alert, adult patients we use a hand-held bipolar stimulator. Our nominal starting current is 30
Peripheral Facial Paralysis
Electrodiagnosis and Prognosis of Facial Nerve Lesions

Reversible Conduction Block (Neurapraxia)
Very Good Prognosis

Degeneration
1. Endoneural Tube Intact (Axonotmesis)
2. Endoneural Tube Severed (Neurotmesis)

Good Prognosis
Bad Prognosis

to 35 milliamps with a 150 microsecond pulsewidth. After the initial evaluation is completed, we increase the current by 5 milliamps and look for a response plateau. We do not test above 40 milliamps.

STIMULATION PREPARATION

A nonconductive (nonmetal) chair is provided for the patient. The stimulus sites are cleaned using an alcohol pledget. Make-up, perspiration, and dirt may increase electrical impedance. Although a clean stimulus site is desired, we do not abrade the skin at the stimulation site.

A drop of electrolyte gel is placed on the anode and the cathode of the stimulator. Too much gel can cause a salt bridge, or a path for shunting. Insufficient gel renders high skin impedance, potentially activating more pain receptors and resulting in an unsatisfactory result.

We instruct patients to close their eyes and teeth gently. We tell them that the first pulse will feel like a small bee sting. We request that they allow their face to twitch, that is, not to fight the response. If the patient is unable to tolerate the stimulation, the current is reduced to 30 milliamps and the pulse width is reduced to 100 microseconds. Typically, pain is more highly related to pulse width than to current level.

RECORDING ELECTRODE MONTAGE

A three-electrode system is used to record the ENoG. The nasal ala serves as the ipsilateral active (−) recording site. The active electrode is referenced to a noncephalic C7 (+) reference site. The contralateral nasal ala serves as the common (or ground) site.

RECORDING PREPARATION

Traditionally, the nasolabial fold has been used as the recording site for bipolar recordings (Smith et al, 1988). Research and our own verification has demonstrated that cleaner, more highly repeatable waveforms are obtained using the above described nasal ala protocol (Gutnick et al, 1990; Kelleher et al, 1990). As the ENoG response is robust, it is not necessary to average these recordings. However, we recommend two or three repetitions of each trace to ensure repeatability.

Prior to attachment of the recording electrodes, the skin is cleaned with an alcohol pledget, and minimally abraded with Omni-prep. Cup electrodes (standard ABR type) are filled with electrolyte gel and are securely taped to the prepared recording sites (Fig. 2). Smaller electrodes may yield a better response.

RECORDING ANALYSIS

The latency of the ENoG has not proven to be a reliable indicator of facial nerve status. Amplitude is the primary measure describing the waveform. By convention, ENoG is displayed and measured with the first peak upward. The peak-to-peak amplitude is measured and recorded from the early positive peak to the subsequent negative peak.
CASE STUDIES

Case 1: Bell’s Palsy

The patient is a 39-year-old female. She presents with a left facial paralysis, 5 days post onset. The otologist assigned her a grade VI (House-Brackmann) facial presentation, and reported the rest of her otolaryngologic examination as normal. The patient was referred for a complete audiometric evaluation and electroneurography.

The audiometric evaluation revealed normal hearing bilaterally. The patient demonstrated speech reception thresholds and pure-tone averages within normal limits bilaterally. Word recognition scores were excellent bilaterally with masking in the non-test ear (Fig. 3).

Impedance audiometry revealed type A tympanograms bilaterally. Acoustic reflex testing revealed normal ipsilateral and contralateral responses when measuring from the right ear. When measuring from the left ear, the ipsilateral response was elevated at 2000 Hz, contralateral stimulation showed an elevated reflex at 500 Hz and no response at 1000 and 2000 Hz (see Fig. 3).

The patient was instructed and prepared. It was confirmed that the patient did not have any electrical devices surgically implanted (such as a pacemaker). Electroneurography was performed.

Electroneurography revealed that the normal (right side) response was 3559 microvolts. This response was repeated several times and found to be repeatable (Fig. 4). The left side revealed a response of 2825 microvolts. This response was repeated several times and found to be reliable. The ENoG was reported as, “AS (left) = 79% AD (right).” The patient was referred back to the otology department for follow-up and management. The otologist determined that this response was consistent with
neurapraxia and the diagnosis of Bell's palsy was made. A repeat ENoG was ordered for 7 days later. The repeated ENoG was similar to the original test. The patient began to regain facial motion on the left side 6 weeks post onset (typically repeated ENoGs are not ordered after visible improvement has occurred).

Case 2: Facial Nerve Trauma

The patient is a 24-year-old male with blunt trauma to the left side of his skull. The patient presented to us 7 days post trauma with facial paralysis and hearing loss. A CT scan demonstrated a left temporal bone fracture.

The audiometric evaluation revealed essentially normal hearing in the right ear with a small decrease in sensitivity at 6000 Hz (30 dB). The left ear presented with a mixed hearing impairment.

The speech reception thresholds were consistent with the pure-tone findings. The word recognition scores were good to excellent bilaterally with masking in the nontest ear. Impedance audiometry revealed a type A (normal) tympanogram on the right side, and a type B (flat) tympanogram on the left side. The only reflexes present were the right ipsilateral (Fig. 5).

Electroneurography revealed that the normal (right) side had a robust, repeatable response measured as 3303 microvolts.

The left side was not stimulable using our standard recording and stimulation protocol. An attempt was made to stimulate the individual branches of the facial nerve using a distal stimulation site, and by individually stimulating the upper and lower branches of the facial nerve. No responses were obtained on the left side (Fig. 6).

The patient was referred back to the otology department for consultation and management. A repeat of the ENoG test was ordered and performed 4 days later. The second test confirmed the findings of the original test. No response was obtained on the injured side. The otologist discussed the findings and treatment options with the patient. A combined middle fossa/mastoid surgical decompression was elected.

At the time of surgery, the otologist found that the geniculate ganglion had been crushed by a small bony fragment. This was removed and the patient's postoperative course was uneventful. Facial function slowly returned over the next 8 months and the patient did achieve an excellent (grade I) result.

**SUMMARY**

Electroneurography is part of the armamentarium used to assess facial nerve integrity. ENoG is noninvasive, quick, and efficient in determining the percentage of stimulable fibers of the facial nerve. ENoG helps to establish a differential diagnosis and a likely prognosis. ENoG is well established as the "gold standard" for facial nerve analysis.

**REFERENCES**


