Intraoperative electrooculographic monitoring of oculomotor nerve function during skull base surgery

Technical note

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Intraoperative monitoring techniques for protecting the integrity of the oculomotor nerves during skull base surgery have been described by several investigators, all of which involved the use of electromyographic (EMG) responses of extraocular muscles, have been described by several investigators. However, these techniques have not yet become popular because of the complexity of the procedures. The authors report an extremely simple and far more reliable technique in which electrooculographic (EOG) monitoring is used. The oculomotor nerves were stimulated with a monopolar electrode during skull base exposure. The polarity of the EOG responses recorded with surface electrodes placed on the skin around the eyeball yielded precise information concerning the location and function of the oculomotor and abducent nerves. In addition, with the aid of continuous EOG monitoring that detected transient changes in the background waves, surgical procedures that might impinge on oculomotor nerve function could be avoided. The present technique has been used in eight patients with skull base tumors and with it, the authors have achieved excellent results.

Key Words • oculomotor nerve • electrooculography • skull base surgery

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Intraoperative Technique

Anesthesia. Anesthesia was induced in the patient by intravenous administration of propofol. Muscle relaxants were given only to facilitate intubation. Generally, propofol was administered at a dose of approximately 10 mg/kg/hour during surgery and a bolus injection of 1 or 2 μg/kg of fentanyl was added on the basis of the patient’s heart rate and blood pressure.

Stimulation Technique. A monopolar stimulator was used to stimulate the cranial nerves during surgery. The tip diameter of this stimulator is 0.75 mm, and it is made of malleable silver. The portion 7 cm from the head of the stimulator can be bent, as necessary, to allow the stimulator to reach a deep, narrow operative field.

Cathodal stimulation was performed through this electrode, and an anodal electrode was placed on frontozygomatic bone. Rectangular pulses of 0.2-msec duration were applied at a repetition rate of three times per second. The maximum stimulus intensity was 3 mA in the present study.

Recording Technique. Surface electrodes were placed on the skin around the eyeball. For Channel 1, the active electrode was placed on the right side and the reference electrode on the left side. For Channel 2, the active electrode was placed on the upper side of the eyeball and the reference electrode on the lower side. However, in four recent cases, we have used only the electrodes on the bilateral sides. In fact, based on our experience, two horizontal electrodes are sufficient to identify the oculomotor nerve and abducent nerve. Under these conditions, movements of the eyeball toward the right side induce a positive wave on the oscilloscope, whereas movements toward the left side induce a negative wave. The surface electrodes used here were not special in any way; ordinary electrodes can be used. In the present study, we applied surface electrodes that were identical to those used for electrocardiograms. The bandpass was established from 5 Hz to 3 kHz, and no signal procession was needed.

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Representative Case
This 50-year-old woman with a large meningioma in
the left petroclival region underwent tumor removal
through a combined transpetrosal approach. Surface elec-
trodes were placed on the skin around her left eyeball.
When the surgeon stimulated the oculomotor nerve, a
clear monophasic positive wave, with a high reproduc-
ibility, was noted on EOG monitoring, indicating ocular
movement toward the right side. Stimulation of the abdu-
cent nerve elicited a clear negative monophasic wave (Fig.
1). This indicated ocular movement toward the left side.
Stimulation of the trochlear nerve, however, elicited no
evident EOG response.
Furthermore, EOG changes indicating ocular move-
ment could be recorded as intermittent polyphasic waves
when the surgeon manipulated the abducent nerve (Fig.
2). These findings helped us to avoid any damage to the
abducent nerve during tumor resection, especially when
the tumor was dissected from the region of Dorello’s ca-
nal. Similar observations were made in the other seven pa-
tients. It was possible to verify the location of the oculo-
motor and abducent nerves in all of the eight patients. In
five patients, transient changes in the background EOG
responses were elicited by surgical procedures that might
have impinged on oculomotor nerve function and serious
damage to the oculomotor nerves was avoided. No patient
experienced any deterioration of ocular movement post-
operatively.

Discussion
Techniques for the intracranial stimulation of cranial
nerves have been described by several investigators. Be-
cause monopolar stimulation is more practical in a narrow
operative field and generally provides a higher spatial
resolution compared with bipolar stimulation, we used
monopolar stimulation. It appears reasonable to assume,
however, that bipolar stimulation can yield similar results.
Among the techniques for intraoperative monitoring of
oculomotor nerves that have so far been reported, all have
made use of EMG responses recorded from extraocu-
lar muscles by means of needle1,2,4 or special ring elec-
trodes.5,6 The extraocular muscles are exceedingly thin
and are located in the deep part of the orbit, which must
be reached in a virtually blind fashion. Thus, precise ins-
ertion of needle electrodes requires skill. These techniques
involve an invasive procedure to some extent and require
time and special tools for preparation. Inappropriate prep-
paration often leads to insensitive recordings and uncer-
tainty in the interpretation of the observed EMG re-
sponses.
An electrical potential difference exists between the
cornea and retina, which reaches approximately 1 mV in
humans when measured by means of electrodes placed on
the skin.7 The eyeball may thus be regarded as a kind of
rotatable battery situated within a conducting medium.5
Electrooculographic monitoring reflects changes in this
potential caused by movement of the cornea–retina axis
and has been used for many years in other fields of medi-
cine as a means of detecting ocular movements.
As compared with EMG monitoring of extraocular
muscles, EOG recording has many advantages when used
as a technique for the intraoperative monitoring of oculo-
motor nerve function. First, it involves very simple nonin-
vasive procedures. Second, EOG responses to stimulation
of oculomotor nerves can be detected sensitively and con-
sistently, even if there are some variations in electrode
placement. Third, the polarity of the EOG responses pro-
vides exact information concerning which part of the ocu-
alomotor nerve and abducent nerve is stimulated. Finally,
surgical procedures impinging on the oculomotor nerve
are instantaneously reflected in either transient or per-
sistent changes in the background EOG response. These
characteristics of EOG recording meet perfectly the re-
quirements for any nerve function monitoring.
The lack of discernible EOG responses to stimulation of
the trochlear nerve appears to reflect the way the trochlear
nerve acts on the eyeball. The trochlear nerve imparts ro-
tational movement to the eyeball around the cornea–reti-
a axis. Such movement would not be detected by EOG
monitoring, because there is minimal change in the posi-
tion of the cornea–retina axis itself. Impairment of troch-
lear nerve function has been reported to cause no serious
impact on the patient’s daily life.4 Thus, difficulty in mon-
itoring trochlear nerve function does not seriously detract
from the clinical value of the present technique. In con-

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![Fig. 1. Electrooculographic recordings showing that when the surgeon stimulated the oculomotor nerve intracranially in the left eyeball, an ocular movement toward the right side was induced. It yielded a clear positive wave with a high reproducibility. Likewise, when the surgeon stimulated the abducent nerve, an ocular movement toward the left side was induced. It yielded a negative wave.](image1)

![Fig. 2. Electrooculographic recordings showing spontaneous ocular movements recorded as intermittent polyphasic waves when the surgeon manipulated (during dissection from the tumor) the abducent nerve (indicated by horizontal bar).](image2)
Oculomotor nerve monitoring

Conclusion, EOG monitoring appears to be a most useful technique for tracking the intraoperative oculomotor nerve function during skull base surgery.

References


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