USEFULNESS OF INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING IN SUPRATENTORIAL BRAIN TUMOUR RESECTION

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Abstract: *Intraoperative neurophysiological monitoring (IONM) is an important technique for the real-time assessment of the integrity of cerebral sensory and motor tracts and areas during the resection of supratentorial tumours. Multimodal monitoring focuses on sensory evoked potentials and phase reversal technique, motor evoked potentials, cortical and subcortical motor mapping. We performed a total of 25 intraoperative neurophysiologic monitorings, confirming the usefulness and safety of this method in supratentorial brain tumour surgery.*

INTRODUCTION

The maximum resection of brain lesions located near functionally eloquent regions may be risky. First, visual inspection may be insufficient to distinguish the normal tissue from the abnormal one due to a distorted anatomy or an invasive pathology. Abnormal brain tissue may still have normal functionality. Cerebral plasticity in the presence of gliomas can lead to significant neurophysiological and neuroanatomic dissociation, which can lead to erroneous identification of the eloquent cortex

Cortical mapping is, therefore, essential for the resection of lesions near eloquent areas. This mapping is performed by multimodal procedures - functional magnetic resonance, positron emission tomography, tractography, neuronavigation, intraoperative neurophysiological monitoring (IONM).

The purpose of mapping and monitoring eloquent cortical areas and subcortical pathways is to carry out a complete, radical excision, while preserving unaltered the neurological functions. The methods used for IONM are sensory evoked potentials (SEPs), phase-reversal technique, motor evoked potentials (MEPs), mapping of motor, sensitive or language areas.(1)

In order to highlight the benefits and safety of the IONM technique, we will present a series of results on cases operated in the Neurosurgery Clinic of the Polisano Hospital in Sibiu.

MATERIALS AND METHODS

Between May 2014 and March 2017, we performed a number of 25 monitorings in patients operated for supratentorial brain tumours. We used the 16-channel Xltek Protektor (Natus) apparatus for the intraoperative neurophysiological monitoring, using scalp corkscrew electrodes and subdermal needle electrodes and peripheral nerve stimulation.

MEP monitoring was performed with transcranial electrical stimulation and SEP monitoring was performed in all patients. Direct cortical stimulation (DCS) with strip electrode was used in 18 patients, cortical motor mapping with monopolar or bipolar stimulator in 20 patients and intralesional subcortical monitoring / mapping with monopolar stimulator in 14 cases. It should be emphasized that in the last cases, for the subcortical mapping, a special device was used which combines the monopolar stimulator with the surgical vacuum cleaner with outstanding results in real time. In 10 cases, a phase reversal technique was needed to detect the central sulcus. One case was performed with the patient awake for language mapping.

Neurophysiological mapping of the sensory-motor cortex can be accomplished by SEP of the median nerve with the "phase reversal" technique and direct cortical stimulation of the eloquent regions recording motor responses or sensory symptoms.(2) The "phase reversal" technique allows the identification of the central sulcus and thus, the localization of the motor and sensory cortex. After identification, direct cortical stimulation, subdurally or epidurally, is achieved obtaining MEPs or movements i.e. sensations in awake surgery, on the contralateral hemibody. Continuous stimulation of the motor cortex can provide intraoperative neuromonitoring of motor tracts.

Localization of central sulcus through SEP and "phase reversal" technique

The method is based on the fact that in all individuals the stimulation of the distal median nerve is followed by the depolarization of the contralateral parietal cortex after about 20 milliseconds. Median nerve SEP will be recorded as a negative wave at 20 ms, so called N20. There is an accepted margin between 18-25 ms depending on height, age, co-pathology or depth of anesthesia.

At the same latency with the N20 wavelength in the precentral frontal regions, positive waves will be obtained; thus, the simultaneous recording of SEP in the parietal and contralateral frontal cortex will show a sudden change of polarity at the boundary between the frontal and the parietal region, respectively the central sulcus, thus helping to identify it. Not always the "phase reversal" technique succeeds, sometimes SEP being difficult to achieve.

Stimulation is most commonly done on the median nerve, others prefer the ulnar nerve that has a simpler morphology and provides greater amplitudes. It is stimulated at a frequency of 3.17 Hz using stimuli with a duration of 0.3 ms and an intensity between 10-25 mA, with the help of stimulator stickers.(3)

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Recording is done using strip electrodes with 6-8 electrical contacts, applied epidurally or subdurally, on the hemispheric convexity contralateral to the stimulated nerve, in the cortical area of the hand and perpendicular to the assumed direction of the motor sulcus (figures no. 1 and 2) The reference electrode is attached to the ipsilateral mastoid, Ai being a needle electrode. Regarding the referential placement (between the electrodes 1-6 and the reference electrode Ai), the phase change of the thalamocortical SEP will indicate the position of the central sulcus (figure no. 3).

Figure no. 1. Strip electrode for the "phase reversal" technique

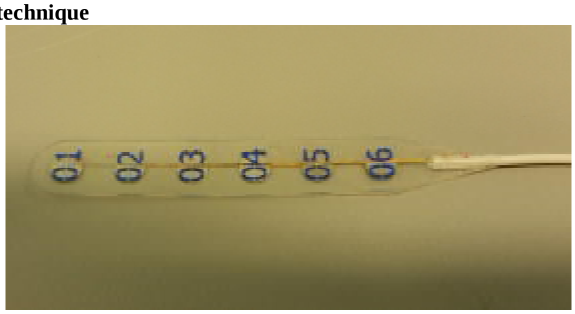


Figure no. 2. Positioning of the strip-electrode on the cerebral cortex in "phase reversal" technique

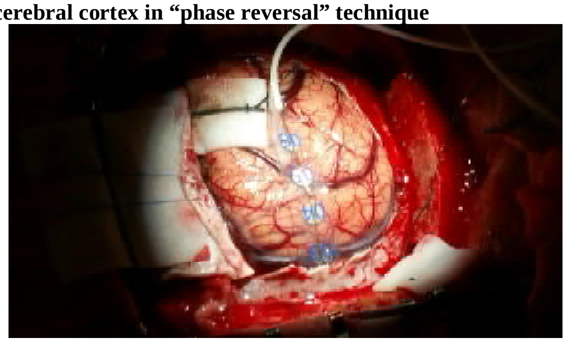
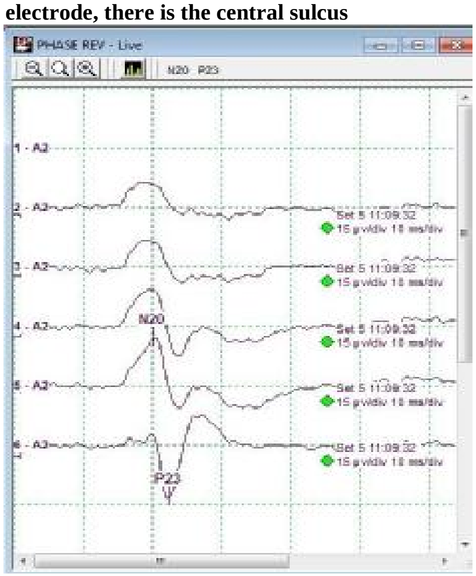


Figure no. 3. Example of obtaining sensory evoked potentials by the "phase reversal" technique; between 5 and 6 contacts of the electrode, there is the central sulcus



The first positioning of the electrode strip rarely leads to a perfect SEP. A perfect position refers to the placement of the strip perpendicular to the assumed direction of the central sulcus and on the area corresponding to the homunculus for the hand. This placement can be difficult due to intraoperative brain movement, anatomical distortion and a small operative field. SEP is sometimes obtained without changing the phase, requiring the electrodes' position to be changed several times.(4)

Electrical placement of SEP

The electrical placement of SEP to record the sensory evoked potentials is made at scalp level based on the EEG 10/20 system. Corkscrew-like electrodes are used at Cz`-Fz` for lower limbs and at C3'-C4` for upper limbs. Corkscrew-like electrodes are used for secure fastening and low impedance (<1 kΩ).

The stimulation is done at the peripheral level on the median or ulnar nerves at the level of the fist, respectively on the tibial nerve in the ankle. Sensory evoked potentials are obtained, the most important being N20 for the upper limbs and P40 for the lower limbs. The latency and amplitude of these potentials relative to their value at the onset of surgery are monitored. An elongation of more than 10% of latency and a decrease of the amplitude of more than 50% are considered an alert and must be reported to the neurosurgeon who decides which measures should be taken to correct the changes, wherever possible.(5)

Alerting the neurosurgeon in case of significant changes in the amplitude and latency of SEP will be followed by corrective measures:

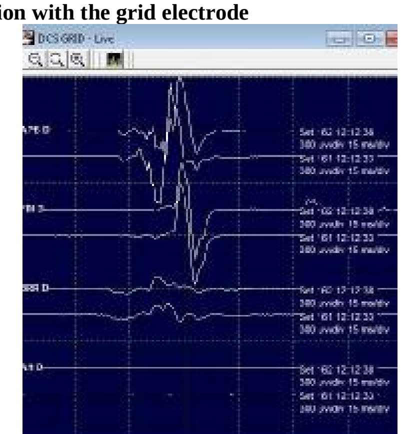
- Checking the anesthesia, blood pressure, body temperature when these changes are diffuse;
- Surgical Procedures - Repositioning of the retractors, removing the temporary clips, temporarily stopping the intervention, checking the bleeding, saline irrigation.(6)

Electrical placement for MEP

The placement of transcranial electric stimulation electrodes is based on the EEG 10/20 system. The standard placement for PEM at the upper limbs is C3/C4 and for the lower limbs, C1/C2. With a suitable intensity, C1/C3 stimulation reveals MEP in the right limbs, and C2/C4 stimulation in the left limbs, the first electrode being the anode.(3)

After identifying the central sulcus and thus, the precentral motor cortex, direct cortical stimulation can be performed to monitor the cortical-spinal tract. Stimulation can be done with a monopolar stimulator or by contacting a strip electrode coupled with the anode. This will allow continued stimulation, namely the corticospinal tract monitoring during resection (figure no. 4).(5)

Figure no. 4. MEP obtained through direct cortical stimulation with the grid electrode



For direct cortical stimulation, a strip-electrode placed subdurally parallel to and over the precental gyrus is used, with distal contacts on the upper limb and those proximal on the area of the lower limb area. Stimulation is also anodal; an electrode placed on Fz will be used as a cathode. The electrode with the smallest threshold at which a contralateral muscle response is obtained will be used for continuous monitoring. In the case of transcranial stimulation, approximately 10-20% of the applied current will reach the motor cortex. In general, an intensity of 50-100 mA at a voltage of 150 V is sufficient to obtain a response to the upper limbs, whereas for the lower limbs, an intensity greater than 150 mA may be required.(7)

The stimulation parameters for direct cortical stimulation are similar except for the intensity that will be much lower, between 25-35 mA.(8)

MEPs are recorded from the upper and lower limb muscles by means of paired subdermal needle electrodes. The most frequently used muscles are the abductor policis brevis (APB), anterior tibialis (TA), abductor halucis (AH).

Transcranial stimulation requires higher intensities due to shunting the current between the low impedance scalp and the high impedance bone. This is why, the DCS determines less extensive movements.(9)

MEP monitoring has a sensitivity of 87% and a specificity of 97% in predictability of postoperative motor deficit. The permanent motor deficit is directly correlated with the permanent changes of the MEP.

Irreversible alteration, loss or reversible alteration of MEP is associated with permanent or transitory motor damage. The reversibility of MEP changes is usually related to some reaction and the neurosurgeon’s action following the early warning.(10)

Complications during MEP monitoring are rare, including:

- biting one’s tongue by shrinking muscles;
- seizures;
- subdural bleeding due to the placement of the strip-electrode;
- infections at the level of the needle-electrode insertion.

To avoid biting the tongue, a double prosthesis is used in the mouth and stimulated with less intensity. There have been reported seizures especially at DCS, but they are rarer at lower intensities.

There can also occur thermal damage at electrode level, cardiovascular alterations, complications related to patient movements.

Among the contraindications of MEP monitoring, mention must be made of the presence of cardiac pacemakers or some cranial implants, epilepsy, intracranial hypertension, cortical lesions or proconvulsant drugs.(1)

Subcortical monitoring

This type of monitoring is performed with the help of a cathodic monopolar stimulator intraoperatively inserted into the lesion as the tumour resection advances, within the vicinity of the corticospinal tract. The latter is considered safe when the stimulation intensity required to obtain a motor response is over 3 mA. It has been conventionally established that 1 mA of stimulation intensity corresponds to 1 mm distance up to the corticospinal tract. This method allows for maximum safe resection.(11)

A large number of studies have suggested that subcortical mapping is of great value in preventing morbidity during the resection of cerebral gliomas.(12,13)

RESULTS AND DISCUSSIONS

Of the 25 brain tumours operated with IONM in our clinic, 15 were in the left hemisphere and 10 in the right hemisphere. From the histopathological point of view, there were 16 astrocytomas of different grades, 5 meningiomas, 1 cavernous hemangioma, 2 metastases, 1 epidermoid tumour. Their location was frontal in 16 cases, 6 temporal, 1 parietal, 1 parietooccipital and 1 insular.

During the intraoperative neurophysiological monitoring, there were alert events with the temporary decrease of MEP in 8 cases, being resumed after anesthetic and surgical procedures (figure no. 5). In these cases, the stimulation threshold was increased until the motor potentials returned; the operator field was irrigated with cold physiological saline or / and cortisone was administered. In none of the cases, MEP were not completely lost to DCS and transcranial stimulation, and only 2 patients developed postoperative transient motor deficit. To these results, intralesional subcortical continuous monitoring has been greatly contributed to allowing maximum resection under conditions of avoiding corticospinal tract damage by adjusting the resection according to the stimulation threshold, which should not have been less than 3 mA (figure no. 6).

Figure no. 5. Decrease and returning of MEP of the left limbs (transcranial stimulation)

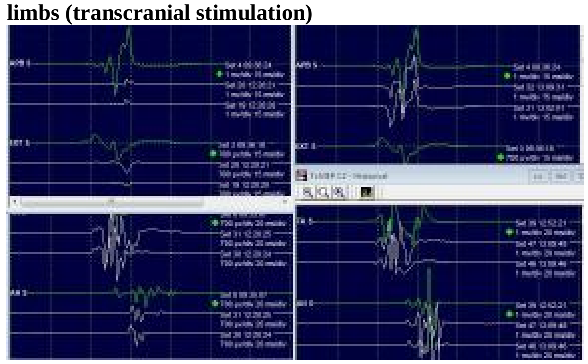
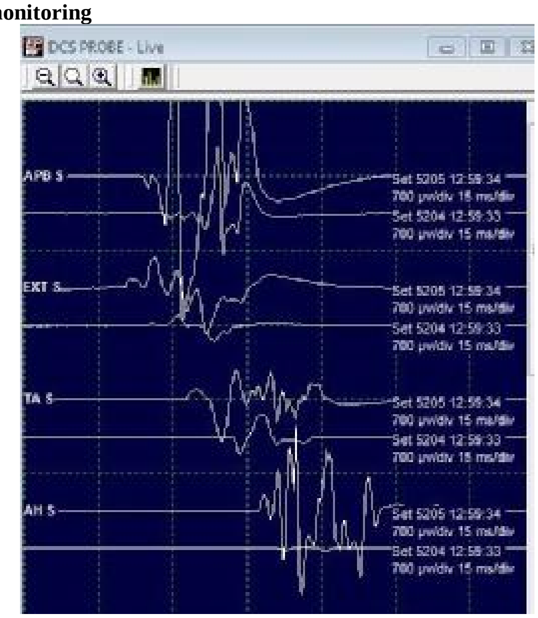
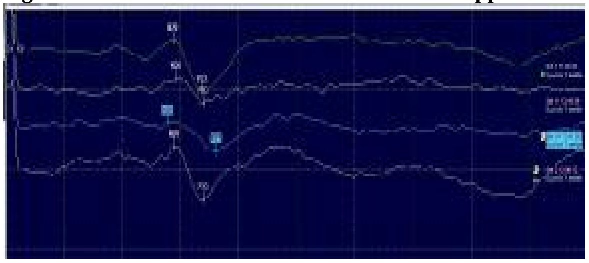


Figure no. 6. MEP obtained by stimulation with the intralesional monopolar electrode for continuous subcortical monitoring



In 3 cases, the decrease of the SEP amplitude was also noted, in 2 of them, there was a diffuse decrease due to systemic causes (anesthesia, blood gases) and a case with decrease of SEP in the left limbs, with return after surgical measures (pause, cold irrigation, changing the surgical procedure) (figure no. 7).

Figure no. 7. Decrease and return of SPE in the upper limbs



Regarding the adverse events, there were 4 cases with short-term intraoperative seizures and a case of tongue trauma. In case of seizures, midazolam or diazepam was administered, the exposed cortical area was irrigated with cold physiological serum and the seizures ended in maximum 20-30 seconds.

CONCLUSIONS

IONM allows the neurosurgeon to perform brain tumour resections by optimizing the risk / benefit ratio by:

- extending the surgical indications, mainly in the eloquent brain areas;
- improved quality of tumour resection with a high neurological impact;
- minimizing the risk of postoperative sequelae and preserving the quality of life of the patient.

The use of neurophysiological mapping can play a vital part in these situations and offers some advantages over the functional imaging techniques:

- allows real-time evaluation of cortical functions and direct intraoperative feedback to neurosurgeon;
- increase location specificity compared to other techniques;
- the accuracy of the results is not distorted by the movement of the brain structures that inevitably occur during surgery;
- detects the eloquent regions that can be dissociated by reorganization and neuroplasticity;
- allows subcortical mapping and continuous monitoring of sensory-motor pathways during resection.

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