Intraoperative Monitoring of the Integrity of the Anterior Visual Pathways: A Methodologic Review and Meta-Analysis

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Key words
- Anterior visual pathway
- Intraoperative monitoring
- Suprasellar
- Visual outcome

Abbreviations and Acronyms
CP: Cortical potential
DTI: Diffusion tensor imaging
ERG: Electroretinography
FA: Fractional anisotropy
LED: Light-emitting diode
MeSH: Medical Subject Headings
MRI: Magnetic resonance imaging
ON: Optic nerve
ONEP: Optic nerve evoked potential
VEP: Visual evoked potential

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BACKGROUND: **Diverse methods have been developed for intraoperative monitoring of the integrity of the visual pathways. We performed a review of the literature to determine the methodology of each technique as well as their recent development. The predictive power of each eligible technique was determined based on a meta-analysis.**

METHODS: **A literature review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Techniques adopted for intraoperative monitoring of the integrity of the visual pathways were extracted and described. The power of each eligible technique to predict the visual outcome was tested.**

RESULTS: **Visual evoked potentials showed marked methodologic improvement in recent studies. Predictive power for visual deterioration after surgery was approximately 60% and reached 100% when coupled with simultaneous monitoring of electroretinography. The sensitivity of visual evoked potentials for detection of deterioration was 47.2%. The decrease of fractional anisotropy of the optic chiasma showed significant correlation with improvement of vision after chiasma compression and showed 100% predictive power for improvement.**

CONCLUSION: **Each technique had limitations. Visual evoked potentials had a high predictive power for detection of deterioration but with low sensitivity. Fractional anisotropy of the optic chiasma had high predictive power for improvement of vision with low predictive power for deterioration.**

INTRODUCTION

The visual pathways, along their course from the optic nerve (ON) to the occipital cortex, can be affected by different pathologies. These pathologies can be manifested by a wide spectrum of disturbances in visual acuity and field of vision. The clinical manifestations depend on the degree and the location of the pathology. Surgery around the anterior optic pathways carries a risk of possible compromise of the pathways as a result of manipulation, direct injury, or jeopardizing the vascular supply.[1,2] Intraoperative testing and evaluation of the integrity of the optic pathways are important to avoid intraoperative insults and to predict the outcome. Visual evoked potentials (VEPs), first applied during surgery by Wright et al. in 1973,[3] have been reported as a possible method of intraoperative monitoring of the visual pathways. Although the value of VEPs is debatable,[4-17] recent studies reported methodologic improvement of the technique to provide more reliable results.[14,15,18] Fiber tracking in the setting of intraoperative MRI is another method to test the integrity of the visual pathway during surgery.[19] Furthermore, diffusion tensor imaging (DTI) provides indexes such as fractional anisotropy (FA) that can detect the integrity of the visual pathways or the efficacy of decompression in cases of chiasma compression.[20] In this article, we review the different intraoperative predictors of the integrity of the anterior visual pathways. A systematic review of the literature was performed to identify these predictors, and a meta-analysis was performed to determine the predictive power of these factors.

MATERIALS AND METHODS

The method and results reported in this review adhere to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[21-23]

Data Source and Search Strategy

We performed a search of the English literature on MEDLINE/PubMed using key words "outcome," "chiasma compression," "pituitary adenoma," "optic radiation," "optic tract," "intraoperative," "visual evoked potentials," "intraoperative monitoring," "craniopharyngioma," "meningioma," and "visual outcome." We also used Medical Subject Headings (MeSH) terms ("Optic Chiasm/diagnosis" [MeSH] OR "Optic Chiasm/diagnostic imaging" [MeSH] OR "Optic Chiasm/surgery" [MeSH]). The abstracts of the resulting articles were screened to define relevant studies. The full text of the relevant studies were then reviewed to select the studies that met the eligibility criteria. A further search was conducted of the reference lists from individual articles to identify any additional relevant studies.

Eligibility Criteria for Meta-Analysis

Studies that fulfilled the following criteria were included in the meta-analysis: 1) evaluated an intraoperative technique for evaluation of the integrity of the anterior visual pathway, 2) analyzed the postoperative visual outcome, and 3) statistically correlated the visual outcome to the intraoperative change of the monitoring parameter.

Data Extraction

Once a final list of included articles was compiled, data from individual studies were extracted. The selected articles were carefully analyzed. The number of cases and the study design were noted. The preoperative visual status and the postoperative outcome were extracted. From each study, the parameters that were tested and correlation to the visual outcome were extracted. The technical aspects of each parameter or monitoring possibility were extracted as well.

Data Analysis

The methodology of each study was reviewed. The predictive power of improvement or deterioration of postoperative visual status was calculated for each technique.

RESULTS

Summary of Techniques

Visual Evoked Potentials. The value of intraoperative VEPs monitoring was debatable in the literature. VEP waves were not consistent or reproducible in all patients, and the results of the analysis were highly variable among different research groups. According to some reports, the VEPs were stable during surgery.[12,24-26] However, some research groups could not elicit stable and reproducible potentials.[4-9,11,16,17,27-29] More recently, researchers have tried to adopt refined, standardized techniques to obtain reproducible results. Two studies, from Sato[15] and Sasaki et al.,[18] provided new insights into the methodology and interpretation of VEPs. These studies focused on the anesthesia protocols and monitoring techniques, especially the optic stimulation to the retina and the recording electrodes. Furthermore, an intraoperative quality check was established to avoid false-negative results. Analysis of the resulting waves has been improved, focusing on both "on" and "off" responses—an "on" state (during which light is emitted) and an "off" state (during which no light is emitted)—with the identification of the specific characteristics of the waves.[15]

Recent reports showed that VEPs were stable under total intravenous anesthesia with propofol as opposed to inhalation anesthesia.[18] However, other studies reported stable VEPs under inhalation anesthesia.[11]

The stimulus is applied by a light-emitting diode (LED) embedded in soft rounded silicone discs (Figure 1) applied on closed eyelids.[14] The small size of the LED allows reflection of the frontal skin flap without obstacles and minimizes possible accidental displacement of the LED while mobilizing the flap. The LED provides luminosity of 2000–5000 lux. The wavelength of the light reaching the retina is a red light as the LED is applied on a closed eyelid.

The cortical response to light stimulation involves a combination of "on" and "off" characteristics. Continuous flashes allow for the separation of 2 response patterns, and each response is recordable as a light emission response ("on" response) or a no-emission response ("off" response).[15]

Changing the emission time did not cause a reduction in individual differences in peak latency in the "on" response. However, lengthening the light emission time reduced the individual differences in peak latency in the "off" response. To overcome the challenge of separation of "on" and "off" responses, the emission time was estimated to be approximately 300 ms. Moreover, an emission time of >500 ms was required to reduce individual differences in the peak latency in the "off" response. Alternatively, the light emission intensity could be adjusted. In the study by Sato,[15] changing the emission intensity caused opposite changes in the "on" response and "off" response. Specifically, the "on" response showed potential for reducing the individual differences in peak latency when the emission intensity was high, and the "off" response decreased the individual differences in peak latency when the emission intensity was lower. The "on" and "off" responses had conflicting stabilizing elements based on the quantity of light. Therefore, when a short flash was used, it was not possible to remove all instability. Thus, stable monitoring could be achieved only when the "off" response was monitored using less light and longer stimulus duration (>300 ms).[15]

The stimulus frequency was set, according to Sato,[15] to 1 Hz. An amplifier

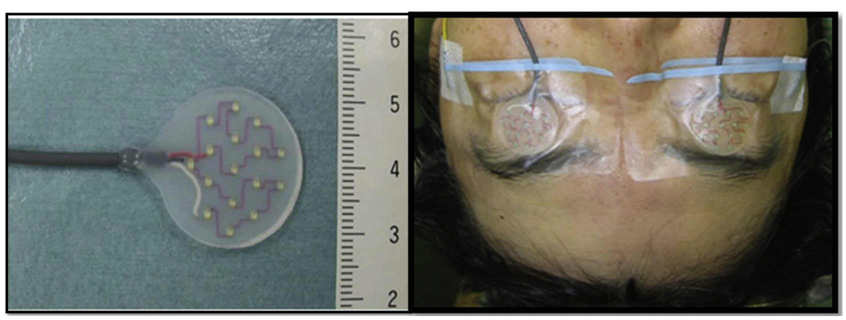

Figure 1. (*Left panel*) Light-stimulating device contains 16 red high-power light-emitting diode (100 mcd) embedded in a 2-cm-diameter soft silicone disc. (*Right panel*) The stimulating device is placed on the closed eyelids, and needle electrodes for electroretinography recording are inserted subcutaneously at the 2 lateral canthi. (Reprinted from Sasaki T, Itakura T, Suzuki K, Kasuya H, Munakata R, Muramatsu H, et al. Intraoperative monitoring of visual evoked potential: introduction of a clinically useful method. *J Neurosurg.* 2010;112:273-284.[18])