Automated single-trial detection and quantification of evoked potentials, a potential tool for neuromonitoring?

For the past 40 years, the continuous recording of evoked potentials (EPs) has been used for the intraoperative monitoring of surgical procedures that are at risk of inflicting a lesion to the nervous system. One aim of this on-line neurophysiological monitoring is to warn the surgeon of a possible insult to the nervous system so that the surgical strategy can be adjusted and the risk of a permanent neurological deficit reduced (Guerit, 1998). According to the surgical procedure and related risk, different types of EPs can be used to monitor different neurological functions. For example, the intraoperative recording of somatosensory EPs, often combined with the recording of motor EPs, is used to monitor the appearance of a possible motor and/or somatosensory dysfunction during scoliosis surgery and surgery for spinal cord tumours, as well as intracranial aneurysm surgery, carotid endarterectomy, and thoracoabdominal aortic surgery (Deletis and Sala, 2008; Fehlings et al., 2010; Moritz et al., 2007; Penchet et al., 2007; Weinzierl et al., 2007). Similarly, the recording of brainstem auditory evoked potentials is used to monitor the integrity of the VIIIth cranial nerve during posterior fossa surgery, in particular, the removal of acoustic neuromas (Bischoff et al., 2008; Neu et al., 1999).

The use of clinical neurophysiological techniques for the continuous monitoring of neurological functions has also found important applications in intensive care medicine (reviewed in Guerit, 2010). There is widespread agreement that these techniques should, in principle, improve patient outcome whenever the early detection of a defined pathophysiological process affecting the nervous system may prompt rapid therapeutic measures, so preventing long-lasting neurological consequences. At present, the main potentially reversible neurological events that can be monitored using EP recordings are those associated with an evolving ischemic penumbra, an increase in intracranial cerebral pressure, variations during scoliosis surgery and surgery for spinal cord tumours, as well as intracranial aneurysm surgery, carotid endarterectomy, and thoracoabdominal aortic surgery (Deletis and Sala, 2008; Fehlings et al., 2010; Moritz et al., 2007; Penchet et al., 2007; Weinzierl et al., 2007). Similarly, the recording of brainstem auditory evoked potentials is used to monitor the integrity of the VIIIth cranial nerve during posterior fossa surgery, in particular, the removal of acoustic neuromas (Bischoff et al., 2008; Neu et al., 1999).

However, at present, it must be acknowledged that the implementation of these techniques remains limited to a relatively small number of centres. There are several reasons to explain this paradox. First, the technical difficulties due to the low signal-to-noise ratio of EP signals, especially when these are recorded in the noisy environments of operating wards and intensive care units, can make it difficult to obtain robust and reliable electrophysiological measures. Second, most surgeons, intensivists and anaesthesiologists lack the training and expertise that is required to interpret the obtained EP waveforms with confidence. Therefore, in order to spread the use of EPs for the neuromonitoring of patients in a critical care setting, one should develop methods to automatically translate EP recordings into a synthetic message for the medical team in charge of the patient (e.g. a quantifiable index, an alarm).

In this issue of Clinical Neurophysiology, Hu et al. (this issue) propose a novel approach for the analysis of EP waveforms, which could readily address this need. Indeed, they present a very effective method to enhance the signal-to-noise ratio of single-trial EP waveforms, combining spatio-temporal filtering based on a probabilistic independent component analysis (PICA) to exploit the spatial information contained in multichannel EEG recordings with subsequent time–frequency filtering based on a continuous Morlet wavelet transform. As shown in Figure 3 of their publication, this two-step procedure can be used to significantly enhance the signal-to-noise ratio of EPs. Importantly, the adaptive filtering parameters are defined entirely by the data itself and, hence, do not require a priori assumptions concerning the spatial, temporal and frequency characteristics of the expected EP waveforms, thus allowing for both inter-trial and inter-individual variability. As such, implementing this powerful denoising approach could markedly enhance the sensitivity and specificity of neuromonitoring techniques based on the continuous recording of EPs.

Furthermore, using these noise-filtered EP waveforms, Hu et al. (this issue) show that it is possible to obtain robust measures of the amplitude and latency of the different peaks of somatosensory evoked potentials, at the level of single trials. Combined with their recently developed methods to estimate these parameters using multiple linear regression techniques (Hu et al., 2010), their approach could be used to perform an automated interpretation and quantification of EP waveforms, whose output could represent a valuable index for the medical team in charge of monitoring the patient.

Finally, it is important to highlight the fact that conventional approaches often require averaging a relatively large number of consecutive trials to obtain a reliable EP waveform (Mouraux and Iannetti, 2008). This inevitably introduces a delay of up to several minutes between the availability of the information provided by the neuromonitoring technique and the state of the monitored neurological function. In certain time-critical circumstances, this delay may either reduce the window of opportunity for intervention, thereby preventing or compromising the reversal of the neurological deficit, or make it more difficult to relate the onset of
neurological dysfunction to its actual origin. For this reason, a neuromonitoring approach based on the methods described by Hu et al. (this issue) could offer another significant advantage: because the method provides EP estimates at the level of single trials, it would allow following quasi-instantaneously the dynamics of the monitored neurological function.

References


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