Neuromonitoring by scalp EEG and Corticography recording during Intracranial Vascular Surgery: a Feasibility Study in 20 Patients

L. Regli, A. Dolinkski, JG. Villemure, E. Pralong, M. Maeder, D. Debatisse

NCH -UNN Neurosurgery CHUV, Lausanne, Switzerland

Purpose:
Temporary vascular occlusions are frequent during vascular surgery. Real-time detection of cerebral ischemia during surgical repair of intracranial aneurysms can be helpful to the surgeon, especially in determining the duration of temporary vascular occlusion that can be tolerated and the optimal systemic arterial pressure. The most common techniques used clinically for this purpose are (1) anterior circulation angiography, (2) somatosensory evoked potentials (SEP), scalp EEG (and direct cortical EEG recordings). The value of SEPs has been investigated in a large number of patients and responses were found to change in roughly 20% of surgical procedures, although there is a significant incidence of false negative results [6]. Changes in the scalp EEG are less well studied with estimates that 5 to 40% of patients show significant changes. There is insufficient data to form conclusions the overall sensitivity of cortical EEG recordings. The purpose of neuromonitorying is to detect a neuronal threshold of tolerance to ischemia. This preliminary study tested the feasibility of peroperative Corticography (cEEG) and surface EEG during intracranial vascular surgery.

Introduction:
By definition and clinically, neuromonitoring includes all the techniques that allow immediate detection of events liable to cause brain, spinal cord or peripheral nerve damage, of their metabolic correlates. It is mainly used in the operating room (OR) and intensive care unit (ICU). Its primary goals are: (1) the detection of brain dysfunction at a reversible stage in order to prevent irreversible lesions, (2) the indirect evaluation, through brain function, of the importance of some metabolic disturbances or of the level of anaesthesia, and (3) a better knowledge of neurological events occurring intra-operatively, in order to improve surgical procedures. The EEG was almost immediately considered as a unique tool to evaluate consciousness fluctuations in comatose patients, so that the history of neuromonitoring in the ICU actually dates back to the EEG discovery in the late 1920s; however the EEG could hardly be systematically implemented before the advent of computerized signal processing and digital EEG. Evoked potentials (EPs) were progressively introduced, both in the ICU and the OR, at the end of the 1990s. Since then, the number of papers on ICU and OR monitoring almost doubled every 5 years until the beginning of the 1990s. In the United States, it is currently evident that neuromonitoring should be accessible in any OR or ICU, to the point that some private companies are now created - with support of private insurance companies - to help these hospitals that are not big enough to develop their own neuromonitoring infrastructure.

The concept of multimodality monitoring:
Multimodality monitoring consists of a triplet: (1) identifying events liable to cause brain damage ("upstream monitoring"), (2) early confirming that these events actually interfere with central or peripheral nervous system function (neuropsychological monitoring), and (3) measuring the metabolic consequences of nervous dysfunction ("downstream monitoring"). Noteworthy, the outcomes of these 3 approaches are not obligatorily correlated with each other and it is even from their convergences or discrepancies that additional useful information can be extracted for optimal patient management.

Electrodes positioning:
- Surface EEG
- Intracranial Aneurysms
- Corticography
- Intracranial Aneurysms
- ST-MC bypass and AVM (2 patient)

Example: intracranial vascular anomalies:
- Surface EEG
- Intracranial Aneurysms
- Corticography
- High Frequency
- Burst and alternant EEG pattern
- Asymmetrical burst activity using propofol

Typical EEG and Corticography responses:

Material and methods:
Perioperative monitoring with scalp EEG and corticography (cEEG) was performed in 11 patients undergoing craniotomy for intracranial aneurysms, 2 patients with ST-MC bypass and AVM (2 patient). All patients had a preoperative baseline surface recording. At surgery scalp electrodes were positioned in F7/F8 and C3/C4, allowing monitoring of aneurysm and in-tradural surface EEG. Three subdural monopolar electrodes were positioned frontal, temporal, and parietal. Online monitoring was performed with 7 leads: 4 scalp EEG (2 peris, 2 controlateral), and 3 patient-level Corticography records were obtained. During temporary clipping (5 to 40 minutes) of the middle or anterior cerebral artery, 5 patients presented focal modifications of the cortical-corticography (cEEG) pattern (slow waves & delta or delta and slow waves pattern), that were not detected on surface EEG. All patients had induced hypertension during temporary clipping. Corticographic changes occurred in all after clip removal. One patient with temporary clipping of the intracranial carotid artery had diffuse slowing seen on corticography that was moderate on the lateral surface EEG. These changes resolved after clip removal (3 minutes). In 3 other patients, an early appearance of "high frequency waves" (Beta 3) was observed on corticography just a few seconds after vascular occlusion. These high frequencies peaked the slow wave (delta) pattern suggesting neuronal ischemia. No patient presented signs or symptoms of cerebral ischemia after surgery.

Results:
All patients' excellent cortical recording were obtained. During temporary clipping (5 to 40 minutes) of the middle or anterior cerebral artery, 5 patients presented focal modifications of the cortical-corticography (cEEG) pattern (slow waves & delta or delta and slow waves pattern), that were not detected on surface EEG. All patients had induced hypertension during temporary clipping. Corticographic changes occurred in all after clip removal. One patient with temporary clipping of the intracranial carotid artery had diffuse slowing seen on corticography that was moderate on the lateral surface EEG. These changes resolved after clip removal (3 minutes). In 3 other patients, an early appearance of "high frequency waves" (Beta 3) was observed on corticography just a few seconds after vascular occlusion. These high frequencies peaked the slow wave (delta) pattern suggesting neuronal ischemia. No patient presented signs or symptoms of cerebral ischemia after surgery.

Discussion:
The interpretation of intraoperative neuropsychologic results during aneurysm surgery is complex. Two elements involved in interpreting this data were explored in this preliminary study performed on a small patient population. The first was the reliability of the decision of whether a significant change in a monitored modality occurred during vascular occlusion. This study has demonstrated that the reliability varies greatly depending on the recording technique, with good inter-observer reliability for corticography by location in different lobe (temporal, parietal and frontal lobe) but poor reliability for scalp EEG. Secondly, the fraction of modifications in each modality associated with cerebral ischemia was determined. We observed that cortical EEG changes more frequently than scalp EEG. The finding that cortical EEG changes more frequently than other modalities with vascular occlusion suggests that cortical EEG would be more sensitive detector of intrasoperative ischemia than the other modalities.

Indeed these first results indicate that changes will be detected more frequently when corticography by topographical lobe location is employed as part of Intraoperative neuropsychologic monitoring during aneurysm and intracranial vascular malformation surgery. It should be noted that this does not guarantee additional sensitivity in the detection of clinically significant ischemia. Corticography is easy to perform and has relatively high reliability of interpretation. We observed different specific corticography EEG pattern during clamping (beta activity before slow waves). Future studies may provide additional information on the true clinical value of this technique in the interpretation and comprehension of vasospasm and level of ischemia during intracranial vascular surgery.