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EDITORIAL

Time to revisit VEP monitoring?

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Progress in clinical science occurs in small steps most of the time. For example, a method once declared unsuitable for a given purpose may prove more useful under mildly changed basic conditions. Revitalizing a seemingly obsolete topic may be commendable, if the context has changed appropriately. Otherwise, it will produce academic idle. Therefore we want to be open-minded regarding new data on an obsolete method, while retaining an attitude of constructive skepticism at the same time.

Intraoperative monitoring of visual-evoked potentials (VEP) [5, 6] has not prevailed for over 30 years. As opposed to somatosensory and auditory evoked responses, a high intra-individual variability and instability of VEP recordings limited the clinical usefulness of this method. Particular disenchantment grew due to a lack of correlation between intraoperative monitoring results and postoperative functional outcome [2]. About 20 years ago, it was concluded that VEPs are unstable and not regularly recordable and that they are not suited as a valid intraoperative indicator of visual function [2–4]. Several methodological shortcomings of the method were discussed [4]. Until recently, no fundamental improvement had been achieved. Occasional reports about successful VEP monitoring were foiled by studies with contrary results [8, 14].

At present, the novelty value of any study on VEP monitoring depends on whether methodological improvements have been achieved. In their present study, Kodama et al. obtained a stunning 97% rate of successful, stable VEP recordings and found an excellent correlation between VEP results and visual outcome. We need to understand the technical reasons for this sudden progress. Is it time to revisit VEP monitoring as a routine method of intraoperative functional preservation?

Stimulus delivery has been ascribed an important role. Standard pattern-reversal stimulation requires gaze fixation and is not possible in the anesthetized patient. Flash stimuli emitted by strobe light, or (red) light-emitting diodes (LEDs), have been employed intraoperatively. LEDs are typically mounted onto goggles or eye patches for stimulus delivery through closed eye lids. Contact lens type stimulators [7] have raised concern about corneal lesions [2]. High-intensity stimuli have brought some improvement [12]; direct electrical stimulation of the optic nerve is another promising suggestion [1]. Electroretinogram (ERG) controls for the presence of retinal signal generation [13]. A new design of flexible silicone-patch LED goggles for a better adaption to the eye lid reportedly enabled successful VEP recordings in most cases [13]. In the present report of Kodama et al., similarly designed soft and also re-sterilizable goggles were used for further optimized adjustment. ERG and supramaximal stimulation were employed to warrant adequate retinal illumination.

The anesthetic regimen presumably has a major influence on intraoperative VEP instability, in particular to the administration of halogenated agents [4]. Total intravenous anesthesia (TIVA) is assumed to affect visual responses to a lesser extent [10]. Kodama et al. argue that the introduction of TIVA was an important reason for the successful VEP recordings in their series. Recent studies yielded conflicting results and did not solicit a decisive role of TIVA alone though. In one recent study, a satisfactory rate of successful VEPs could not be achieved despite TIVA [14]. In other series, significant signal attenuation as compared with low-dosage sevoflurane narcosis was [10] or was not observed [11].

The VEP signal is recorded from subcutaneous or surface scalp electrodes. However, recordings directly from the cortical surface yield higher amplitudes and a better

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signal-to-noise ratio. In a recent study, cortically recorded VEPs were detected in over 90% of cases with essentially preserved vision and correct placement of recording electrodes, independently from the type of anesthesia [11]. However, cortical recordings are only available with occipital lesions, and are of limited practical importance.

Steady-state VEP responses as opposed to the typical triggered, transient waveforms (like in Kodama's series) are obtained with high-frequency flickering stimulation. However, the method has not prevailed, and a major benefit is not obvious [15].

Patient selection according to preoperative visual function may have contributed significantly to the impressive figures in the Kodama's report: Only patients with a visual acuity of at least 0.4 were included except of one case with unsuccessful recordings. Unfortunately, impaired preoperative vision is a major predictor of postoperative deterioration. A strong dependence of VEPs on intact vision would therefore limit their clinical usefulness.

When rating VEP monitoring unsuitable for intraoperative monitoring, it appeared that *the VEP generating system does not sufficiently reflect visual function* [2]. Improved feasibility alone would not therefore save the method's role in functional monitoring. Conspicuously, the most recent reports, including Kodama's present article, describe an excellent correlation of intraoperative VEPs and postoperative visual function. These data suggest that standard VEPs *do* represent visual function (acuity) indeed, provided that they are recorded under optimized conditions.

In conclusion, how can we explain the unprecedented success rate and clinical validity of intraoperative VEPs in the most recent studies, notably in the report of Kodama et al.? As the latter authors point out, the high feasibility and clinical validity of VEPs in their series must be due to progress in stimulation, anesthesia, and patient selection. No important innovation has occurred in (scalp) signal recording and interpretation; neither cortical recordings nor steady-state responses were employed in their series. TIVA alone does not explain their figures. In accordance with recent data, flexible LED goggles and high-luminance flash stimulation must have contributed significantly to the successful recordings. In addition, patient selection for little impaired preoperative vision greatly facilitates VEP recordings (however, it may also limit their clinical usefulness). In summary, a coincidence of minor achievements in different areas best explains the fundamentally improved conditions for VEP monitoring in the study of Kodama et al.

Given these new results, should we introduce VEPs into routine functional monitoring? Obviously, there is need for continuous monitoring of visual function. For example, the cases in the article of Kodama et al. clearly show the dynamic nature of ischemic events, which are picked up by VEPs but would have been missed by imaging data [9]. Evidence from carefully analyzed case series does legitimatize the introduction of such a method for further exploration. However, at present, the reports of successful and valid VEP monitoring are very recent and rely on low numbers of critical events. Given the strong previous evidence contradicting these results (albeit under less advantageous conditions), a cautious attitude is justified. More data from independent groups as well as easy availability of the new goggles appear to be necessary before further exploration, and wide adoption of the method can be advocated. Future efforts should then be directed at VEP monitoring in patients with significant visual impairment.

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