Monitoring visual evoked potentials during retraction of the canine optic nerve: protective effect of unroofing the optic canal

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To evaluate the effects of unroofing the optic canal during retraction of the optic nerve, the authors monitored changes in visual evoked potentials (VEPs) stimulated by a light-emitting diode in the canine model. At rest, an early VEP wave was reliably observed with an amplitude of 8.2 ± 0.6 μV and a latency of 51.5 ± 0.7 msec; this wave was named N50. The intracranial optic nerve was retracted using a weight of 5, 10 or 50 g. The earliest change in VEP noted during retraction was a reduction in N50 wave amplitude. The length of time required until N50 amplitude decreased to 50% of the control group (T50) was 10.7 ± 1.8 minutes with a weight of 5 g, 4.9 ± 0.7 minutes with 10 g, and 2.9 ± 0.4 minutes with 50 g, with statistically significant differences between the groups. Retraction of the optic nerve with all weights finally resulted in the disappearance of the N50 wave. The amplitude of the N50 wave recovered fully to control size when retraction was released immediately after the wave disappeared. The time course of amplitude recovery did not differ significantly between groups. Unroofing the optic canal prolonged the T50 during retraction significantly to 20.7 ± 2.9 minutes with a weight of 5 g, 18.9 ± 4.2 with 10 g, and 9.0 ± 2.4 with 50 g. These results demonstrate that unroofing the optic canal can protect the optic nerve from damage during operations that require optic nerve retraction.

KEY WORDS • visual evoked potentials • optic nerve retraction • unroofing of optic canal

Materials and Methods

Animal Preparation

Forty-three conditioned mongrel dogs of both sexes, weighing 8 to 12 kg, were anesthetized by intramuscular injection of 10 mg/kg ketamine hydrochloride followed by intravenous administration of 5 mg/kg thiopental sodium. Thiopental sodium was selected because barbiturate drugs have been shown to produce fewer effects on VEPs. All dogs were intubated and mechanically ventilated. A femoral vein and artery were cannulated for fluid replacement and drug administration, as well as for monitoring blood pressure and arterial blood gases, respectively. Neuromuscular blockade was induced by intravenous administration of 0.1 mg/kg pancuronium bromide. Rectal temperature was maintained between 38.5°C and 39.5°C. Arterial blood was analyzed intermittently throughout the experiments with the ventilator adjusted to maintain PaO₂ at 110 ± 10 mm Hg, PaCO₂ at 26 ± 4 mm Hg, pH at 7.40 ± 0.05, and bicarbonate at 15 to 19 meq/L. Mean arterial blood pressure was maintained between 80 and 120 mm Hg.

Animals were placed prone with their heads rotated 30° to the left. Following resection of the temporal muscle and the zygoma, a low right frontal craniectomy was performed. A right occipital craniectomy was also made to insert the electrodes. Using an operative microscope, the dura mater was opened over the frontal lobe and the lobe was retracted gently. The arachnoid membrane over the optic nerve and ophthalmic artery was opened in a bloodless field, and an L-shaped stainless steel wire, 1 mm in diameter, was placed under the right optic nerve (Fig. 1A). After recording control VEPs, the optic nerve was retracted upward using a counterweight of 5, 10, or 50 g.
Unroofing the optic canal was initiated at least 1 hour after full recovery of VEPs. The canal was unroofed completely to the orbital apex using a high-speed electric drill with a diamond head and the dural sheath over the intracranial and intracanalicular optic nerve was opened (Fig. 1B). Because the dural sheath adheres tightly to the optic nerve and the ophthalmic artery crosses over the optic nerve in the canal, there is danger of injuring the optic nerve when opening the sheath and thus impairing evoked responses. In 17 animals, the optic nerve sheath was successfully opened, and the optic nerve was retracted with the same weight used prior to unroofing to compare VEPs before and after unroofing.

**Visual Evoked Potentials**

Red light–emitting diodes (LEDs) situated inside opaque goggles were used to generate reliable responses. A recording electrode was placed in the epidural space over the right occipital lobe near the confluens. A reference electrode was placed on the ipsilateral earlobe. The animal was grounded in the nose and electrode impedance was contained at less than 5 kohm. Pupils were dilated by a topical application of atropine sulfate. Stimuli to the right eye were delivered from an array of 10 LEDs set at 1 Hz with each diode having a peak intensity of 600-nm candellas. The left eye was tightly covered to isolate it from the flash and the responses were recorded.* Filters were set to yield band pass from 5 to 100 Hz. After confirming a background electroencephalogram, recording of VEPs was begun and one hundred responses were analyzed for 200 msec each and averaged. At the beginning of each experiment, three consecutive waves were recorded to confirm that the responses were reliable and reproducible. Visual evoked potentials were recorded every 2 minutes throughout the whole procedure. At the end of each experiment, the optic nerve was incised to confirm flat VEPs without artifacts.

**Statistical Analysis**

Data were expressed as mean ± standard error. Time–amplitude relation curves were compared using two-way analysis of variance followed by the Scheffé's t-test. The time that elapsed until the amplitude of N50 decreased to 50% of the control level was expressed as T50. This number was compared between the groups using the Wilcoxon two-sample test and the Kruskal-Wallis test.

*Neuropack Four manufactured by Nihon Koden, Tokyo, Japan.

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**Results**

In our experiments, we found a reliable and reproducible peak in the VEP at approximately 50 msec in all animals; we named this peak N50. Other peaks varied both in amplitude and latency between individuals. The mean amplitude of the N50 at rest was $8.2 \pm 0.6 \mu V$, and its mean latency was $51.5 \pm 0.7$ msec. We have confirmed that under experimental conditions, with no optic nerve retraction, no change in N50 occurred over a 5-hour period (data not shown). In all animals, the first change noted during retraction of the optic nerve was a reduction in N50 amplitude, which continued to decrease in all dogs. Increases in N50 latency were found in only a few animals. In view of these results, we focused on the amplitude of N50 for this study. To compensate for variations in N50 amplitude between individuals, amplitudes measured were expressed as percentage of control amplitude before optic nerve retraction.

A typical time course of VEP responses to retraction is shown in Fig. 2. Retraction of the optic nerve by weights of 5, 10, or 50 g reduced the amplitude of N50 proportionately (Fig. 3). There were statistically significant differences in the three curves: VEP amplitude decreased gradually, disappearing entirely within 20 minutes using 5-g or 10-g retraction and within 10 minutes using 50-g retraction. The T50 also differed significantly between the three groups: $10.7 \pm 1.8$ minutes with 5-g, $4.9 \pm 0.8$ minutes with 10-g, and $2.9 \pm 0.4$ minutes with 50-g retraction (Table 1).

After successfully unroofing the optic canal, the N50 response did not differ from controls; N50 amplitude was $8.0 \pm 0.6 \mu V$ and its latency was $52.0 \pm 0.9$ msec after unroofing. As shown in Fig. 4 and Table 1, unroofing the optic canal significantly lengthened the time required to reduce N50 amplitude in all three weight groups. The T50 was also increased by two to three times after unroofing the optic canal. When retraction was released immediate-
The visual cortex respond. Mammals have a high concentration of cones in the area centralis. The cones are preferentially responsive to red light, and consequently, LEDs maximize VEPs.\textsuperscript{17} On the other hand, cortical neurons are insensitive to diffuse light,\textsuperscript{12} and, therefore, pattern reversal evoked potentials (shifting black and white squares in a chessboard pattern) yield more reproducible responses than diffuse flash stimulation.\textsuperscript{7,15} Unfortunately, intraoperative use of pattern-reversal VEPs is impossible in anesthetized patients.

Intraoperative monitoring of VEPs has been controversial.\textsuperscript{5,9} There have been clinical reports of monitoring during surgery on parasellar lesions that suggest that monitoring is useful and has prognostic value.\textsuperscript{1,14,20} On the other hand, LED VEPs can be susceptible to a variety of non-specific influences, especially those of volatile anesthetics.\textsuperscript{4,6} In addition, VEPs vary in amplitude and latency both within one individual’s responses and between individuals, and there is no correlation between intraoperative changes of VEPs and postoperative visual function.\textsuperscript{4,10} This is probably due to the participation of the non-specific visual network in VEP generation that is markedly affected by anesthesia, blood pressure, body temperature, and blood gas changes.\textsuperscript{3,12} These factors must be stabilized to obtain reliable VEPs.

In experimental use, VEPs have proved to be a reliable monitor of visual system and cerebral function.\textsuperscript{2,8,16,17,19} The number and latency of reported peaks vary in these reports, probably due to varying experimental conditions. In our experiments we found one reliable negative peak at approximately 50 msec (N50). This peak showed a shorter latency than that reported by Aunon,\textsuperscript{2} and may correspond to the peak reported by Sims,\textsuperscript{17} In both clinical and experimental work, including this study, acute manipulation of the optic pathway reduced peak amplitude and lengthened the latency of VEP waves\textsuperscript{4,6,21} or abolished them,\textsuperscript{10} probably because of transient abnormalities in axon conduction secondary to ischemia.\textsuperscript{20,21} These changes in VEPs can usually be reversed by ceasing the manipulation and preserving visual function.\textsuperscript{1,6,21}

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<thead>
<tr>
<th>Retraction Weight</th>
<th>Before Unroofing</th>
<th>After Unroofing</th>
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<tbody>
<tr>
<td>5 g</td>
<td>10.7 ± 1.8</td>
<td>20.7 ± 2.9†</td>
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<tr>
<td>10 g</td>
<td>4.9 ± 0.8*</td>
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<tr>
<td>50 g</td>
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<td>9.0 ± 2.4†</td>
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* p < 0.01 compared with the T50 at 5-g retraction before unroofing.
† p < 0.05 compared with the T50 at the same weight before unroofing.
Effect of optic canal unroofing

Although VEPs are too sensitive to predict the final effects of trauma on visual function, changes in amplitude and latency observed in them probably provide an early indication of reversible damage to the visual system. The force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22 Our data demonstrated that the force of retraction in this study was similar to that used for retraction of the brain.11,22

Unroofing the optic canal has been used to relieve optic nerve compression. In addition, it is an important step for a longer time after unroofing the optic canal. These effects were observed during retraction with all weights tested. Thus, our data suggest that the optic nerve can be retracted safely for a longer time after unroofing the optic canal.

References


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