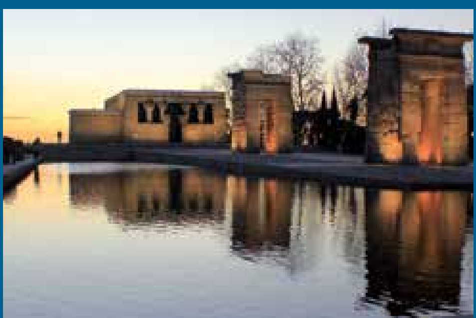
INTERNATIONAL SOCIETY OF ISIN INTRAOPERATIVE NEUROPHYSIOLOGY



ISIN MADRID 2018 EDUCATIONAL COURSE (2nd course, 3rd cycle)

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ABSTRACT BOOK

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Hospital General Universitario Gregorio Marañón

NOVEMBER 1, 2018

BACK TO BASICS:
INTRODUCTORY COURSE ON IONM (Part I)

Chairman: Vedran Deletis

BASIC PRINCIPLES OF INTRAOPERATIVE NEUROPHYSIOLOGY

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In this presentation we will try to draw some basic principles about the specific use of the Intraoperative Neurophysiology (ION) in the operating room (OR). We will try to show what Clinical neurophysiology can offer in the OR, to understand the utility of ION, to show the differences between neurophysiology in the office and in the OR, and to introduce some practical tips for the daily work in the operating room. Neurophysiology can delineate the function of most of the different nervous tracts and centers, but, in the OR the neural function is modified by the anesthesia, so we need to modify our tests accordingly. It will be showed that ION is useful from both a scientific and an economic point of view. The main differences between clinical neurophysiology in the office and ION in OR will also be showed, with special remark on immediacy of our warnings and our responsibility as neurophysiologists. Lastly, we will point out some practical tips for making easier the obtention of the different signals, in spite of being in a hostile electrical environment, and we will try to show some tricks to avoid the main artifacts that can obscure our potentials.

Objective: Safety for the intra-operative monitoring individual/team can be divided into three concerns: (A) the patient – outside of the monitoring goals; (B) the operating room personnel; (C) the IOM and operating room equipment. It is the goal of this lecture to describe each of these areas.

SAFETY ISSUES IN THE OPERATING ROOM

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The patient: IOM includes the placement of invasive recording and stimulating transducers that have the potential to inflict injury by either poor electronic isolation, improper connection to the patient potentially causing erroneous data, or a change in the medical status of the patient (i.e. infection, lacerations, burns ...). Poor electronic isolation can potentially expose the patient to higher than normal currents in either the IOM electrodes touching the patient, or even other electrical conduits touching the patient such as from the cautery system. Proper electrical safety checks, even having the IOM recommend equipment checks for other system in the OR if a failure is suspected. The most likely cause of these electrical failures are: (1) stimulation or even recording isolation devices to fail allowing a direct pathway from the outlet power to the patient; (2) isolation failures that can cause ground loops to generate unwanted signals at the patient that have the potential to cause burns at high stimulation levels; (3) multiple grounds on the patient that can set-up unwanted ground loops causing similar issues; (4) ground failures in other IOM equipment connected to the patient that can cause unwanted energy to enter the IOM equipment.
Simple impedance test only tell you whether or not an electrode is in contact with the patient, not whether or not it is in the correct place. Improper returns can cause erroneous data by picking up large signals that can obscure the real signals. Finally, placing low signal level recording electrodes, wires, or amplifiers near equipment that can generate noise in frequency bands other than line noise, or even line noise, can obscure signals, even placing a masking signal that may mistakenly be interpreted as a real signal. Constant vigilance in the OR is necessary to minimize these affects because these change throughout the course of a case.

The operating room personnel: The two biggest issues with the safety of the operating room personnel are the wires that go from the patient to the IOM equipment and the needles that many groups use for recording. A third, less common safety issue, but is an issue for the data is the potential for electrode wires to be knocked about or even disconnected by the surgeon or assistants. All wires, whether going from the amp and stimulation boxes to the IOM machine, or electrode wires should be neatly hidden under

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the patient or OR table or run in a neat way, trying to follow areas that are hard to walk over. The stimulator and the amplifier cables should be run in separate areas. OR personnel should be made aware of the cables and also the needles. If needles are placed prior to positioning or any time the patient is going to be moved with needles in place the OR team involved in that moving need to be informed of the needles.

IOM and operating room equipment: In the United States all equipment that is brought into an operating room requires electrical isolation testing and ground safety checks. Some centers even require that any equipment removed from the hospital be checked every time it comes back to the hospital. This helps to minimize the potential for issues stated above. In addition, all equipment needs to be cleaned at the end of every case even if no visible contaminates are noticed. Equipment should be visually inspected, especially boxes placed on the OR table or near the patient for any points where fluid may enter the electronics. Any fluid entering the device my cause a device failure by causing a short circuit in the system. Also, many of the newer devices have complex circuitry in the boxes that are placed near the patient so overheating if the device is covered for a long time can occur.

Conclusion: Better isolation and failure detection circuitry have helped to minimize the serious electrical failures, but they have not eliminated them thus it is critical for the IOM team to be as vigilant to safety of the equipment and OR staff as they are to the protection of the patient.

References:

1. *Electrical safety in the operating room: dry versus wet* Barker SJ. Doyle DJ. Anesthesia & Analgesia. 110(6):1517-8, 2010 Jun 1.
2. *Ensuring electrical safety.* McConnell EA. Nursing. 26(10):20, 1996 Oct.
3. *Medical equipment electrical safety.* Anonymous. Healthcare Hazardous Materials Management. 9(3):1-5, 1995 Dec.
4. American Association of Medical Technology http://www.aami.org/publications/books/esm.html Electrical safety in the operating room: important old wine, disguised new bottles. Litt L. Ehrenwerth J.
5. Anesthesia & Analgesia. 78(3):417-9, 1994 Mar. *Basic electronics for clinical neurophysio logy]* Misulis KE. Journal of Clinical Neurophysiology. 6(1):41-74, 1989 Jan.

CORTICOSPINAL AND CORTICOBULBAR MOTOR EVOKED POTENTIALS

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The Objective: To provide the basis and general principles for implementation, interpretation, and to recognize meaningful changes of Corticospinal, and Corticobulbar Intraoperative Motor Evoked Potentials. This technique is essential to detect and prevent damage to the motor system.

Methodology for Motor Evoked Potentials: It is essential to know the right stimulation of the cortical motor area M1 and recording from the muscles of interest in the limbs (Corticospinal) or the face and cephalic region (Corticobulbar).
Stimulation of Motor Evoked Potentials is feasible transcranial (TES) or directly on the motor cortex (DCS). For recording, it is recommended to use distal muscles of the limbs as the abductor pollicis brevis in the hands, or the abductor hallucis in the feet. For recording in the face, there is experience with the orbicularis oris for the facial nerve, the genioglossus for the hypoglossus, the vocal cords for the vagus ramus superior laryngeal, and cricothyroid for the vagus nerve ramus superior laryngeal.
The principle is the same for both Corticospinal and Corticobulbar, and the methodology is similar; however, it has subtle differences that are relevant to know.
We are more familiar with Corticospinal than Corticobulbar motor evoked potentials. To stimulate, we use corkscrew electrodes localized in one of three type of montages 1) Inter-Hemispheric 2) Midline 3) hemispheric. These montages are recommended to stimulate the four limbs, the lower limbs, and cranial muscles respectively.
In the interhemispheric montage, we use an anodic stimulation one centimeter anterior to C3 or C1 referred to contralateral C4 or C2 or vice versa. This kind of stimulation is well suited to monitor the four extremities, with the advantage of having less movement of the patient with the montage C1 vs. C2.

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The hemispheric montage is more space-limited than the interhemispheric montage. The electrodes are located on C3 vs. Cz or C4 vs. Cz to stimulate the contralateral side of the body, and the cranial muscles, being particularly well suited to obtain Corticobulbar MEPs. Midline montage uses electrodes in Cz -1 cm and 6 cm anterior in the midline. This montage is well suited to obtain MEPs in the lower extremities, however, not in the uppers.

The stimulation parameters for TES and Direct Cortex Stimulation for the limbs in the corticospinal pathway are the same, a train of 3 to 7 pulses, being the most used the train of five, Interstimulus Interval (ISI) of 4 ms, duration of the pulse 0,5 ms with an Intensity constant voltage of 100---250 V for the uppers and 200 ----400 V for the lowers. For DCS the parameters are the same only the intensity must be limited to less than 40 mAmps.
We consider MEPs useful for mapping and to monitor cortical and subcortical motor areas and pathways. The parameters used for direct cortical stimulation (DCS) are the same than transcranial stimulation, except for the intensity that is usually below 40 mAmps. A useful montage for continuous monitoring of the motor area is an anodal montage using a strip of eight contacts choosing the electrode more suitable for the surgery and a reference at FPz. For subcortical mapping of the corticospinal tract, a cathodic monopolar stimulation is recommended.
The corticobulbar motor pathway can also be monitored in the same way, giving us information about all the motor pathways from the cortex to the muscle, especially in the lower facial muscles. It can also be used in other cranial nerves, like the genioglossus and the pharyngeal muscles. With this technique, it is possible to monitor in real time the supranuclear, nuclear, and peripheral function in the different cranial nerves.
The stimulation parameters for Corticobulbar are similar, but not the same, using stimulation with multipulse stimulus: a train of 3 stimuli, interstimulus interval (ISI) 2 milliseconds, duration 0.5 ms. Electrodes in C3-Cz for the right-side muscles and C4-Cz for the left side. The intensity between 50 to 200 mAmps with a constant current, or 100 to 300 volts in constant voltage. It is recommended to use hook wire needles in the muscles to avoid the far field registration.

Some caveats about the corticobulbar technique are the following:
It is possible to stimulate in a loop through the foramen magnum or brainstem, in which case, it is frequent to obtain a false positive response for direct stimulation of the cranial nucleus or peripheral nerve. The way to differentiate this situation is by using a single stimulus vs. a train of stimulus to generate myogenic MEPs that can only be obtained with a train stimulus technique to overcome the general anesthesia.
If the technique obtains a muscle response with a single stimulus, this is the direct stimulation of the cranial nerve and not the stimulation of the corticobulbar pathway.
The latency is also different, the real MEPs for the facial is close to 13 milliseconds, but in the direct stimulation, it is less, in the order of 7 milliseconds.
When the stimulation is taking place, some movement in the surgical field can occur. It is recommended to warn the surgeon.
Also interesting is the fact that the amplitude of the response in the facial muscles is approximately a fifth of the obtained with direct supramaximal cortical stimulation. This fact reflects that only a subset of the motor axons of the facial nerve is being stimulated with this transcranial technique.
The filters deserve special attention. For Corticospinal MEPs filters of 10-100 Hz to 1500-3000 Hz is appropriate. For Corticobulbar low-frequency filters must be modified to 0,2-2,0 Hz or constraining to 150-300 Hz.

Tailoring warning criteria:
The warning criteria for Motor Evoked Potentials must be tailored for different surgical scenarios. Some relevant clinical situations that show this tailoring concept include:
1. Intramedullary Spinal Cord Tumors: It is essential to consider the oncological point of view, where a total resection can cure the patient, which is why the necessity to count on robust warning criteria that have the objective to avoid long-term motor deficits is essential. A well-balanced approach is to consider D-waves amplitude and muscle MEPs, if the D-waves are kept with an amplitude of 50 % or more, it is possible to continue the resection even if the muscle MEPs are lost, because of the well-documented experience of the transitory paraplegia. If D-waves are unavailable, the one primary warning criteria to consider is the disappearance of the muscle

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MEPs, and if they reappear with the implementation of restorative maneuvers, it is feasible to continue the resection. It is relevant to know other warning criteria such as amplitude, threshold, and morphology.

2.-Scoliosis and other spinal deformities: In this clinical situation, D-waves are not well suited, the reason for which the primary warning criteria is the presence or absence of the muscle MEPs. If they do not recover with the restorative maneuvers including to go one step back with the retrieval of the instrumentation, it is necessary to abandon the surgery. The amplitude warning criterion has been described to be relevant to a loss of 80% or more. Threshold warning criteria imply to have an elevation of stimulation intensity of 100 V in one or more muscles for more than an hour.

3.-Cerebral surgery of tumors and vascular lesions: In this kind of surgery the consensus is to consider a loss of amplitude of 50% or more of the muscle response as a warning criterion. The reason for this difference is that the cortical and subcortical representation of the motor function is broader and spread than in the spinal cord, brainstem or internal capsule.

In the cerebral cortex and corona radiata, it is frequent to have lesions that only cause a partial decrement of the muscle response amplitude.

There is a rule of thumb of 1 mm of distance per each mAmp of subcortical threshold stimulation intensity; this is useful to recognize the distance of the corticospinal tract from the resection limits. In other words, if there is a muscle response in the contralateral side with five mAmps, it is approximately five mm of distance from the corticospinal tract.

4.-Posterior fossa lesions: In this subgroup of pathology the Corticobulbar MEPs are especially relevant to monitor the cranial motor nucleus in the brainstem and the cranial nerves in their trajectory inside and besides the brainstem.

Especially for cortico-facial motor evoked potentials, the monitoring technique is only for a part of a contingent of axons of the nerve, which is why the correlation between damage and the clinical result is not 1 to 1, and mild deficits without modification of the cortico-facial MEPS are well described. The warning criterion of consensus is 50 % or more of amplitude reduction as significative.

Even when Corticobulbar is running smoothly, if it is possible and accessible, try to stimulate the nerve directly in the proximal segment of the tumor, checking the post-nuclear contingent of efferent axons directly.

We have to keep in mind that with the corticobulbar technique we are monitoring only the efferent pathway and not the afferent pathway involved in some relevant reflexes such as swallowing.

Interpretation:

The people who are in charge of intraoperative neurophysiological monitoring are a part of the surgical team. It is not enough to give an alarm; they have to figure out the possible cause or causes of that alarm, as well, based on an in-depth knowledge of the neurophysiological basis and methodology, neuroanatomy, confounding factors, especially anesthesiologic factors. It is a right to stop the surgery as many times as needed according to the well-balanced criteria of the professional that is practicing the monitoring. The primary surgeon has to give the time and opportunity to install and practice the neurophysiological tests in a fluid and constructive way. The intraoperative neurophysiology can modify the surgical results for a patient, the reason for which it is a great responsibility that must be afforded only for skilled professionals, according to the rules and laws of every country.

Conclusions:

1. Motor evoked potentials are a powerful technique, safe and trustable if qualified people are in charge.
2. Motor evoked potential can modify the surgical strategy.
3. Motor evoked potentials give real-time information of the status of the corticospinal and corticobulbar tracts.
4. Interpretation of the results requires expertise, each one of these techniques has some caveats that the professionals have to be familiar.
5. Warning criteria for MEPs must be tailored to different clinical situations.

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SOMATOSENSORY EVOKED POTENTIALS IN THE OR

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Somatosensory evoked potentials (SSEPs) are signals produced by the central nervous system in response to electrical stimulation of a peripheral nerve. It allows to assess the sensory pathway from the peripheral nerve, dorsal column of the spinal cord to the brain during surgical procedures in which the spinal cord, brainstem, or cerebrum is at risk. 1,2

Simulation: For stimulation a constant current stimulator delivering monophasic rectangular pulses of 100-300 μs duration, repetition rate of 2-8 Hz and 30-40 mA intensity are recommended for stimulation of the peripheral nerves. System bandpass of 30 – 1 kHz is used most often and self -adhesive, subdermal, bar or EEG electrodes are commonly placed over the nerve, cathode proximal and anode 2-3 cm distally. Stimulation may fail due to patient related factors such as limb edema, peripheral or other misplaced electrodes.

Recording: Either standard disk EEG electrodes, sterile subdermal needle or corkscrew electrodes may be used for recording. Recording electrodes for upper SSEPs are placed at C3'(C3 prime) and C4' and at right and left Erb's points. For lower SSEPs at Cz'scalp location. The "prime" mark indicates a modified site located 2 cm posterior to the named International 10–20 system scalp site. Short distances to the reference reduce noisiness in channels due to distant sources. But short distances also may reduce peak amplitudes. Both subcortical and cortical SSEPs increases reliability.3 Therefore for subcortical responses, electrodes should be placed at cervical or lumbar spinous process /referenced to Fz.
Recording electrode impedance should be less than 5 Kohms Recording may fail due to hypotension, hypothermia or noise in the operating room. Inhalational anesthesia may interfere with SSEPs recording and total intravenous anesthesia is commonly used.

SSEPs waveforms and criteria for abnormalities: Assessment of amplitude, morphology and latency of Erb's potential, P14, N18 and N20 for upper and P37 potentials for lower SSEPs are recommended and each patient serves as his or her own control. Alterations of SSEPs are reported immediately to the surgical team as warning that neural function may be compromised. Typically, a 50% drop in amplitude and a 10% prolongation in latency is considered a significant change in SSEPs. 4,5
SSEPs monitoring in surgeries: In spinal procedures the selection of the nerve to be stimulated to obtain the SSEP is determined by the segmental level of the surgical procedure. Spinal cord surgery above the C6 level can be monitored by SSEPs to median nerve stimulation. Ulnar nerve SSEP monitoring can be used when the surgery involves the lower cervical segments (above C8). If the patient is placed in prone position, ulnar nerve stimulation may be preferred to follow up brachial plexus ischemia. Surgery involving levels below the C8 segment requires stimulation of the posterior tibial nerve. Stimulation of the common peroneal nerve at the knee is technically more difficult, but it can be useful when the posterior tibial nerve cannot be stimulated
Ischemic brain injury is a major complication during intracranial vascular surgeries such as aneurysm and arteriovenous malformation surgeries. SSEPs are useful in measuring cortical perfusion.6 The medial lemniscus in the thalamus or the thalamocortical projections rising through the posterior limb of the internal capsule and corona radiata should cause SSEPs changes when these structures undergo ischemic changes as a result of reduced cerebral blood flow. The main limitation for SSEPs is that they fail to indicate motor ischemia in instances of isolated motor pathway injury. Both upper SSEPs are commonly used for surgeries at the middle cerebral artery and lower SSEPs for anterior cerebral artery territory.
SSEPs can be recorded directly from the cortical surface to localize the central sulcus and the precentral and postcentral gyri. 1,7
Tibial SSEPs can be used for dorsal column mapping. Dorsal column mapping is a useful technique for guiding the surgeon in locating the midline for myelotomy in intramedullary spinal cord surgery .8

Conclusion: SSEPs are a vital part of intraoperative neuromonitoring (IOM). They assess the functional integrity of the dorsal spinal cord They can also be used to warn of peripheral nerve/brachial plexus injury from patient positioning. Median SSEPs can be used to localize the central sulcus and pre and postcentral gyri. SSEPs are useful in measuring cortical perfusion and can serve as a supplemental for IOM. For proper monitoring multimodal IOM is recommended.

References:

1. Lueders, H., R. P. Lesser, et al. (1983). "Cortical somatosensory evoked potentials in response to hand stimulation." J Neurosurg

58(6): 885-94.
2. Jones, S. J., M. A. Edgar, et al. (1983). "A system for the electrophysiological monitoring of the spinal cord during operations for scoliosis." J Bone Joint Surg Br 65(2): 134-9.
3. Emerson, R. G. and D. C. Adams (2003). Intraoperative monitoring. Current practice of clinical electroencephalography, 3rd ed. J. S. Ebersole and T. A. Pedley. Philadelphia, Lippincott Williams & Wilkins: 936-954.
4. Schramm J, Koht A, Schmidt G, Pechstein U, Taniguchi M, Fahlbusch R. Surgical and electrophysiological observations during clipping of 134 aneurysms with evoked potential monitoring. Neurosurgery. 1990 Jan;26(1):61-70.
5. Friedman WA, Kaplan BL, Day AL, Sypert GW, Curran MT. Evoked potential monitoring during aneurysm operation: observations after fifty cases. Neurosurgery. 1987 May;20(5):678-87.
6. Neuloh G, Schramm J. Monitoring of motor evoked potentials compared with somatosensory evoked potentials and microvascular Doppler ultrasonography in cerebral aneurysm surgery. J Neurosurg. 2004;100:389-399.
7. Robertson, S. C., V. C. Traynelis, et al. (1994). Identification of the sensorimotor cortex with SSEP phase reversal. Intraoperative monitoring techniques in neurosurgery. C. M. Loftus and V. C. Traynelis. New York, McGraw-Hill, Inc: 107-111.
8. Yanni DS, Ulkatan S, Deletis V, Barrenechea IJ, Sen C, Perin NIUtility of neurophysiological monitoring using dorsal column mapping in intramedullary spinal cord surgery. J Neurosurg Spine. 2010 Jun;12(6):623-8.

ELECTROENCEPHALOGRAPHY (EEG)

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Objectives:
After attending the lecture and reading this abstract, the participant should be able to:
• Describe the physiologic basis.
• Detail the intraoperative methodology.
• List the main intraoperative applications.

Introduction: Hans Berger developed human electroencephalography in the 1920's. It evolved into a diagnostic specialty applicable to epilepsy, disorders of consciousness, dementia, and other brain disorders. In addition, it was quickly adapted to intraoperative use for epilepsy surgery and later on became a useful tool intraoperative cerebral monitoring.

Definitions: An EEG is a multi-channel recording of spontaneously fluctuating scalp potentials. An electrocardiogram (ECoG) is a similar recording made directly from cortex. Electroencephalography is the discipline of analyzing and interpreting these recordings.

Physiologic basis: Fluctuating postsynaptic potentials of a cerebral neuron generate extracellular currents that volume conduct through tissue, but decline in strength with the square of distance. Consequently, single neuron activity recordable very near the cell is too weak to register farther away. However, synchronous extracellular currents from many neurons can spatiotemporally summate to generate aggregate potentials strong enough to record on the cortex or scalp.
The uniform radial geometry of cortical pyramidal neurons enables spatiotemporal summation, while potentials of other more randomly oriented neurons cancel out. Thus, EEG selectively records synchronous potentials of pyramidal neuron populations. Subcortical input modulates cortical activity, contributing to rhythmic waveforms traditionally classified as delta (< 4 Hz), theta (4 to < 8 Hz), alpha (8–13 Hz), and beta (> 13 Hz).
Large pyramidal neuron populations — about 5–6 cm2 cortical surface area — must be synchronously active to generate scalp EEG signals. The potentials diffuse and attenuate through the skull and other intervening tissues, thereby forming wide low-voltage scalp fields characterized by a peak surrounded by declining voltage, like a hill. Localizing EEG signals involves analyzing their fields as sampled by all scalp electrodes in order to estimate the cortical source.
Smaller pyramidal neuron populations generate more focal and higher voltage ECoG signals: a large potential at one electrode can be absent a centimeter away. Localization considers each electrode separately and the activity of unrecorded cortex is unknown. The difference between EEG and ECoG can be likened to viewing a forest vs. viewing a sample of individual trees.

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Individual epileptic neurons exhibit abnormal 'paroxysmal depolarizing shift' discharges. Synchronous discharges in a large enough pyramidal neuron population generate ECoG or EEG 'spikes' that demarcate the interictal 'irritative zone'. Ictal transformation produces a seizure pattern characterized by various combinations of attenuation, rhythmic, or epileptiform discharges that evolve in frequency, amplitude, and distribution over time. The cortical seizure onset region helps demarcate the 'epileptogenic zone' that is usually smaller than the irritative zone.

Intraoperative methodology
For intraoperative EEG, collodion-fixed cup or needle electrodes are applied to 10–20 system coordinates. Modified locations may be needed to accommodate craniotomy. Gold-standard ≥ 16 channel montages are preferable because of their wide coverage and enhanced localization. However, truncated 4–8 channel montages may be needed to free channels for other modalities, or for intracranial procedures. Two channels are sufficient for anesthesia pattern tracking. Tight lead braiding, < 2 kΩ impedance and bipolar montages reduce extraneous electromagnetic interference.
For intraoperative ECoG, referential recordings are made from subdural strip or grid arrays, or from an ECoG headset. When mapping an irritative zone, a 16–64 electrode array should extend beyond the putative epileptogenic zone and the montage should be anatomically logical to enhance localization. When used only for afterdischarge detection, a smaller array of 4–16 electrodes around cortical stimulation sites may be sufficient.
To avoid aliasing, the minimum analog-to-digital sampling rate should be > 2 × the highest frequency of interest: 200 Hz for standard frequencies of up to 70 Hz. A 1–70 Hz bandwidth is appropriate for traditional EEG. Display sensitivity is adjusted to utilize dynamic range without trace overlap. Sweeps of 10–20 s is suitable for epileptiform discharge or anesthesia pattern assessment, while compressed 20–600 s sweeps enhance visualizing ischemic changes.
Processed EEG spectra displays can help summarize frequency content changes over time, but include potentially misleading artifacts, so are an adjunct but not a replacement for expert raw signal analysis.

Intraoperative applications: Intraoperative EEG is mainly used for cerebral ischemia detection during carotid endarterectomy, intracranial vascular procedures, or open heart surgery. Ischemic changes consist of reduced alpha/beta amplitude, followed by increased delta/theta amplitude, and then suppression. They are reversible when perfusion is restored before infarction.
Anesthesia pattern tracking is another application that can assist evoked potential interpretation. For example, evolution from continuous waveforms to burst–suppression or suppression can implicate deepening anesthesia as an explanation for declining somatosensory or motor evoked potential amplitudes.
Intraoperative ECoG is mainly used for irritative zone mapping and afterdischarge detection. Thus, epilepsy surgery is a longstanding application. Afterdischarges are seizure patterns induced by direct cortical stimulation. By spreading to adjacent and distant cortex, they can produce clinical signs or evolve into generalized seizures. Their detection with ECoG is mandatory during 'Penfield technique' stimulation (50–60 Hz pulse trains lasting 1–5 s) to avoid false localization. ECoG is optional for the brief high-frequency pulse train MEP technique because the short-latency transient responses are not subject to afterdischarge false localization.

Selected references:
1. Chatrian GE, Quesney LF. Intraoperative Electrocorticography. In: Engel J, Pedley TA, editors. Epilepsy - A Comprehensive Textbook. New York: Lippincott - Raven Press; 1998. p. 1749–65.
2. Huffelen AC. Electroencephalography used in monitoring neural function during surgery. In: Nuwer MR, editor. Intraoperative Monitoring of Neural Function. Vol. 8, Handbook of Clinical Neurophysiology. Amsterdam: Elsevier; 2008. p. 128–40.
3. Salvian AJ, Taylor DC, Hsiang YN, Hildebrand HD, Litherland HK, Humer MF, et al. Selective shunting with EEG monitoring is safer than routine shunting for carotid endarterectomy. Cardiovasc Surg 1997;5:481–5. Worrell GA, Stead M, Cascino GD. Electrocorticography. In: Nuwer MR, editor. Intraoperative Monitoring of Neural Function. Vol. 8, Handbook of Clinical Neurophysiology. Amsterdam: Elsevier; 2008. p. 141–9

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BACK TO BASICS:
INTRODUCTORY COURSE ON IONM (Part II)
Chairman: Sedat Ulkatan

EMG
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Intraoperative EMG serves two main purposes: Identification of a motor nerve and its course in the operative field (= “mapping”) on the one hand and monitoring of motor function conveyed by the same nerve on the other hand. Intraoperative use of EMG is very different from diagnostic EMG in the neurophysiological lab, beginning with electrode montage and the general approach. The peripheral motor system is organized in motor units: one nerve fiber activates a varying number of motor fibers, which are located in in circumscript region of a skeletal muscle. While diagnostic EMG will usually aim to analyze very small numbers of such motor units (ideally only one), an intraoperative approach will aim for monitoring of the largest possible number of motor units. This is done in order to achieve a representative sample of all units within the monitored nerve, as not all motor units may be damaged intraoperatively in the same moment and to the same extent. Electrode montage should reflect this and use multichannel-approaches wherever possible.
Intraoperative mapping by EMG is straightforward, reliable and robust. In most cases, it will either be used when the surgeon is not sure about the identity of a nerve within the operative field, or when the presence of a nerve is suspected, but the anatomical situation is so distorted/scarred that it cannot be identified in the microscope. The surgeon uses a hand-stimulator (mono- or concentric bipolar each with certain pros and cons) and “scans” the operative field with comparatively high voltage/current (constant current and constant voltage both work well for this). Once the stimulator touches or comes near the motor nerve, a strong signal will be seen in the EMG as most motor units are activated synchronously by the current. Voltage/current are then turned down to the lowest setting still eliciting a signal, and the course of the nerve is identified with high accuracy in the operative field. In many cases, this exact knowledge of the nerve´s position will be the best possible safeguard for its protection – provided that the anatomical situation allows the surgeon to keep out of the nerve´s way.
EMG-monitoring is most important when this is not possible, and the nerve needs to be manipulated, or when the surgeon manipulates a nerve the presence of which she/he was not aware of. Understanding of physiological “behavior” of motor activation and motor units is paramount for understanding EMG-activity observed during surgery, as physiological activity may be present without any correlation with nerve damage or even manipulation in some cases (example: shallow anesthesia level). Pathological activity indicating damage done, however, is profoundly different from this. The difference is not in the quantity of the signal (amplitude or overall “power”), but in the quality. Pathological activity (most important: “A-trains”) is activity of single motor units (individual discharges have the same morphology) with comparatively low amplitude and unphysiologically high frequency (inter-discharge-frequency 60-200Hz). It may be present for only a few seconds or for up to a minute.
The overall amount of A-train activity is closely correlated with functional outcome, which has been shown for the facial nerve and the facial muscles, but it should also be true for other motor systems. Because of this, monitoring is based on detection of this kind of activity by the neurophysiologist and instant feedback to the surgeon, as elicitation of A-trains is almost always directly correlated to nerve manipulation not tolerated by the nerve. Systems for automated analysis of intraoperative EMG (“automatic alarm”) do exist, but only on prototype-level as yet.

REFLEXOLOGY
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A reflex is a relatively simple motor behavior driven by afferent inputs of various modalities such as cutaneous, proprioceptive, vestibular, etc. For instance, cutaneous reflexes produce automatic movements that support protective and postural functions. Proprioceptive reflexes play an important role in regulating automatic movements. Reflexes are also essential for regulating movement and voluntary motor tasks. They transform gross movements in precise motor tasks that require fine coordination to achieve a directed goal. The

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motor system is organized hierarchically. The spinal cord mediates reflexes and rhythmic automatisms such as locomotion. The brainstem mediates cranial nerve reflexes and motor patterns such as respiration and swallowing. Descending systems of the brainstem also contribute to the control of posture by integrating visual, vestibular and somatosensory information. Ultimately, the descending pathways from the pre-motor and motor cortex and the brainstem integrate into spinal cord pathways, directly or through interneurons, to command the voluntary movement of body and limbs.
Intraoperative Monitoring with brainstem reflexes is today possible as long as general anesthesia is total intravenous anesthesia. They should be used as a supporting monitoring tool for surgeries where cranial nerves or related central structures are at risk of injury as their value has to be yet established in cranial surgery. Available methodologies for eliciting brainstem reflexes under general anesthesia include the blink reflex (Deletis et al, 2009), the masseter reflex (Ulkatan et al, 2017) and lately the laryngeal adductor reflex (Sinclair et al, 2017), a new
methodology introduced in head and neck surgeries for monitoring the laryngeal and vagus nerves. The blink reflex is a cutaneous trigeminal-facial reflex that protects the cornea from being injured by closing the eyes. The masseter reflex is a monosynaptic proprioceptive trigeminal-trigeminal reflex that modulates masticatory muscle activity and speech. The laryngeal adductor reflex is a cutaneous vago-vagal reflex that protects the airway from penetration of foreign bodies by closing the glottis. Loss of the laryngeal adductor reflex increases the risk of pneumonia due to aspiration. Monitoring with reflexes provides fast function assessment of sensory, motor and central pathways without the need of average (direct response) and does not interrupt surgery due to movement, what are great advantages during brainstem surgeries. Here we explain in detail the methodologies for eliciting these brainstem reflexes in the operating room.

References:

1. Deletis V, Urriza J, Ulkatan S, Fernandez-Conejero I, Lesser J, Misita D. The feasibility of recording blink reflexes under general anesthesia. Muscle Nerve 39: 642–646, 2009
2. Ulkatan S, Jaramillo AM, Téllez MJ, Goodman RR, Deletis V. Feasibility of eliciting the H reflex in the masseter muscle in patients under general anesthesia. Clin Neurophysiol. 2017 Jan;128(1):123-127.
3. Sinclair CF, Tellez MJ, Tapia OR, Ulkatan S, Deletis V. A novel methodology for assessing laryngeal and vagus nerve integrity in patients under general anesthesia. Clin Neurophysiol. 2017;128(7):1399-1405.

AUDITORY EVOKED POTENTIALS AND THEIR APPLICATION IN MONITORING OF THE AUDITORY PATHWAYS

Charles Dong, PhD | Department of Surgery, University of British Columbia, Vancouver, Canada

Objectives: This presentation is to give an overview of the neural substrates and neurophysiological bases of auditory evoked potentials and provide an introduction of using these auditory potentials to monitor the function of the auditory pathways during surgery.

Introduction: Auditory evoked potentials (AEPs) are electrical manifestations of activation of the auditory system in response to transient sound stimuli. Among them, Brainstem Auditory Evoked Potentials (BAEPs) and Auditory Nerve Compound Action Potentials (AN-CAPs) are commonly used in the clinical laboratory and the operating theatre.
Following the first report on BAEPs by Sohmer and Feinmesser1, Jewett and colleagues2 clearly described the waveform of human BAEPs and correctly interpreted the late waves of BAEPs as arising from the brainstem structures in the early 1970's. The clinical application of BAEPs came along shortly after. In 1975, Starr and Achor3 were among the first to demonstrate the relationship between BAEP abnormalities and neurological disorders. In the late 1970's, techniques of BAEPs were taken into the operating theatre aimed at improving hearing preservation during surgical removal of vestibular schwannomas4. In 1983, Moller and Jannetta5 recorded CAPs directly from the exposed cranial nerve VIII during cerebellopontine (CP) angle surgery. Available evidence supports the conclusion that AEP monitoring improves hearing preservation during CP angle procedures for resection of vestibular schwannomas and microvascular decompression of cranial nerves6,7.

Description of Auditory Evoked Potentials: BAEP: The BAEP is a series of electrical waves generated in the auditory nerve and the ascending auditory brainstem pathway in response to transient acoustic stimuli (e.g. clicks). It is recorded from an electrode at the vertex referenced to the mastoid or the ear lobe. In normal subjects, it consists of 5 - 7 vertex positive peaks designated with the Roman numerals, and falls within 10 milliseconds after the stimulus (Fig. 1). Among these peaks, waves I, III and V are most stable and prominent and therefore are usually measured for clinical use.

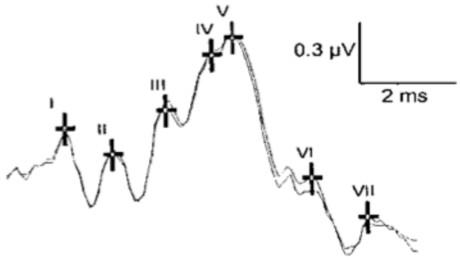

Fig. 1 A BAEP waveform recorded from a normal subject after averaging of 3000 individual trials. Stimuli: clicks of 70 dB HL; Recording montage: ipsilateral earlobe Ai (-) – vertex Cz (+).

AN-CAP: The AN-CAP is exclusively recorded intraoperatively from the electrode placed on or in close vicinity to the exposed proximal auditory nerve. It is a measure of signal conduction along the auditory nerve and usually has a triphasic waveform (Fig. 2). The depolarization front of the nerve generates the P1 potential and the large negative N1 is produced when the depolarization passes under the recording electrode.

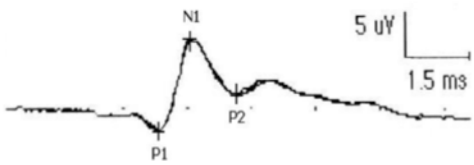

Fig. 2 Auditory nerve CAP recorded directly from the intracranial portion of cranial nerve VIII. Note the high-amplitude response which was obtained after averaging of 50 trials.

To better understand auditory evoked potentials and their application in neuromonitoring, knowledge of the anatomy of the ascending auditory pathway and the neural generators of these potentials is essential.

Anatomy of the Ascending Auditory Pathway and Neural Generators of BAEPs

The ascending auditory pathway begins with auditory nerve fibers leaving the cochlea, passing through the spiral ganglion and forming a nerve bundle in the internal acoustic canal (IAC) where it merges with the vestibular nerve to become the eighth cranial nerve. Together with the facial nerve, the eighth nerve exits the IAC through the porus acousticus and transverses the subarachnoidal space in the CP angle to enter the brainstem at the pontomedullary junction.

Neural elements in the ascending auditory brainstem pathway include the cochlear nucleus (CN), the superior olivary complex (SOC), the lateral lemniscus (LL) tracts and nuclei, and the inferior colliculus (IC), which are arranged in a “hierarchical” order (Fig. 3). Obviously, the auditory brainstem pathway is bilateral with connections of nuclei between two sides at almost all levels and incorporates complex parallel processing. These features make it unlikely that there is a one-to-one relationship between the brainstem structures and individual BAEP waves. In fact, all but the earliest waves (i.e. waves I and II) in the BAEP arise as a composite of electrical activities from multiple sources.

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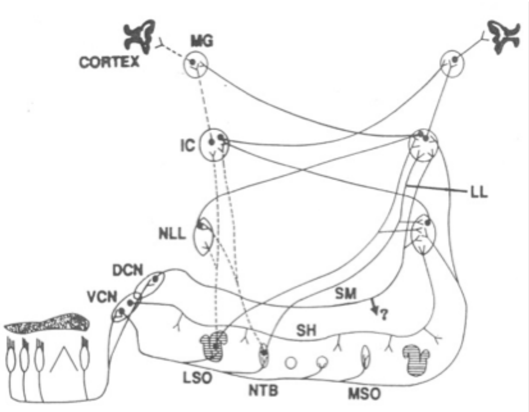

Fig. 3 Schematic drawing of the ascending auditory pathway (from Moller 1983)

Waves I and II are generated in the distal and proximal auditory nerve, respectively. Wave III is generated in the CN and the SOC in the lower pons. Less is known about Wave IV, but bilateral SOC and LL are among its contributors. Wave V also has multiple sources and is believed to be generated in the LL and the IC of both sides.

Clinical Utility of BAEPs

Interpretation of BAEPs in a clinical lab usually involves measuring the absolute latency of waves I, III and V, their interpeak latencies (i.e. IPL I-III, IPL I-V, and IPL III-V) and interaural differences, and comparing them with normative data. Although BAEPs have long been used to investigate patients with possible multiple sclerosis and other neurological disorders, and lesions of the CP angle and the brainstem, their diagnostic roles have gradually been replaced by the development of neuroimaging techniques (e.g. MRI). Owing to their properties of being objective and minimally affected by anaesthetics or the state of consciousness, however, BAEPs have found their utility in the operating room as a monitor of the ascending auditory pathway and in the intensive care unit as a prognostic indicator.

Monitoring of Auditory Evoked Potentials

Surgical procedures involving the CP angle and other areas of the posterior fossa pose risks of injury to the auditory nerve and sometimes brainstem structures, resulting in postoperative hearing loss and other associated neurological deficits. AEPs provide objective methods to monitor the function of the auditory nerve and brainstem auditory pathways and have been used during these surgical procedures to help preserve hearing and minimize the risk of postoperative neurological deficits4,5,6.

During surgery, many factors can cause AEP changes, which include technical, systemic and surgical. Only after confounding factors are excluded, can changes of AEPs be attributed to surgical manipulations. Consequences of surgical manipulation that can compromise the auditory pathway and lead to intraoperative AEP changes include direct mechanical or thermal injury and ischemia. Although some AEP changes resulting from mechanical trauma or thermal injury of the auditory pathway are rapid and irreversible, detection of these changes can potentially prevent more damage to the surrounding neural tissues. In the case of compression, traction or ischemia of the auditory pathway, the resulted AEP changes are usually gradual and reversible. Early detection of these changes and subsequent application of corrective measures may restore the normal function to the neural structures affected, leading to improved outcome.

Commonly used warning criteria include 50% amplitude decrease and/or 10% prolongation of latency of wave V. However, since the BAEP is relatively insensitive to alterations of anesthesia, any consistent changes exceeding normal variability should be given serious consideration. On the basis of our current understanding of the neural generators of BAEPs and the pattern of BAEP changes, the locus or loci of dysfunction in the auditory pathway may be roughly inferred.

The primary goal of AEP monitoring is to detect functional changes of the auditory pathways and provide early warning to the surgeon before they become irreversible. Each AEP technique has its own advantages and limitations. Their intraoperative application depends

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on the status of preoperative hearing, the pathology, and the location/size of the lesion. When deemed suitable, the BAEP alone or combined with the AN-CAP can be monitored during surgery to provide timely and accurate information about the function of the auditory pathways and improve postoperative outcome.

Summary
It is crucial to understand the anatomy and neurophysiology of AEPs in order to appreciate their clinical and intraoperative applications. Although their value in the assessment of certain neurological disorders has faded away due to the advances in neuroimaging techniques, AEPs have found their utility in the operating room. During monitoring, examination of the pattern of AEP changes, investigation of possible contributory factors and correlation of the changes with surgical maneuvers can help determine the underlying causes and provide the correct interpretation.

Key References

1. Sohmer H and Feinmesser M. (1967) Cochlear action potentials recorded from the external ear in man. Ann Otol Rhinol Laryngol 76:427-435.
2. Jewett DL, Romano MN and Williston JS. (1970) Human auditory evoked potentials: possible brain stem components detected on the scalp. Science 167:1517-1518.
3. Starr A and Achor J. (1975) Auditory brain stem responses in neurological disease. Arch Neurol 32(11):761-768.
4. Ojemann RG, Levine RA, Montgomery WM, et al. (1984). Use of intraoperative auditory evoked potentials to preserve hearing in unilateral acoustic neuroma removal. J Neurosurg 61(5): 938-948.
5. Moller AR and Jannetta PJ. (1983) Monitoring auditory functions during cranial nerve microvascular decompression operations by direct recording from the eighth nerve. J Neurosurg 59: 493-499.
6. Harper CM, Harner SG, Slavit DH, et al. (1992) Effect of BAEP monitoring on hearing preservation during acoustic neuroma resection. Neurology 42: 1551-1553.

Recommended Reading

1. Chiappa KH. (1997) Evoked potentials in clinical Medicine. 3rd ed. Lippincott-Raven, New York.
2. Moller AR. (2011) Intraoperative neurophysiological monitoring. 3rd ed. Springer, New York.

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SESSION I:
VASCULAR BRAIN SURGERY
TALKING ABOUT ANATOMY
Chairman: Karl Kothbauer

FUNCTIONAL VASCULAR ANATOMY
Dr. Olga Mateo Sierral Department of Neurosurgery | Gregorio Marañón University Hospital | Madrid, Spain

Functional vascular anatomy of the brain encompasses the study of anatomy in its relation to function and includes the normal development of brain vessels and their collaterals. Central nervous system circulation is a system of vascular redundancy, however genetic and environmental factors contribute to anatomical variations that are associated with aneurysms, arteriovenous malformations (AVMs) or ischemic events.
Three main aspects are selected regarding its implication in vascular disease:
1. Normal development of brain circulation according to embryologic and phylogenic studies. Comparative anatomy shows different patterns and anomalies in posterior and anterior circulations in animals compared to humans, although many aspects of vessel development is shared among species and may share some knowledge on human variations.
2. Collateral circulation includes primary (circle of Willis) and secondary (external carotid artery, leptomeningeal) routes that may allow specific tolerance to arterial occlusions. However, collateral flow changes among individuals and along lifetime, depending on genetic and vascular risk factors still considered controversial and subjected to deeper evaluations, and are here reviewed.
3. Aneurysms are known to be associated with anatomic brain vessel variations contrary to AVMs, and this aspect is concordant with our recent experience in patients harboring these lesions. Complementarily, ischemic events can appear associated with arterial anomalies, and these anomalies as we have reviewed may influence final outcomes of these patients.
Understanding of the patterns of normal and pathologic development of brain circulation may help in the evaluation and management of these conditions.

TALKING ABOUT ANATOMY
Chairman: Karl Kothbauer

SURGERY OF INTRACRANIAL ANEURYSMS & AVM
Kunihiko Kodama, M.D. and Yoshikazu Kusano, M.D. | Nagano Municipal Hospitall Japan

Objective and background:
Neurosurgical procedures for treatment of intracranial aneurysms (ICAns) and arteriovenous malformation (AVM) are discussed here. ICAns have penetration rate of 1% of population and have approximately 1% rupture rate annually, and aneurysm rupture results in subarachnoid hemorrhage (SAH). Probability of the aneurysm rupture is calculated by scoring system (PHASES score) depends on the aneurysm characteristics such as location, size and past medical history and so on. AVM also caused SAH or intracerebral hemorrhage. Surgical procedures are planned to eliminate these rupture risk. Ruptured ICAns and AVMs has higher re-rupture rate and surgery is absolutely indicated when neurological recovery is anticipated. Surgical indications on the incidentally found non-ruptured lesions are discussed on some guidelines, and treatment indication is decided on surgical risk and natural history of the lesion. Intraoperative neuromonitoring (IOM) plays indispensable role to reduce the surgical risk.

Surgery of intracranial aneurysmsms
Two major surgical procedures are aneurysm neck clipping by craniotomy and coil embolization of aneurysm by endovascular approach. The numbers of coil embolization has been increasing because of its less invasiveness and development of adjunctive technique in these days. But, long term outcome of the coil embolization remains unclear compared with clipping surgery. Better surgical approach is also determined by aneurysm characteristics. Generally saccular-shape aneurysms are to be treated by coil

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embolization, and wider aneurysm neck or fusiform or complex-shape aneurysm by clipping surgery. Obliteration of aneurysm and preserved patency of the relevant vessels, especially anterior choroidal artery and lenticulostriate artery, need be confirmed by supportive technique including IOM and intraoperative video angiography.

Surgery of AVMs

Non-ruptured AVM has annual rupture risk of 2-4%, and ruptured one has annual rupture risk of 6-18% in the first year. AVM is usually classified by Spetzler-Martin grading system (nidus location: eloquent or non-eloquent, size: <3cm, 3-6cm, >6cm, and draining system: superficial only or deep), and it was reported that the grading system well reflects the surgical risk. Surgical resection of the nidus is the primary goal for AVM treatment, however, multimodality treatment strategy is considered for each case. S-M grade 1-2 AVM is treated by surgery alone and S-M grade 3 AVM by surgery sometimes combined with endovascular feeder and/ or nidus embolization prior to surgical resection of the nidus. S-M grade 4-5 AVM has a certain surgical risk, so that treatment option need be discussed meticulously.

Conclusions

Surgery for ICAn and AVMs are discussed. Best surgical treatment strategy is determined with various factors and multimodal treatment approach became common, and favorable outcome are anticipated with aids of multimodal supportive technique including IOM.

SURGERY OF CAROTID ENDARTERECTOMY

Teresa Cervera Bravo, Spain

Introduction:

Carotid endarterectomy (CEA) used to be the most common vascular procedure in vascular surgery practice; current evidences have decreased this tendency, but is still the gold standard treatment for symptomatic moderate to high grade carotid stenosis.
On the other hand, carotid stenting (CAS) is an alternative to endarterectomy that may be considered, although with less evidence, in most of the same indications as CEA.
Both techniques have risks of stroke. The most common causes of cerebral peri- operatory ischemic events occur from embolic phenomenon, but decrease in cerebral perfusion may be the aetiology in certain circumstances.

Objectives:

Review the recommendations of the most updated clinical guide
List the methods of brain monitoring to detect cerebral hypo perfusion
Describe the techniques and identify the risks of new neurological adverse events

Final considerations

Success of carotid revascularization depends on:
- Correct indications
- Correct selection of the technique
- Accurate knowledge of the possible complications
- Careful performance of the procedure

References

1. Management of Atherosclerotic Carotid and Vertebral Artery Disease: 2017 Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS)
2. Eur J Vasc Endovasc Surg (2018) 55, 3e81

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TALKING ABOUT NEUROMONITORING

Chairman: Francesco Sala

NEUROMONITORING IN CAROTID ENDARTERECTOMY

Michael J. Malcharek, MD, PhD I Klinikum St. Georg gGmbH Leipzig, Germany

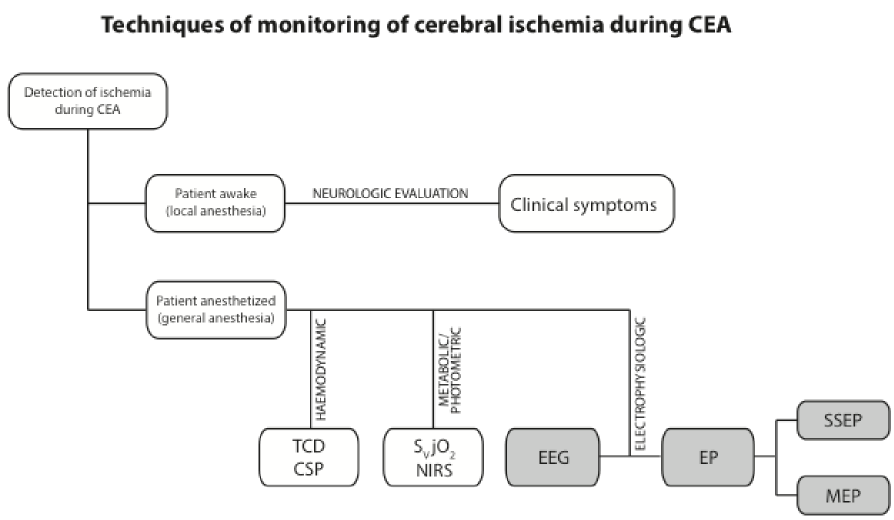
Objectives:

A controversy exists regarding which monitoring technique is superior in cases in which general anesthesia is necessary for carotid endarterectomy (CEA). This lecture is supposed to show some developments in the field of intraoperative neurophysiology with regard to monitoring of cerebral ischemia during internal carotid artery (ICA) cross clamping.

Historical review:

CEA is an effective intervention to prevent strokes in patients with symptomatic and asymptomatic carotid stenosis but it also has a potential risk of perioperative stroke. Ischemia related to ICA cross clamping and arterial embolism are the most common intraoperative causes of stroke. Therefore, selective shunt application based on different criteria evaluating the patient while awake or anesthetized has been shown to be sufficient in reducing the rate of perioperative stroke (e.g. Woodworth et al. 2007).

Figure 1 shows neurophysiologic monitoring methods in the context of neuromonitoring techniques used for CEA.



(Fig. 1: Scheme of various neuromonitoring methods during CEA. TCD – transcranial doppler; CSP – carotid stump pressure; SvjO2 – jugular venous oxygen saturation; NIRS – near infrared spectroscopy; EEG – electroencephalogram; EP – evoked potentials; SSEP – somatosensory evoked potentials; MEP – motor evoked potentials)

With regard to neurophysiologic methods meanwhile SSEP recording after stimulating the median nerve seems to be the gold standard monitoring technique during CEA in many institutions. However, EEG monitoring, essentially more channel EEG, was officially recommended in US in 1993 (Nuwer et. al 1993). In contrast to SSEP monitoring under general anesthesia during CEA EEG has some potential limitations, such as the low specificity in patients with preexisting EEG-changes, e.g. history of stroke (Blume et al. 1986) and the comparably strong dependency of the EEG criteria for ischemia on anesthesia regime. In addition animal experiments showed SSEP alteration at lower levels of cerebral blood flow, whereas significant EEG changes occurred earlier at higher levels. Thus, shunt rates may be higher under EEG monitoring. However, both EEG and SSEP are indirect predictors for cerebral ischemia providing more or less information about global ischemic events. Even though the high sensitivity and specificity of SSEP monitoring false negative results with regard to the outcome of motor function after CEA have been described in up to 3.5% (Schwartz et al. 1996, Prokop et al. 1996).

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Similar to results from cerebral aneurysm surgery false negative SSEP rates suggest differences of global cortical CBF and focal subcortical perfusion of the corticospinal tract (CST) (Szelényi et al. 2006, Neuloh and Schramm 2004). Since MEP monitoring provides direct information about the integrity of the CST it was successfully implemented in aneurysm surgery a decade ago. However, pathophysiology during CEA can be similar - Why not using MEP monitoring to detect subcortical ischemia of the CST during ICA cross clamping in carotid surgery?

Summary of recent developments:

A multicenter trial including 600 patients undergoing CEA under general anesthesia showed evidence that MEP recording was technical wise feasible in this particular cohort comparable to SSEP results (Malcharek et al. 2013). Secondly, there was found an isolated MEP loss in 1.5%. The time from MEP loss until intervention was significantly related to the postoperative outcome of motor function. The longer the delay until shunt application the higher the probability of postoperative motor deficit. Figure 2 illustrates a case of isolated MEP loss during ICA cross clamping suggesting subcortical focal ischemia of the CST

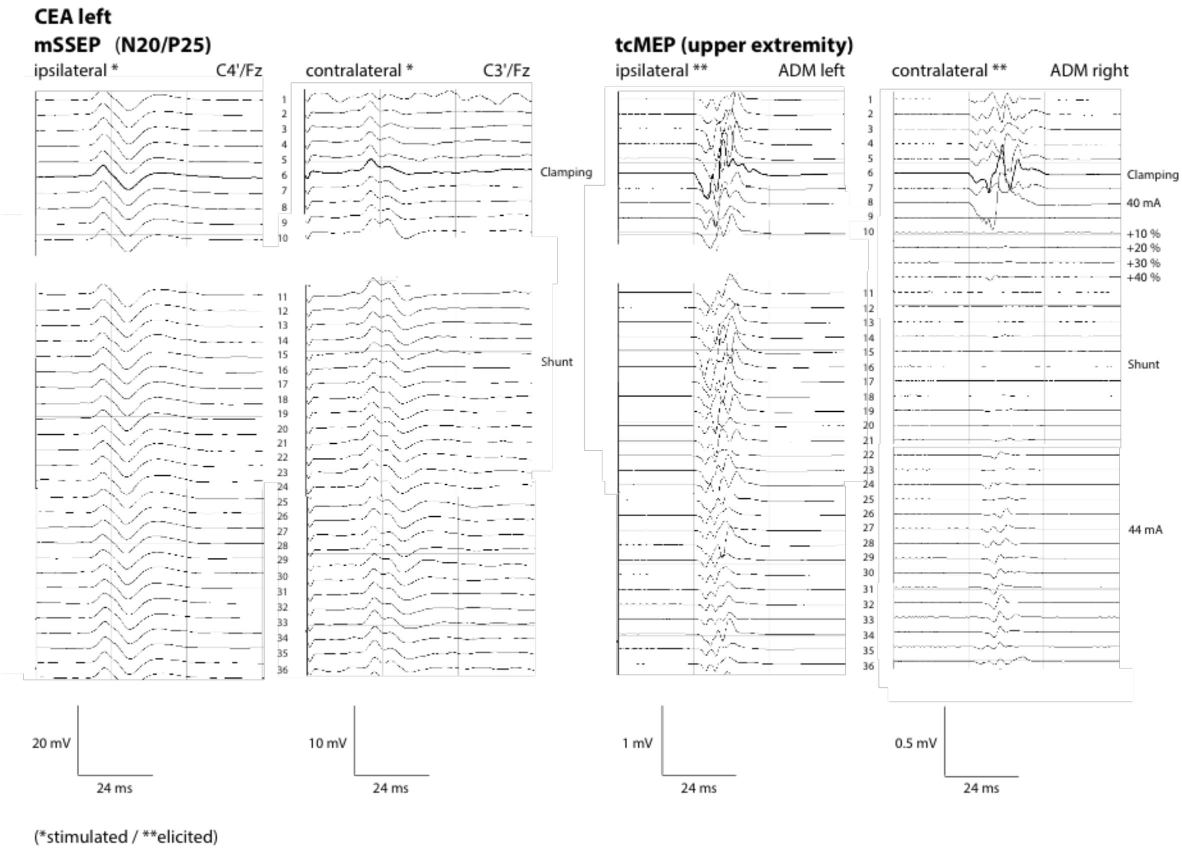

Fig. 2: Exemplarily case of isolated unilateral MEP loss during ICA cross clamping

Further single center studies supported the useful implementation of MEP method in addition to SSEP recording (multimodal EP monitoring) during CEA (Malcharek et al. 2015a, Alcantara et al. 2013).

Furthermore the technical stability of the multimodal EP concept in patients under general anesthesia was recently compared to the

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feasibility of awake neurologic evaluation in patients undergoing CEA under local anesthesia (Malcharek et al. 2015b). Multimodal EP monitoring failed significantly less than awake monitoring of the patients (1% vs. 5.4%). Even though a historical control (awake patients) was used and the power of the study is limited, the trial points out that the combination of SSEP and MEP monitoring under general anesthesia should be considered as effective alternative to awake evaluation of patients during CEA.

Conclusions:
Recent developments in intraoperative neurophysiologic monitoring during CEA suggest an effective combination of SSEP and MEP monitoring to reduce false negative results. Hereby the differentiation between cortical and subcortical ischemia seems pathophysiological wise essential - similar to cerebral aneurysm surgery. However, prospective investigations including a control group without MEP monitoring would be necessary to provide clear evidence. Since the above described retrospective trials showed some usefulness of MEP monitoring in a small group of patients, and according to pathophysiologic considerations, a control group would probably be unethically.

Key references and recommended readings:
1. Alcantara SD, Wuamett JC, Lantis JC 2nd, Ulkatan S, Bamberger P, Mendes D, Benvenisty A, Todd G. Outcomes of combined somatosensory evoked potential, motor evoked potential and electroencephalography monitoring during carotid endarterectomy. Ann Vasc Surg 2013;28(3):665-72.
2. Blume WT, Ferguson GG, McNeill DK: Significance of EEG changes at carotidendarer-ectomy. Stroke 1986; 17:891-7.
3. Malcharek MJ, Ulkatan S, Marinò V, Geyer M, Lladó-Carbó E, Perez-Fajardo G, Arranz-Arranz B, Climent J, Aloj F, Franco E, Chiacchiari L, Kulpok A, Sablotzki A, Hennig G, Deletis V. Intraoperative monitoring of carotid endarterectomy by transcranial motor evoked potential: a multicenter study of 600 patients. Clin Neurophysiol 2013;124(5):1025-30.
4. Malcharek MJ, Kulpok A, Deletis V, Ulkatan S, Sablotzki A, Hennig G, Gille J, Pilge S, Schneider G. Intraoperative Multimodal Evoked Potential Monitoring During Carotid Endarterectomy: A Retrospective Study of 264 Patients. Anesth Analg 2015a;120(6):1352-60.
5. Malcharek MJ, Herbst V, Bartz GJ, Manceur AM, Gille J, Hennig G, Sablotzki A, Schneider G. Multimodal evoked potential monitoring in asleep patients versus neurological evaluation in awake patients during carotid endarterectomy - a single-centre retrospective trial of 651 patients. Minerva Anaesthesiol 2015b. [Epub ahead of print]
6. Neuloh G, Schramm J. Monitoring of motor evoked potentials compared with somatosensory evoked potentials and microvascular Doppler ultrasonography in cerebral aneurysm surgery.J Neurosurg 2004;100:389–99.
7. Nuwer MR, Daube J, Fischer C, Schramm J, Yingling CD. Neuromonitoring during surgery. Report of an IFCN Committe. Electroenceph Clin Neurophysiol 1993;87:281-8.
8. Prokop A, Meyer GP, Walter M, Ersami H. Validity of SEPS in carotid surgery. J Cardiovasc Surg (Torino) 1996;37(4):337-42.
9. Schwartz ML, Panetta TF, Kaplan BJ, Legatt AD, Suggs WD, Wengerter KR, Marin ML, Veith FJ. Somatosensory evoked potentials monitoring during carotid surgery. J Cardiovasc Surg 1996;4(1):77-80.
10. Szelényi A, Langer D, Kothbauer K, De Camargo AB, Flamm ES, Deletis V. Monitoring of muscle motor evoked potentials during cerebral aneurysm surgery: intraoperative changes and postoperative outcome. J Neurosurg 2006;105:675–81.
11. Woodworth GF, McGirt MJ, Than KD, Huang J, Perler BA, Tamargo RJ. Selective versus routine intraoperative shunting during carotid endarterectomy: a multivariate outcome analysis. Neurosurgery 2007;61:1170-1176.

MONITORING DURING ENDOVASCULAR PROCEDURES (BRAIN AND BRAINSTEM)

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Intraoperative monitoring (IOM) has been used mainly in endovascular treatment for Spinal cord procedures and has demonstrated to be of critical value for decision making via provocative tests1,2,3. Very recently, the interest of IOM for endovascular treatment of brain and brainstem procedures has been raised too. Brainstem procedures require the same level of IOM support indeed as spinal cord procedures, but brainstem procedures can be only done in highly experienced units. In the past decade, endovascular treatment of brain aneurysms has become the first option of treatment, but just very recently IOM has become an integral part of these procedures.
Endovascular treatment of a brain aneurysm entitles various procedural maneuvers, such as balloon occlusion, that may cause ischemia and postoperative permanent or transient neurological deficit. Lukui reported that in 4.8% of patients, changes in IOM triggered some

procedural action in order to prevent a neurological deficit. However, five patients had postoperative neurologic deficits that could not be predicted using IOM 4. Similarly, Amon et al. reported that 26% of the patients showed IOM changes during endovascular procedures and in 14% of them the procedure was altered due to those changes5. In a large series of 873 patients of endovascular brain procedures Phillips et al.reported IOM changes in 6% of the patients. The positive predictive value was 21%, the negative predictive value was 83%, sensitivity 60%, and specificity 48%6.

Interestingly, Sala et al. in their 11-patient series did not observe any false negative results, by using lidocaine as provocative test7. Kinshuk et al. reported IOM changes in 3.8% of 406 patients who underwent endovascular treatment of aneurysms. They also reported Irreversible changes highly correlated with postoperative neurologic deficits8.

The IOM modalities used in endovascular brain treatments are still mainly limited to somatosensory evoked potential (SEP), and brainstem auditory evoked potentials (BAEP). Unsurprisingly, postoperative motor deficits were not detected by SEP and BAEP modalities in several studies4,5,6,8. However, all the authors of these studies agreed that motor evoked potentials (MEP) might also be useful in endovascular procedures. Only one study reported that MEP would not add extra value to IOM in endovascular treatment of aneurysm9. This statement can be contested given the fact that aneurysm procedures pose a different type of risk than general brain endovascular procedures. Hiraishi et al. reported in a small series of Choroideal artery aneurysms even the angiography doesn't reveal any problems, they detected MEP changes and patients showed postoperative transient motor deficits, MEP monitoring prevented permanent deficits10. The risk during an aneurysm is more comparable to the risk during carotid endarterectomy because embolization and ischemia can happen in both procedures in a different mechanism than Brain aneurysm clipping. Brain vascular malformations and their endovascular treatment are more similar to spinal procedures and require MEP monitoring for very same reasons. In our experience, during endovascular treatment of brain vascular anomalies, MEP, as well as SEP, is an essential technique of IOM because provocative testing with lidocaine and amytal are systematically used. IOM for endovascular brain procedures should be multimodality monitoring. Particularly, aneurysms and vascular malformations located at the brainstem require wide-ranging IOM methods. Unfortunately, there is not a big series published about the utility of multimodal IOM, and so far studies are few with also a little number of cases. Only personal communications of highly expert institutes state that multimodal IOM should be used in brain and brainstem endovascular procedures. The predictive value of the provocative tests should be expected to be the same for spinal endovascular procedures as for Endovascular brain procedures.

Conclusions:

Brain endovascular treatment procedures are becoming a big part of vascular neurosurgical treatments; Multimodality IOM and provocative tests have shown to be effective tools preventing neurological complications.

References

1. Lukui Chen. Detection of Ischemia in Endovascular Therapy of Cerebral Aneurysms: A Perspective in the Era of Neurophysiological Monitoring. Asian Journal of Neurosurgery 2010; 5: 60-67.
2. Amon Y. Liu, Jaime R. Lopez, Huy M. Do, Gary K. Steinberg, Kevin Cockroft, and Michael P. Marks. Neurophysiological Monitoring in the Endovascular Therapy of Aneurysms. AJNR Am J Neuroradiol 24:1520–1527, September 2003.
3. Phillips JL, Chalouhi N, Jabbour P, Starke RM, Bovenzi CD, Rosenwasser RH, Wilent WB, Romo VM, Tjoumakaris SI.Somatosensory evoked potential changes in neuroendovascular procedures: incidence and association with clinical outcome in 873 patients. Neurosurgery. 2014 Nov;75(5):560-7; discussion 566-7
4. Sala F, Beltramello A, Gerosa M. Neuroprotective role of neurophysiological monitoring during endovascular procedures in the brain and spinal cord. Neurophysiol Clin. 2007 Dec;37(6):415-21. Epub 2007 Nov 9
5. Sahaya K, Pandey AS, Thompson BG, Bush BR, Minecan DN. Intraoperative monitoring for intracranial aneurysms: the Michigan experience.J Clin Neurophysiol. 2014 Dec;31(6):563-7. Horton TG, Barnes M, Johnson S, Kalapos PC, Link A, Cockroft KM. Feasibility and efficacy of transcranial motor-evoked potential monitoring in neuroendovascular surgery.AJNR Am J Neuroradiol. 2012 Oct;33(9):1825-31.
6. Hiraishi T, Fukuda M, Oishi M, Nishino K, Shinbo J, Sorimachi T, Ito Y, Fujii Y.
7. Usefulness of motor-evoked potential monitoring during coil embolization of anterior choroidal artery aneurysms: technical reports. Neurol Res. 2011 May;33(4):360-2.
8. Malcharek MJ, Ulkatan S, Marinò V, Geyer M, Lladó-Carbó E, Perez-Fajardo G, Arranz-Arranz B, Climent J, Aloj F, Franco E, Chiacchiari

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L, Kulpok A, Sablotzki A, Hennig G, Deletis V. Intraoperative monitoring of carotid endarterectomy by transcranial motor evoked potential: a multicenter study of 600 patients.Clin Neurophysiol. 2013 May;124(5):1025-30.

SESSION II:
EPILEPSY SURGERY
TALKING ABOUT ANATOMY
Chairman: Elif Aydinlar

THE NEW CLASSIFICATION OF SEIZURES: THE 2017 ILAE SEIZURE CLASSIFICATION
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The purpose of this talk is:
- spreading knowledge on the background of the new ILAE seizure and epilepsy classification, in which seizure type classification is the first step.
- Learn how to use the new classification of seizure types, to enable good communication with other health care professionals and patients.
- Giving you tools to use the seizure type classification in IONM reports, and enable you to understand medical reports in which these seizure types are mentioned.
- Gain insight in the new 2017 ILAE epilepsy types and epilepsy syndrome classification.

Background:
In 2017, the International League Against Epilepsy (ILAE), presented a revised classification of seizures.1 The ILAE is the world's main scientific body devoted to the study of epilepsy. Their classifications are used around the globe. The new system is based upon the earlier model formulated in 1981. The new classification of the ILAE is intended "to make diagnosing and classifying seizures more accurate and easier."

The classification includes three consecutive levels: (1) describing the seizure type, defined by the new 2017 ILAE Seizure Classification. (2) diagnose epilepsy types, including focal epilepsy, generalized epilepsy, combined generalized, and focal epilepsy, and also an unknown epilepsy group. (3) Describe the epilepsy syndrome, where a specific syndromic diagnosis can be made. The aetiology should be considered at all three levels and is divided in six subgroups, selected because of their potential therapeutic consequences.2

For us, as health care professionals performing intraoperative neuromonitoring, and/or performing EEG diagnostics pre-operatively, it is important to describe seizures according to this new classification. Using a common language for seizure classification, makes it easier to communicate with other clinicians caring for people with epilepsy and doing research on epilepsy. Moreover, one of the motives to change the classification, is to enhance communication with non-experts and patients.

In this course we will focus on the classification of the seizure types. The old classifications worked for many years but did not capture all types of seizures. This is now changed, although the definition of a seizure is still the same. The official definition of a seizure is "a transient occurrence of signs and/or symptoms due to an abnormal excessive or synchronous neuronal activity in the brain." So, during a seizure, large numbers of brain cells are activated abnormally at the same time. As you all know, seizures can be registered using EEG via electrodes on the scalp (sEEG). Intraoperative it is also possible to record epileptic activity via electrodes on the cortex itself, electrocorticography (ECoG). Both discrete electrodes and electrode grids can be used.

The ILAE classification of seizure types
The new basic seizure classification is based on 3 key features:
1. The localization: where do seizures begin in the brain,
2. the level of awareness during a seizure, and
3. other features of seizures.

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1. Where seizures begin in the brain

The first step to separate seizures is to identify where they begin in the brain. This is extremely important for it affects, among other things, the possibilities for surgery.

- **Focal seizures: (previously called partial seizures)**

Start in an area or network of cells on one side of the brain.

- **Generalized seizures: (previously called primary generalized)**

Engage or involve networks on both sides of the brain at the onset of a seizure.

- **Unknown onset:**

If the onset of a seizure is not known, the seizure falls into the unknown onset category. If later on it does become clear if the onset is focal or generalized, it can be switched.

- **Focal to bilateral seizure:**

A seizure that starts in one side or part of the brain and spreads to both sides.

2. Describing Awareness

The second step to classify a seizure is to describe whether a person is aware during a seizure. This is of practical importance because it is one of the main factors affecting a person's safety during a seizure. Awareness is used instead of consciousness, because it is easier to evaluate.

- **Focal aware:**

If awareness remains intact, even if the person is unable to talk or respond during a seizure, the seizure would be called a focal aware seizure.

- **Focal impaired awareness:**

If awareness is impaired or affected at any time during a seizure, even if a person has a vague idea of what happened, the seizure would be called focal impaired awareness.

- **Awareness unknown:**

Sometimes it's not possible to know if a person is aware or not, for example if a person lives alone or has seizures only at night. In this situation, the awareness term may not be used or it would be described as awareness unknown.

- **Generalized seizures are all presumed to affect a person's awareness or consciousness in some way.**

Thus, no special terms are needed to describe awareness in generalized seizures.

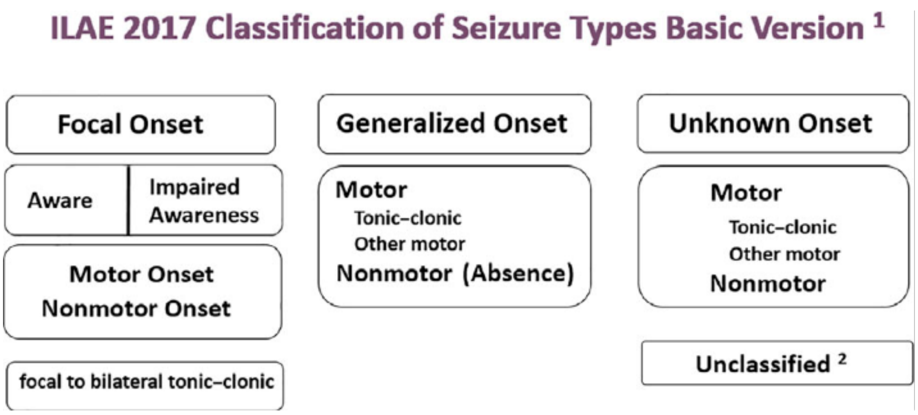

Figure 1. The basic ILAE 2017 operational classification of seizure types. 1Definitions, other seizure types, and descriptors are listed in the accompanying paper and glossary of terms. 2Due to inadequate information or inability to place in other categories. Epilepsia©ILAE from Fisher et al. Instruction manual for the ILAE 2017 operational classification of seizure types. Epilepsia doi 10.1111/epi.136711

3. Motor and other features of seizures

Many other symptoms may occur during a seizure. Most seizures can be classified by signs and symptoms that happen during a seizure. However, for practical purposes, long descriptive terms are probably not useful for day-to-day life. In this basic system, seizure

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behaviours are separated into groups that involve movement. In this basic system, seizure behaviours are separated into groups that involve movement.

- **Focal seizures:**

  Focal motor seizure:
  This means that some type of movement occurs during the event. For example, twitching, jerking, or stiffening movements of a body part or automatisms (automatic movements such as licking lips, rubbing hands, walking, or running).

  Focal non-motor seizure:
  This type of seizure has other symptoms that occur first, such as changes in sensation, emotions, thinking, or experiences.

- **Focal aware or impaired awareness seizure:**

It is also possible for a focal aware or impaired awareness seizure to be sub-classified as motor or non-motor onset.

Auras: The term aura, which describes symptoms a person may feel in the beginning of a seizure, is not in the new classification. Yet people may continue to use this term. It's important to know that in most cases, these early symptoms may be the start of a seizure.

- **Generalized onset seizures (that start in both sides of the brain), can also be motor or non-motor.**

  Generalized motor seizure: The generalized tonic-clonic seizure term is still used to describe seizures with stiffening (tonic) and jerking (clonic). This loosely corresponds to "grand mal." Other forms of generalized motor seizures may happen. Many of these terms have not changed, and a few new terms have been added (see image below).

  Generalized non-motor seizure: These are primarily absence seizures. These seizures involve brief changes in awareness, staring, and some may have automatic or repeated movements like lipsmacking.

- **Describing Unknown Onset Seizures**

When the beginning of a seizure is not known, this classification still gives a way to describe whether the features are motor or non-motor.

In the following image, the types of features under motor and non-motor seizures are listed for all types: focal, generalized, and unknown onset.

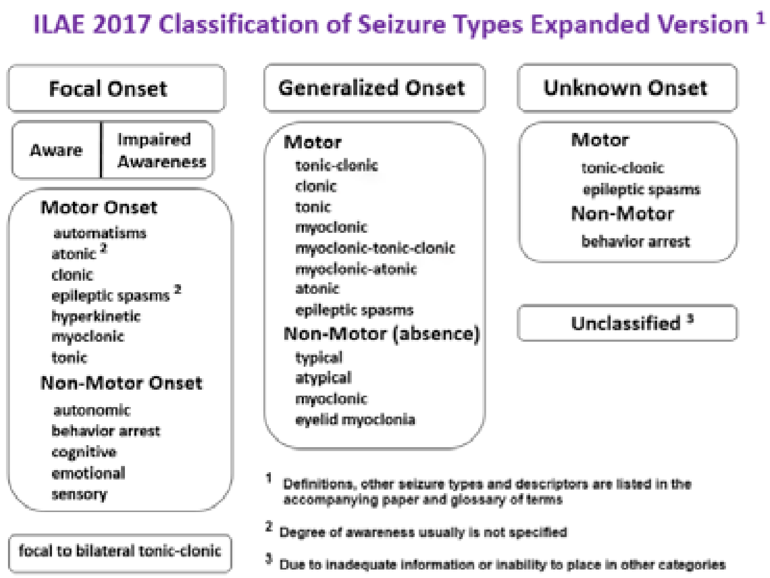

Figure 2. The expanded ILAE 2017 operational classification of seizure types For further clarifications see Fisher et al. Epilepsia, 58(4):531–542, 2017, doi 10.1111/epi.13671

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The second level after classification of the seizure type is epilepsy classification. The ILAE has also produced a new classification and terminology of the epilepsies.2 The epilepsy classification includes the whole clinical picture, with information on seizure types, causes, EEG pattern, brain imaging, genetics, and epilepsy syndromes. It includes focal epilepsy, generalized epilepsy, combined generalized and focal epilepsy, and also an unknown epilepsy group. The third level is that of epilepsy syndrome. At this level a specific syndromic diagnosis can be made.

A part of the content of this manuscript is a brief abstract of the following articles:

1. RS Fisher et al. Instruction manual for the ILAE 2017 operational classification of seizure types.
Epilepsia, 58(4):531–542, 2017, doi 10.1111/epi.13671
2. IE Scheffer et al. ILAE classification of the epilepsies: Position paper of the ILAE Commission for Classification and Terminology. Epilepsia, 58(4):512–521, 2017 doi: 10.1111/epi.13709

NEUROMONITORING OF EPILEPSY SURGERIES

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Objectives

After attending the lecture and reading this abstract, the participant should be able to:

- State the goals of monitoring epilepsy surgery.
- Describe intraoperative epileptic focus mapping and its limitations.
- Outline functional mapping and monitoring relevant to epilepsy surgery.

Introduction

The legendary epilepsy surgeon Wilder Penfield and his neurologist colleague Herbert Jasper developed intraoperative neurophysiology for epilepsy surgery beginning in the 1930's. Their basic approach is still in use — although modified by subsequent advances. In particular, modern preoperative imaging, functional testing and monitoring combined with intraoperative neuronavigation dramatically enhance the design and safety of resective epilepsy surgery. However, preoperative tests and images may not fully match visible anatomy after craniotomy and cannot evaluate intraoperative neural integrity. Thus, direct neurophysiologic assessment of exposed brain tissue remains valuable and complimentary.

Goals of monitoring epilepsy surgery

Surgical decisions in epilepsy consider multiple investigations seeking congruent evidence for an epileptic focus that could be safely resected to achieve seizure freedom or worthwhile reduction. Neurophysiologic results are one part of this holistic process. Thus, the goals of monitoring epilepsy surgery are to help optimize epileptic tissue resection while avoiding neurological deficits. Achieving these goals may involve mapping the epileptic focus as well as mapping and monitoring functionally critical brain structures.

Epileptic focus mapping

Epilepsy surgery aims to resect the epileptogenic lesion identified by imaging along with its associated 'epileptogenic zone' defined as the seizure-generating cortex that has to be removed for seizure freedom. Electrocorticography (ECoG) is a method for estimating the epileptogenic zone. Epileptic neurons manifest abnormal paroxysmal depolarizing shifts that when arising synchronously in a large enough neuronal population summate as 'spike' discharges. The cortical region exhibiting interictal spikes is the 'irritative zone' that may offer some guide to the epileptogenic zone, but can be much larger. The 'seizure onset zone' is the cortical region where an ECoG seizure pattern first begins. It is usually a subregion of the irritative zone and better estimates the epileptogenic zone, subject to electrode coverage.

Intraoperative ECoG has serious limitations because it only briefly maps the irritative zone and may be influenced by anesthetic agents that can suppress, mimic or provoke spikes. Nevertheless, resecting a small congruent irritative zone along with the lesion seems reasonable because it is likely to contain the epileptogenic zone. On the other hand, resecting a large or incongruous irritative zone may be inappropriate. Furthermore, post-excision ECoG often shows activation of new spikes due to the acute surgical injury, but having no

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significance for seizure recurrence. While methods to differentiate significant from insignificant pre- and post-resection spikes have been suggested, there is no generally confirmed way of doing so. Consequently, the value of intraoperative ECoG for tailoring epilepsy surgery remains controversial after decades of clinical experience.

Extraoperative ECoG monitoring with implanted intracranial electrodes has fewer limitations. It enables thorough irritative zone assessment without anesthetic influence and also maps the seizure onset zone by capturing seizures. This is the method of choice for epilepsy surgery candidates needing detailed epileptic focus mapping.

Thus, the use of intraoperative ECoG for epileptic focus mapping is declining. Some programs incorporate it for straightforward cases, while others omit it with no apparent detrimental effect on outcome. Most programs use extraoperative ECoG for complex patients, thus removing the need for intraoperative epileptic focus estimation.

Functional mapping and monitoring

Functional mapping and monitoring are not needed for epilepsy resections away from critical cerebral structures. However, they are important for resections near sensorimotor, language, or visual cortex. In these circumstances, mapping can permit a complete resection that might otherwise not be done for fear of a deficit, or help decide a safe subtotal resection limit. Intraoperative mapping is particularly important for patients who have not had preoperative mapping, but may also be done to confirm or modify preoperative results. Stable intraoperative monitoring results build confidence to complete the resection, while deteriorating signals can prompt restorative intervention to avoid injury, or help decide a surgical stopping point.

The traditional Penfield intraoperative mapping technique consists of direct cortical stimulation with 50-60 Hz biphasic pulse trains lasting 1–5 seconds while observing the awake patient for responses. Primary motor cortex stimulation produces localized contralateral tonic muscle contractions; primary sensory cortex stimulation produces localized contralateral somatosensory experiences; language cortex stimulation produces aphasia or dysphasia; and primary visual cortex stimulation produces phosphenes. The technique is not feasible for patients unable to collaborate with awake craniotomy, forgoes monitoring, and often induces afterdischarges — seizure patterns in adjacent or distant cortex induced by and outlasting the stimulus. Afterdischarges risk false localization because they can produce clinical signs from unstimulated cortex, and build to clinical seizures in 5–15% of patients. Thus, concurrent ECoG monitoring is mandatory: one ignores patient responses with an afterdischarge, and tries to keep stimulus intensity below afterdischarge threshold.

Modern intraoperative sensory evoked potential (SEP), motor evoked potential (MEP), and possibly visual evoked potential (VEP) methods enable mapping and monitoring, and are applicable to all patients because they are done under general anesthesia. In addition, concurrent ECoG is not needed for SEPs or VEPs, and is optional for direct cortical stimulation MEPs because these short-latency transient responses are not subject to false localization from afterdischarges, and because the technique induces fewer seizures. SEPs and MEPs are gradually replacing traditional sensory and motor functional testing, and recent evidence suggests similar value for VEPs.

There are also preliminary efforts towards developing language mapping under anesthesia. One possible method consists of cortico–cortical potentials with language cortex stimulation and recording. Another consists of pulse train stimulation of premotor cortex near Broca's area with long-latency laryngeal muscle MEP recording. For the time being, however, accurate language mapping still requires the traditional awake Penfield technique.

Selected references

1. Chatrian GE, Quesney LF. Intraoperative Electrocorticography. In: Engel J, Pedley TA, editors. Epilepsy - A Comprehensive Textbook. New York: Lippincott - Raven Press; 1998. p. 1749–65.
2. Lüders HO, Awad I. Conceptual Considerations. In: Lüders HO, editor. Epilepsy surgery. New York: Raven Press; 1992. p. 51–62.
3. MacDonald DB. Intraoperative monitoring. In: Toga AW, editor. Brain Mapping: An Encyclopedic Reference. Academic Press: Elsevier; 2015. p. 871–9.
4. MacDonald DB, Pillay N. Intraoperative electrocorticography in temporal lobe epilepsy surgery. Can J Neurol Sci 2000;27(Suppl 1):S85–91.

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SESSION I:
BRAIN TUMOR SURGERY
TALKING ABOUT ANATOMY

Chairman: Jeff Arle

THE FUNCTIONAL ANATOMY OF BRAIN CORTEX AND ITS SUBCORTEX PATHWAY

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The human brain is an organ that controls all functions of the body, interprets information from the outside world. The brain receives information through our five senses: sight, hearing, smell, and taste. It performs higher functions like interpreting touch, vision, and hearing, as well as speech, reasoning, emotions, learning, and fine control of movement. Each hemisphere controls the opposite side of the body. The left hemisphere is dominant in hand use and language in the majority of the population.

The cerebral hemispheres have distinct fissures, which divide the brain into four lobes: frontal, temporal, parietal, and occipital. Each lobe may be divided into areas that serve very specific functions. Each lobe of the brain does not function alone. There are very complex relationships between the lobes of the brain. Certain cortical regions have some simpler functions, termed as the primary cortices. These include areas directly receiving sensory input (vision, hearing, and somatic sensation) or directly involved in the production of limb or head and face movements. The association cortices subserve more complex functions. Regions of association cortex are adjacent to the primary cortices and include much of the rostral part of the frontal lobes also regions encompassing areas of the posterior parietal lobe, the temporal lobe and the anterior part of the occipital lobes. These areas are important in more complex cortical functions including memory, language, abstraction, creativity, judgment, emotion and attention. They are also involved in the synthesis of movements. In this presentation, the motor, somatosensory, visual, hearing and language system are reviewed in more detail.

TALKING ABOUT SURGERY

Chairman: Jeff Arle

SURGERY OF TUMORS IN MOTOR AREAS

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A) Introduction:

Intraoperative neurophysiology in brain surgery for tumors in motor areas is based on a combination of neurophysiological mapping and monitoring methods to warrant preservation of voluntary movement, patient's empowerment and independent life. Clinical practice shows that patients will not ask for expected motor grading, scales of individual muscle strength, or precise prediction of survival time but for preservation a normal life, physical and social independence. Patient may eventually ask about the risks of impairment of ADLs. It is the responsibility of the medical team to translate these requests into an offer of the best medical and surgical therapy that reflects the brain tumor patients' expectations.

Extent of resection represents an important prognostic factor in the treatment of brain tumors in respect to overall survival time (Stummer 2008, Sanai 2008, Duffau 2005). When tumors are seated in eloquent areas, the rate of incomplete resection is higher than after tumor resection in non-eloquent areas (Jakola 2012). Development of intraoperative neurophysiology has tremendously improved the safety and the preservation of motor function in surgery within eloquent brain areas. Additionally, presurgical methods for optimizing the surgical approach such as preoperative MRI using DTI imaging and navigated transcranial magnetic stimulation can be applied in the planning phase of the resection of tumors located in the central area. Recently, however, there is doubt into the prognostic accuracy of intraoperative neurophysiology and reluctance to use the strong neuroprotective value of continuous monitoring of motor pathways under general anesthesia. This may lead surgeons to indicate awake surgery not only in the situation of language area tumors, but also in central area tumors. Furthermore, there is a tendency to explore again the validity of awake craniotomy in skull base tumors as in

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cerebral aneurysm surgery and surgical treatment of cerebral arterio-venous malformations (Duffau 2010, Shinoura 17, Abdulrauf 17) for the purpose of awake functional testing.

What is the evidence on predictability of motor deficit in in correlation to the results of intraoperative monitoring, and, is there a significant rate of false negative MEP monitoring, and if so, what are the mechanisms? An analysis of surgeries in of central area lesions by Neuloh and coauthors has shown significant changes of MEP monitoring in 39% of surgeries, where irreversible loss of MEP always predicted new, usually permanent motor deficit (Neuloh 2004). The rare events of unchanged or fully recovered MEPs followed by a new motor deficit could be attributed to secondary hemorrhage, edema or ischemia, or supplementary motor area syndrome (Neuloh 2009, Krieg 2012)

B) Intraoperative Methodology:
Intraoperative neurophysiological monitoring

Motor evoked potentials
Based on the experience that discharges elicited by cortical electrical shocks can be recorded along the pyramidal tract (Patton and Amassian, 1954) and the experiment in which high-voltage transcranial electrical stimulation (TES) elicited responses in limb muscles (Merton and Morton, 1980), two techniques were developed to monitor motor function in humans under general anesthesia: epidural recording of MEPs (eMEPs) after single stimuli of TES and muscle MEPs (mMEPs), which are generated from trains of TES or direct cortical stimulation (DCS).

While the application of eMEPs in cranial tumor surgery could provide prognostic information to the event of a surgically induced motor deficit (Fujiki 2006), the methodology that requires the percutaneous insertion of an epidural electrode has not been acquired in institutions outside of Japan.

mMEPs: Train stimulation technique was developed to overcome the influence of general anesthesia on synaptic activity in the motor cortex and at the level of ⍰-motoneurons (Taniguchi 1993). Widespread use of intraoperative assessment of motor function in neurosurgery has become feasible since the introduction of dedicated stimulation methodology (TES) for continuous recording of mMEPs (Pechstein 1994; Jones 1996). TES using corkscrew electrodes as well as direct cortical stimulation is used to elicit motor responses that are recorded form limb muscles using a multichannel recording workstation (Kombos 2000). Without delay from averaging, presence, deterioration, or absence of MEPs can predict the functional motor outcome in supratentorial surgery (Neuloh 2004).

Somatosensory evoked potentials
Somatosensory evoked potentials (SEPs) have initially been applied in spinal surgery by orthopedic surgeons (Nash 77, Engler 78). Later they were used in posterior fossa surgery and, due to their correlation with cerebral blood flow, in supratentorial surgery. Median and posterior tibial nerves are stimulated at frequencies between 2 and 10 Hz. Potentials are recorded from corkscrew electrodes placed in the scalp and at the craniocervical junction. Peak-to-peak measurements of SEP amplitude serve as a robust parameter to assess the functional integrity of cortical fields and subcortical sensory pathways. On average, depending on signal quality and signal to noise ratio 100 to 200 responses are needed to yield reliable monitoring of SEPs.

EMG
EMG can be continuously between the trains of MEP stimulation, recorded from twisted needle electrodes placed bilaterally in limb muscles. EMG monitoring can detect seizure early at the onset of a convulsive epileptic activity.

EEG
EEG can be recorded from two or more channels, either as raw EEG traces (unprocessed EEG) or in the form of a computer processed frequency trend (compressed spectral array, CSA) from each EEG channel. EEG monitoring warrants basic information on the depth of anesthesia throughout the surgical procedure, which may correlate to systemic changes of evoked potential monitoring. EEG monitoring may detect seizure activity, when clinical effects of seizure activity are no yes visible.

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Electrocorticography (ECoG)

Intraoperative recording of epileptiform activity has been used to identify tissue that may, if spared during resection, cause persistence of chronic epilepsy (Wennberg 1998). Though the terms of interpretation are controversial, in cortical dysplastic lesions the use of ECoG has beneficial effect on seizure outcome (Palmini 1995). For the surgery of brain tumors, the beneficial effect of routine use of ECoG on seizure outcome has not been accepted unanimously (Pilcher 1993; Tran 1997). However, the application of ECoG for the monitoring of afterdischarges during direct cortical stimulation is essential to proof that the effect of cortical stimulation remains local and to reduce the risk of stimulation induced seizures (Pouratian 2004)

Intraoperative mapping

Phase Reversal Technique

The signal of SEPs after stimulation of the contralateral median or tibial nerve is recorded from a subdural strip electrode placed on the sensorimotor cortex, across the central sulcus. High amplitude potentials are recorded from the electrodes lying on the postcentral gyrus, corresponding to the N20 or P40, respectively. Inverted N20 or P40 potentials are recorded from the electrodes positioned on the primary motor cortex (King and Schell, 1987). The central sulcus is then neurophysiologically identified between the electrode positions, which show the phase reversal of SEPs (Woolsely et al., 1979; Wood et al., 1988; Fig. 1 and 2). The strip electrode can be left in place for subsequent direct cortical stimulation (mapping and monitoring) of the motor cortex.

Cortical and subcortical stimulation mapping

The motor response is recorded from limb muscles using the train stimulation technique. Short trains of 5 to 7 electrical stimuli (duration, 500µs; interstimulus interval, ISI, 4 ms) are applied through the electrodes of the subdural strip using monopolar anodal stimulation. The electrode with the highest amplitude of the inverted SEP response and the adjacent electrodes are used to map the best motor response at threshold stimulation intensity and to identify the primary motor cortex. Additionally, the motor cortex can be identified using a handheld monopolar or bipolar stimulation probe.

Two stimulation techniques are available for motor cortex mapping:

Penfield and Boldrey (1937) described stimulus frequencies of 55 to 65 Hz applied via monopolar or bipolar probes on the human cortex. Penfield's technique has been modified as bipolar 60 Hz technique and is widely used in epilepsy and tumor surgery. Electrical stimulation is usually applied for a period of 2 to 5 seconds via a bipolar probe. The effect of motor cortex stimulation is validated through observation of tonic contraction of contralateral limb and face muscles. The motor cortex is identified and marked where the lowest threshold of stimulation intensity elicits motor response. Multichannel EMG recording can facilitate recognition of motor responses (Yingling 1999). The disadvantage of the 60 Hz technique is the higher risk of stimulation-induced seizures in up to 24% of patients (Szelényi 2006, Yingling 1999). Intraoperative seizures can interfere with the surgical procedure as well as with the reliability of further neurophysiological mapping and monitoring. A combination of bipolar stimulation with ECoG is supposed to reduce the risk of intraoperative seizures when recording of afterdischarges is used to limit the intensity of the 60 Hz stimulus (Berger 1989, Pouratian 2004).
Alternatively, mapping of the motor cortex can be performed with a monopolar handheld probe using the train stimulus technique. Short trains of five stimuli are applied at a frequency of 250 Hz. The motor response at threshold stimulus intensity is recorded from EMG needle electrodes placed in the limb and face muscles. Szelényi and coauthors have shown that the train stimulation technique allows localizing the motor cortex with a very low risk of induction of intraoperative seizures (Szelényi 2007).

C) Workflow of intraoperative neurophysiology in tumor surgery for central area tumors.

Set up of the equipment in accordance to the topographical position of the tumor: check for the muscle groups that deserve intraoperative TES MEP monitoring and mapping. One would generally select upper as well as lower extremity muscles, even when the tumor is not in the arm but leg motor area, or in the leg but not arm motor area, respectively. The reason is that we want to sustain a global assessment of motor function, in addition to the area at high risk receiving an injury during tumor resection. The set-up of facial motor monitoring depends on the tumor extension. For the control of physiological TES MEP response from the contralateral side the preferred set-up consists one or two muscle from upper and lower extremity, and facial muscle recording. During every procedure that may require direct cortical stimulation it is important to inform the anesthesiologist about the risk of stimulation induced seizures and pharmacological measures that have to be taken to stop a seizure immediately. Monitoring of TES MEP and SEP is established. After craniotomy a

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subdural strip electrode can be placed across the central sulcus. It is useful to establish one trace from median nerve or tibial nerve SEP via transcranial SEP response to establish the latency of N20 or P40 within the phase reversal test to facilitate assignment of cortical response to a typical motor or sensory cortex response. SEP phase reversal will now indicate the position of the precentral and post-central cortex. A subdural electrode can be established to perform continuous MEP monitoring (via monopolar anodal stimulation) until the end of the surgical resection (time of dural closing) for the assessment of integrity of motor cortex and corticospinal tract. During any procedure that requires direct cortical or subcortical stimulation it is important to have a quantity 20-50 ml of ice-cold (4� Celsius) Ringer' s solution on the table, prepared and maintained by the scrub nurse, to stop a stimulation induced seizure immediately at the time of first clinical or electrophysiological (EMG, EEG) appearance by cold irrigation of the cortex in the operative field (Sartorius 1998). Monitoring the ECoG from an additional subdural strip electrode, that may detect afterdischarges via electrocorticography can reduce the risk of generating seizures due to direct cortical electrical stimulation. Stimulation mapping of the cortex via a handheld monopolar probe, an additional subdural electrode, or the topographical verification of the stimulation site via the neuronavigation pointer can be applied to improve the DCS MEP monitoring (e.g. mapping for the desired motor response via a target muscle, set-up of monitoring from additional target muscles response from lower extremity or upper extremity or facial muscles).
At time of corticotomy as well as during access to the tumor and during tumor resection a handheld monopolar probe can be used at any time upon the surgeon's request to acquire confirmation of the functional anatomy of the primary motor area or the corticospinal tract fibers. The vicinity from the probe to the cortex and the corticospinal tract fibers can be estimated by the stimulus intensity necessary to reach motor threshold (Seidel 2012). At least within close vicinity of 1-10 mm it seems that there is linear correlation of threshold stimulus intensity with the distance according the rule that 1 mA stimulus amplitude increment correlates with 1 mm distance from pyramidal tract fibers (Yamaguchi 2009, Kamada 2009, Nossek 2011). This technique therefore requires a close interaction between the neurophysiologist and the neurosurgeon to adjust the stimulus intensity repeatedly. Alternatively, the stimulation probe can be replaced by an electrified surgical tool, which is already in the surgical field such as the suction device or the CUSA (Raabe 2014, Roth 2017). The combination of subcortical stimulation with DCS MEP monitoring (Seidel 2013) is recommended to optimize the neuroprotective strength of intraoperative neurophysiology in tumor resections in the motor area.

References:

1. Abdulrauf S et al. (2017) "Awake" clipping of cerebral aneurysms: report of initial series. J Neurosurg 127:311–318
2. Berger MS, Kincaid J, Ojemann GA et al. (1989). Brain mapping techniques to maximize resection, safety, and seizure control in children with brain tumors. Neurosurgery 25: 786–792.
3. Duffau H, Lopes M, Arthuis F, Bitar A, Sichez J-P, Van Effenterre R, Capelle L (2005). Contribution of intraoperative electrical stimulations in surgery of low grade gliomas: a comparative study between two series without (1985–96) and with (1996–2003) functional mapping in the same institution. J Neurol Neurosurg Psychiatry 76:845–851.
4. Duffau H (2010) Awake Surgery for Nonlanguage Mapping. Neurosurgery 66:523-529
5. Engler GL et al. (1978) Somatosensory evoked potentials during Harrington instrumentation for scoliosis. J Bone Joint Surg 60A:528-32
6. Fujiki M et al. (2006) Intraoperative corticomuscular motor evoked potentials for evaluation of motor function: a comparison with corticospinal D and I waves. J Neurosurg 104:85-92
7. Jakola AS et al. (2012) Low Grade Gliomas in Eloquent Locations – Implication for Surgical Strategy, Survival and Long Term Quality ofLife. PLoS One 7(12):e51450
8. Jones SJ, Harrison R, Koh KF et al. (1996). Motor evoked potential monitoring during spinal surgery: responses of distal limb muscles to transcranial cortical stimulation with pulse trains. Electroencephalogr Clin Neurophysiol 100: 375–383
9. Kamada K et al. (2009) The motor-evoked potential threshold evaluated by tractography and electrical stimulation. J Neurosurg 111:785-795
10. King RB, Schell GR (1987). Cortical localization and monitoring during cerebral operations. J Neurosurg 67:210–219
11. Kombos T, Suess O, Funk T et al. (2000). Intra-operative mapping of the motor cortex during surgery in and around the motor cortex. Acta Neurochir (Wien) 142: 263–268
12. Krieg S et al. (2012) Predictive value and safety of intraoperative neurophysiological monitoring with motor evoked potentials in glioma surgery. Neurosurgery 70:1060–1071

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13. Nash CL et al. (1977) Spinal cord monitoring during operative treatment of the spine. Clin Orthop 126:100-5
14. Neuloh G et al. (2004) Motor evoked potential monitoring with supratentorial surgery. Neurosurgery 54:1061-1072
15. Neuloh G, Schramm J (2009) Are there false-negative results of motor evoked potential monitoring in brain surgery? Cent Eur Neurosurg 70: 171 – 175
16. Nossek E et al. (2011) Intraoperative mapping and monitoinrg od corticospinal tracts with neurophysiological assessment and 3-dimensional ultrasonography-based navigation. J Neurosurg 114:738-746
17. Palmini A, Gambardella A, Andermann F et al. (1995). Intrinsic epileptogenicity of human dysplastic cortex as suggested by corticography and surgical results. Ann Neurol 37: 476–487
18. Patton HD, Amassian VE (1954). Single and multiple-unit analysis of cortical stage of pyramidal tract activation. J Neurophysiol 17: 345–363
19. Pechstein U, Taniguchi M, Nadstawek J et al. (1994).Recording of myogenic motor evoked potentials (mMEP) under general anaesthesia using a train of transcranial electric stimuli. In: SJ Jones, S Boyd, M Hetreed et al.(Eds.), Handbook of Spinal Cord Monitoring. Dordrecht, Kluwer, pp. 346–352
20. Penfield W, Boldrey E (1937). Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. Brain 60: 389–443
21. Pilcher WH, Silbergeld DL, Berger MS et al. (1993). Intraoperative electrocorticography during tumor resection: impact on seizure outcome in patients with gangliogliomas. J Neurosurg 78: 891–902
22. Pouratian N et al. (2004) Variability of intraoperative electrocortical stimulation mapping parameters across and within individuals. J Neurosurg 101:458-466
23. Roth J et al. (2017) Subcortical mapping using an electrified CUSA in pediatric supratentorial surgery. World Neurosurg 101:357-364
24. Sanai N, Berger MS (2008) Glioma extent of resection and its impact on patient outcome. Neurosurgery 62:753–766
25. Sartorius CJ, Berger MS (1998). Rapid termination of intraoperative stimulation-evoked seizures with application of cold Ringer's lactate to the cortex. Technical note. J Neurosurg 88:349-351
26. Shinoura N et al. (2017) Preservation of hearing following awake surgery via the retrosigmoid approach for vestibular schwannomas in eight consecutive patients. Acta Neurochir (2017) 159:1579–1585
27. Stummer W et al (2008). Extent of resection and survival in glioblastoma multiforme : Identification of and adjustment for bias. Neurosurgery 62:564–576
28. Szelényi A, Joksimovic B, Seifert V. (2007) Intraoperative risk of seizures associated with transient direct cortical stimulation in patients with symptomatic epilepsy. J Clin Neurophys 24(1):39-43
29. Taniguchi M, Cedzich C, Schramm J (1993). Modification of cortical stimulation for motor evoked potentials under general anesthesia: technical description. Neurosurgery 32: 219–226
30. Tran TA, Spencer SS, Javidan M et al. (1997). Significance of spikes recorded on intraoperative electrocorticography in patients with brain tumor and epilepsy. Epilepsia 38: 1132–1139
31. Wennberg R, Quesney F, Olivier A et al. (1998). Electrocorticography and outcome in frontal lobe epilepsy. Electroencephalogr Clin Neurophysiol 106: 357–368
32. Woolsey CN, Erickson TC, Gilson WE (1979). Localization of somatic sensory and motor areas of human cerebral cortex as determined by direct recording of evoked potentials and electrical stimulation. J Neurosurg 51: 476–506
33. Wood CC, Spencer DD, Allison T et al. (1988). Localization of human sensorimotor cortex during surgery by cortical surface recording of somatosensory evoked potentials. J Neurosurg 68: 99–111
34. Yingling CD, Ojemann S, Dodson B et al. (1999). Identification of motor pathways during tumor surgery facilitated by multichannel electromyographic recording. J Neurosurg 91: 922–927

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SURGERY FOR INSULAR AND DEEP SEATED TUMORS

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Objective

Insular gliomas are a significant tumor entity and their resection requires applications of surgical technology as well as intraoperative neurophysiological techniques for mapping and monitoring. This overview intends to highlight the surgical considerations, the diagnostic aspects of insular glioma surgery, as well as the need for and application of neurophysiological methods.

Brief historical review

The insula plays an important role in visceral sensorimotor processing, somatosensory input and pain processing, swallowing; as well as gustatory, auditory, vestibular, emotional, and cognitive functions. Insular gliomas come from the white matter under the insular cortex. Since the insula is part of the mesocortex, the initial growth of insular gliomas appears to involve other mesocortical areas such as the temporal pole, the caudal orbitofrontal cortex, and cingular and parahippocampal gyri. About 1 in 4 low grade gliomas arise here, as well as about 10% of glioblastomas. The anatomical structure of the insula makes it an area difficult to access because the involuted architecture of the insular cortex with the overlaying opercula and the spreading branches of the middle cerebral artery. Microsurgical resection as initially described by Yaşargil in 1992 and later perfected by many groups, most importantly by Berger is designed to respect the essential vasculature and to maximize resection in between the MCA branches. The evidence supporting extensive resection of low grade gliomas has grown since these earlier surgical attempts. The landmark publication of Jakola in 2012 has shown that resection is beneficial to patients with low grade gliomas, which supports the strategy of these tumors in the insular region.

Summary of recent developments and/or future directions

The improving evidence that resection of low grade glioma improves survival and probably does so by postponing the advent of malignant transformation puts emphasis on the surgical goal to maximize resection of all low grade gliomas. Due to their anatomical property in the insular and opercular region these tumors are more difficult to access and resect than those in more favorable locations. Microsurgical manipulation of the passing MCA-branches, which serve the motor cortex may lead to vasospasm and vascular compromise which may well result in cortical ischemia which in turn can be detected using sensory and motor evoked potentials. Intraoperative Neurophysiology therefore in this entity serves at least three objectives. First: Mapping of the cerebral cortex to obtain safe entry into the tumor area if it involves the opercula, particularly the frontal operculum and more particularly on the language dominant side. Second: Continuous monitoring of SEPs and MEPs from cortical stimulation provides a continuous monitoring concept for early detection of cortical ischemia due to vascular compromise of MCA-branches. Third: continuous monitoring of MEPs optimally evoked by direct cortical stimulation over a grid electrode provides ongoing information on the functional integrity of the corticospinal tract deep to the resection site. Ongoing mapping using a hand-held stimulator or a suction tip-turned stimulator provides information about the proximity of the corticospinal tract in the internal capsule deep to the resection site in the depth of the insula.

Conclusions

Insular and other deep seated low grade gliomas should be aggressively resected to optimize long term survival and prevent malignant transformation. At the same time, it is essential to preserve neurological function as neurological deficits result in a loss of survival benefits aggressive resection may offer. Intraoperative neurophysiological techniques provide an essential tool to mapping the motor cortex, particularly in language associated areas, and continuous monitoring to detect cortical ischemia as well ongoing mapping to assess the proximity to deep motor pathways in the case of deep seated tumors.

Key references and recommended readings

1. Yaşargil MG, von Ammon K, Cavazos E, Doczi T, Reeves JD, Roth P: Tumours of the limbic and paralimbic systems. Acta Neurochir (Wien) 118:40–52, 1992
2. Duffau H: A personal consecutive series of surgically treated 51 cases of insular WHO Grade II glioma: advances and limitations. Clinical article. J Neurosurg 110:696–708, 2009

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3. Sanai N, Polley MY, Berger MS.: Insular glioma resection: assessment of patient morbidity, survival, and tumor progression. J Neurosurg. 2010 Jan;112(1):1-9.
4. Rey-Dios R., Cohen-Gadol A.: Technical nuances for surgery of insular gliomas: lessons learned. Neurosurgical Focus 2013; 34(2) E6, 2013
5. Hervey-Jumper SL, Li J, Osorio JA, Lau D, Molinaro AM, Benet A, Berger MS. Surgical assessment of the insula. Part 2: validation of the Berger-Sanai zone classification system for predicting extent of glioma resection. J Neurosurg. 2015 Sep 4:1-7. [Epub ahead of print]
6. Benet A, Hervey-Jumper SL, Sánchez JJ, Lawton MT, Berger MS. Surgical assessment of the insula. Part 1: surgical anatomy and morphometric analysis of the transsylvian and transcortical approaches to the insula. J Neurosurg. 2015 Sep 4:1-13
7. Jakola AS., et al. Comparison of a Strategy Favoring Early Surgical Resection vs a Strategy Favoring Watchful Waiting in Low-Grade Gliomas, JAMA 2012, 308(18):1881-1888
8. Seidel K, Beck J, Stieglitz L, Schucht P, Raabe A. The warning-sign hierarchy between quantitative subcortical motor mapping and continuous motor evoked potential monitoring during resection of supratentorial brain tumors. J Neurosurg. 2013;118(2):287-96

TALKING ABOUT NEUROMONITORING

Chairman: Sedat Ulkatan

VISUAL EVOKED POTENTIAL MONITORING

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Objective

Neurosurgical procedures for treatment of tumors or vascular lesions along the visual pathways carry a risk of visual dysfunction. This applies mostly to parasellar tumors and aneurysms, but also to temporal and occipital lobe tumors and intraorbital lesions. A reliable method for real time visual function monitoring assists in intraoperative decision making regarding radicality of excision and intermittent maneuvers near the optic apparatus.

Recent clinical and research developments

Usefulness of intraoperative VEP using flash stimulation has been reported. We present our experience of intraoperative flash VEP monitoring.

1) Indications for intraoperative VEP monitoring: The indication for VEP monitoring is to avoid postoperative worsening of visual function. Intraoperative electrophysiological monitoring is an important alarm for keeping the patient's neurological condition intact. Cooperation between the surgeon and staff responsible for monitoring is essential in this field.

2) Anesthesia: Under total intravenous anesthesia (TIVA), the VEP shows larger amplitude with less variability and latency. We request that the anesthesiologist not use inhaled anesthetic gas, and there have been no problems in over 100 cases in our 8 years of experience. Nitrous oxide does not cause changes in the waveform. On the other hand, inhaled anesthetics, such as sevoflurane and isoflurane, markedly decrease the amplitude.

3) Stimulation: Flash VEP and ERG are recorded with a Neuropack evoked potential measuring system (Nihon Kohden Corporation, Tokyo, Japan). The bandpass is from 10 to 1000Hz and averaging is 100 times. Preconditioning of flash stimulation before starting averaging should be done to obtain a steady VEP waveform. As the retina shows a greater reaction to the initial period of flash light stimulation, it is necessary to wait at least 1 minute to obtain a steady reaction after commencement of flash stimulation. The stimulation intensity is decided by the supramaximal stimulation to the retina. As the evoked ERG is easy to record and the waveform is stable, it is utilized for checking the supramaximal value. Routine ERG has an amplitude of 5 μV and 4 or 5 peaks from 30 to 70 ms. If VEP attenuation is suspected, the ERG amplitude should be checked. If the baseline amplitude of ERG is not obtained, the attenuation is caused by inappropriate stimulation, usually inadequate stimulation to retina due to stimulator dislocation. Figure shows standard set up for VEP stimulation.

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4) VEP Recording: Reference electrodes are set at A1 and A2, and these are electrically connected. Recording electrodes are set near Oz, O1, and O2. Five recording electrodes are routinely placed. Even in the event of unexpected dislodgement during an operation, it is difficult to set new electrodes. Thus, stable and secured setting of the recording electrode is essential, because reducing the noise by stable setting can decrease the number of averagings. Diagram below demonstrates VEP set up and typical waveforms.
5) Optic nerve action potential: In the cases of parasellar lesions such as craniopharyngiomas and giant aneyrysms, optic nerves, chiasm and tracts are sometimes streched around the lesion. And, it is difficult to identify the location of the optic apparatus. In these situations, flash stimulation is deliverd as same manner as VEP, and action potentials recoeded from the operative fields facilitates to identifiy the optic apparatus.

Conclusions

Intraoperative flash VEP monitoring is essential method for preserving visual function. VEP can be monitored in a patient with visual acuity greater than (0.04). The flat VEP indicates postoperative severe visual disturbance (nearly blindness). Judgment of waveform change by mechanical damage is more difficult than that for ischemic compromise. Pitfalls for intraoperative VEP monitoring are: preoperative severe visual dysfunction, low amplitude of control VEP may interfere with intraoperative VEP monitoring in this method. Visual field defect without decrease in the visual acuity may not be predicted by VEP monitoring. Attention should be paid for these pitfalls for reliable intraoperative VEP monitoring.

MEP MONITORING UNDER GENERAL ANESTHESIA IN BRAIN TUMOR SURGERY

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Objectives

This overview intends to highlight motor evoked potentials (MEP) monitoring under general anesthesia in brain tumor surgeries. For this, it will review methodologies for MEP and their neurophysiological characteristics, and describes their essential role and importance in these surgeries.

Brief historical review and summary of recent developments

During the resection of subcortical or deep seated brain tumors adjacent to the subcortical corticospinal tract (CT), subcortical motor mapping can localize the subcortical CT and confirm its functional integrity distally, while it cannot detect damage such as vascular injury to the CT proximal to the points of subcortical stimulation. Therefore, MEP monitoring should be needed almost always to evaluate a functional integrity of the whole CT during brain tumor surgeries.

Methodologies for MEP

For a performance of MEP, electrical stimulations can be delivered either transcranially (transcranial stimulation; TCS) or directly on the cerebral cortex (direct cortical stimulation; DCS), and evoked potentials can be recorded with either subdermal electrodes in the limb muscles (compound muscle action potentials; CMAP) or cervical epidural electrodes (D-wave).

MEP monitoring using TCS

Muscle MEP monitoring using TCS has a few advantages. It does not use strip electrode which can damage the bridging veins or cerebral cortex itself, and MEP results can be compared with those of contralateral side. An amplitude reduction greater than 50% was adopted as an alarming criterion in the studies with this technique (Zhou and Kelly, 2001; Szelenyi et al, 2010). And it was reported persistent MEP amplitude reductions of more than 50% were associated with postoperative motor deteriorations, and the degree of MEP reduction was correlated with postoperative worsening of motor status (Zhou and Kelly, 2001).

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MEP monitoring using DCS

Continuous muscle MEP monitoring with DCS using a strip electrode directly over motor cortex can identify a functional integrity of the whole CT and has been known to enhance the safety of tumor resection close to CT. This technique has been used more commonly than MEP monitoring using TCS. There is still controversy on a so-called significant reduction of muscle MEP amplitude. However, an amplitude reduction more than 50% was also considered an alarming criterion in most of the studies with this technique on brain tumor surgeries (Neuloh et al, 2007; Krieg et al, 2012; Gempt et al, 2013). Transient or permanent postoperative motor deficit was reported in 27.8 to 30.3% of the patients (Neuloh et al, 2007; Krieg et al, 2012), and postoperative ischemic change in MRI in 46% (Gempt et al, 2013).

D-wave monitoring is also possible in brain tumor surgery. A 30% to 40% amplitude reduction was suggested as alarming criterion for DCS cervical D-wave monitoring during peri-Rolandic brain tumor surgery (Yamamoto et al, 2004; Fujiki et al, 2006). However, a percutaneous insertion of an epidural electrode at cervical spines is required for D-wave monitoring in brain tumor surgery, which can cause additional risk of complication.

Future directions

Alarming criterion of MEP monitoring during brain tumor surgeries is still controversial. Additional studies are necessary to confirm its level and reliability related with the surgical outcomes including neurological and/or neuroimaging deteriorations.

Conclusions

During the resection of subcortical or deep seated brain tumors, MEP monitoring is essential to identify a functional integrity of the whole CT. MEP monitoring, combined with subcortical motor mapping enables real-time functional feedback during surgeries of brain tumor within or adjacent to the eloquent motor areas and/or CT.

References

1. Fujiki M, Furukawa Y, Kamida T, Anan M, Inoue R, Abe T, Kobayashi H. Intraoperative corticomuscular motor evoked potentials for evaluation of motor function: a comparison with corticospinal D and I waves. J Neurosurg. 2006 Jan;104(1):85-92.
2. Gempt J, Krieg SM, Hüttinger S, Buchmann N, Ryang YM, Shiban E, Meyer B, Zimmer C, Förschler A, Ringel F: Postoperative ischemic changes after glioma resection identified by diffusion-weighted magnetic resonance imaging and their association with intraoperative motor evoked potentials. J Neurosurg 2013;119: 829–836.
3. Kombos T, Suess O, Ciklatekerlio O, Brock M. Monitoring of intraoperative motor evoked potentials to increase the safety of surgery in and around the motor cortex. J Neurosurg. 2001 Oct;95(4):608-14.
4. Krieg SM, Shiban E, Droese D, Gempt J, Buchmann N, Pape H, Ryang YM, Meyer B, Ringel F: Predictive value and safety of intra-operative neurophysiological monitoring with motor evoked potentials in glioma surgery. Neurosurgery 2012;70: 1060–1070. discussion 1070–1071.
5. MacDonald DB. Overview on Criteria for MEP Monitoring. J Clin Neurophysiol. 2017;34(1):4-11.
6. Neuloh G, Pechstein U, Schramm J: Motor tract monitoring during insular glioma surgery. J Neurosurg 2007;106: 582–592
7. Neuloh G, Pechstein U, Cedzich C, Schramm J. Motor evoked potential monitoring with supratentorial surgery. Neurosurgery 2004;54:1061 –1070.
8. Szelényi A, Hattingen E, Weidauer S, Seifert V, Ziemann U: Intraoperative motor evoked potential alteration in intracranial tu-mor surgery and its relation to signal alteration in postoperative magnetic resonance imaging. Neurosurgery 2010;67: 302–313.
9. Yamamoto T, Katayama Y, Nagaoka T, et al. Intraoperative monitoring of the corticospinal motor evoked potential (D-wave): clinical index for postoperative motor function and functional recovery. Neurol Med Chir (Tokyo) 2004;44:170 – 180.
10. Zhou HH, Kelly PJ: Transcranial electrical motor evoked potential monitoring for brain tumor resection. Neurosurgery 2001;48: 1075–1080. discussion 1080–1081.

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BRAIN MAPPING- SUBCORTICAL MOTOR MAPPING AND MOTOR EVOKED POTENTIAL MONITORING IN BRAIN TUMOR SURGERY

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Objective

In modern neuro-oncology two main concepts are maximizing the extent of tumor resection to improve survival and avoiding postoperative deficits to improve quality of life.1, 2 Therefore, tumor resection should be based on function of the nervous system rather than anatomy alone.1-6

Modern literature review

To achieve functional guidance during tumor resection two main intraoperative neurophysiological techniques are available. Continuous monitoring of MEPs enables real time assessment of the functional integrity of the cortico-spinal tract (CST). 5-13 Subcortical stimulation with a handheld probe (called mapping) is used to localize motor tracts in deep white matter structures at different stages of tumor resection.1-4, 14-21

Recent clinical and research developments

The gold standard for electrical cortical and subcortical stimulation is the classical Penfield technique (bipolar probe, 50-60 Hz).15, 16, 18 Later the short train stimulation (3-5 stimuli, 0.5 msec pulse duration, ISI 4 msec) has been introduced.8, 9, 22 The temporal summation of multiple descending volleys in high frequent short train stimulation finally triggers a time-locked MEP response which has a defined latency and which amplitude is easy to quantify.8, 9, 22 The radiant current by monopolar (referential) stimulation enters distant structures perpendicular and therefore is most effective in stimulation.14

An imminent question during tumor removal is how distant the resection cavity is at a certain point to the CST. Recently several important studies were done to correlate the stimulation site to the distance of the CST and most of them came up with to the "rule-of-thumb" of 1 mA would correspond to 1 mm.23-27 Yet comparing those different studies the applied number of stimuli, pulse duration, polarity and especially charge might be of important value. Therefore, we would recommend for motor mapping to keep a constant number of stimuli and pulse duration and to apply constant current cathodal subcortical stimulation.3, 6, 28

We had recently analyzed what would be a reasonable lowest mapping threshold (MT in mA) to stop tumor resection. We had demonstrated that 1) mapping MTs correlate with the risk of CST injury, 2) there is safe mapping corridor between the first (high) and critical (low) MTs and 3) the critical (low) mapping MTs are lower than previously thought.6, 29 In this context, we had shown that mapping thresholds of even below 3 mA might be safe provided that DSC-MEP monitoring remains stable at the same time.6, 29

Therefore mapping should not been applied intermittently but continuously with the highest temporal coverage and directly at the site of tumor removal. This is absolutely necessary at very low mapping thresholds in close proximity to the CST. We had described recently a new mapping protocol.3 By integrating a monopolar stimulation tip to a classical suction device, stimulation is possible during the whole process of tumor removal at the site of tumor removal. This technique allows that mapping is achieving the same temporal coverage as monitoring but being able to give spatial information of the CST at the same time.3, 30 This is achieved by adopting the simulation current to the estimated distance to the CST.3, 6, 31 Nowadays already several groups are applying the concept of continuous subcortical stimulation vie a surgical instrument- either the suction aspirator or CUSA.3, 31-33
It is important to highlight that mapping provides only information of the stimulation site and distal to this point. If feedback of the whole integrity of the motor system is needed MEP monitoring is indicated.5, 6, 29 Remote vascular injury can only be detected that way10-12 and should be therefore always combined with mapping techniques. As long as direct cortical stimulated (DCS) MEP are preserved, there is a very low risk for postoperative change in motor function.5-7, 10-12, 29 The downside is that DCS MEP changes often occur abruptly and are irreversible in around 40% of cases.6, 11, 29

Future questions and direction

Still the exact distance in mm of a stimulation site to the CST remains unclear.3, 6 Even more the reliability of different stimulation paradigms to recognize essential motor fibres might depend on the clinical context (infiltrative versus non-infiltrative tumors, prior radiation).4

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Whether any mapping strategy may help to improve long term survival has to been shown in future studies. 2

Conclusion

The combined approach of DCS MEP monitoring for remote vascular injury and continuous dynamic mapping with high spatial and temporal solution by stimulation over a modified surgical instrument like the suction device enables real-time functional feedback during motor eloquent tumor surgery.

Key references, recommended reading:

1. Chang EF, Clark A, Smith JS, et al. Functional mapping-guided resection of low-grade gliomas in eloquent areas of the brain: improvement of long-term survival. Clinical article. Journal of neurosurgery 2011;114:566-573.
2. De Witt Hamer PC, Robles SG, Zwinderman AH, Duffau H, Berger MS. Impact of intraoperative stimulation brain mapping on glioma surgery outcome: a meta-analysis. Journal of clinical oncology : official journal of the American Society of Clinical Oncology 2012;30:2559-2565.
3. Raabe A, Beck J, Schucht P, Seidel K. Continuous dynamic mapping of the corticospinal tract during surgery of motor eloquent brain tumors: evaluation of a new method. Journal of neurosurgery 2014;120:1015-1024.
4. Bello L, Riva M, Fava E, et al. Tailoring neurophysiological strategies with clinical context enhances resection and safety and expands indications in gliomas involving motor pathways. Neuro-oncology 2014;16:1110-1128.
5. Sala F, Lanteri P. Brain surgery in motor areas: the invaluable assistance of intraoperative neurophysiological monitoring. Journal of neurosurgical sciences 2003;47:79-88.
6. Seidel K, Beck J, Stieglitz L, Schucht P, Raabe A. The warning-sign hierarchy between quantitative subcortical motor mapping and continuous motor evoked potential monitoring during resection of supratentorial brain tumors. Journal of neurosurgery 2013;118:287-296.
7. Deletis V, Camargo AB. Transcranial electrical motor evoked potential monitoring for brain tumor resection. Neurosurgery 2001;49:1488-1489.
8. Deletis V, Isgum V, Amassian VE. Neurophysiological mechanisms underlying motor evoked potentials in anesthetized humans. Part 1. Recovery time of corticospinal tract direct waves elicited by pairs of transcranial electrical stimuli. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology 2001;112:438-444.
9. Deletis V, Rodi Z, Amassian VE. Neurophysiological mechanisms underlying motor evoked potentials in anesthetized humans. Part 2. Relationship between epidurally and muscle recorded MEPs in man. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology 2001;112:445-452.
10. Neuloh G, Pechstein U, Cedzich C, Schramm J. Motor evoked potential monitoring with supratentorial surgery. Neurosurgery 2004;54:1061-1070; discussion 1070-1062.
11. Neuloh G, Pechstein U, Schramm J. Motor tract monitoring during insular glioma surgery. Journal of neurosurgery 2007;106:582-592.
12. Szelenyi A, Hattingen E, Weidauer S, Seifert V, Ziemann U. Intraoperative motor evoked potential alteration in intracranial tumor surgery and its relation to signal alteration in postoperative magnetic resonance imaging. Neurosurgery 2010;67:302-313.
13. Krieg SM, Shiban E, Droese D, et al. Predictive value and safety of intraoperative neurophysiological monitoring with motor evoked potentials in glioma surgery. Neurosurgery 2012;70:1060-1070; discussion 1070-1061.
14. Szelenyi A, Senft C, Jardan M, et al. Intra-operative subcortical electrical stimulation: a comparison of two methods. Clinical neurophysiology : official journal of the International Federation of Clinical Neurophysiology 2011;122:1470-1475.
15. Penfield W. Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. Brain : a journal of neurology 1937;60:389-443.
16. Duffau H, Capelle L, Denvil D, et al. Usefulness of intraoperative electrical subcortical mapping during surgery for low-grade gliomas located within eloquent brain regions: functional results in a consecutive series of 103 patients. Journal of neurosurgery 2003;98:764-778.
17. Duffau H. The huge plastic potential of adult brain and the role of connectomics: new insights provided by serial mappings in glioma surgery. Cortex; a journal devoted to the study of the nervous system and behavior 2014;58:325-337.

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18. Berger MS. Functional mapping-guided resection of low-grade gliomas. Clin Neurosurg 1995;42:437-452.
19. Kombos T, Suss O, Vajkoczy P. Subcortical mapping and monitoring during insular tumor surgery. Neurosurgical focus 2009;27:E5.
20. Schucht P, Seidel K, Jilch A, Beck J, Raabe A. A review of monopolar motor mapping and a comprehensive guide to continuous dynamic motor mapping for resection of motor eloquent brain tumors. Neuro-Chirurgie 2017.
21. Plans G, Fernandez-Conejero I, Rifa-Ros X, Fernandez-Coello A, Rossello A, Gabarros A. Evaluation of the High-Frequency Monopolar Stimulation Technique for Mapping and Monitoring the Corticospinal Tract in Patients With Supratentorial Gliomas. A Proposal for Intraoperative Management Based on Neurophysiological Data Analysis in a Series of 92 Patients. Neurosurgery 2017;81:585-594.
22. Taniguchi M, Cedzich C, Schramm J. Modification of cortical stimulation for motor evoked potentials under general anesthesia: technical description. Neurosurgery 1993;32:219-226.
23. Kamada K, Todo T, Ota T, et al. The motor-evoked potential threshold evaluated by tractography and electrical stimulation. Journal of neurosurgery 2009.
24. Nossek E, Korn A, Shahar T, et al. Intraoperative mapping and monitoring of the corticospinal tracts with neurophysiological assessment and 3-dimensional ultrasonography-based navigation. Clinical article. Journal of neurosurgery 2011;114:738-746.
25. Ohue S, Kohno S, Inoue A, et al. Accuracy of diffusion tensor magnetic resonance imaging-based tractography for surgery of gliomas near the pyramidal tract: a significant correlation between subcortical electrical stimulation and postoperative tractography. Neurosurgery 2012;70:283-293; discussion 294.
26. Prabhu SS, Gasco J, Tummala S, Weinberg JS, Rao G. Intraoperative magnetic resonance imaging-guided tractography with integrated monopolar subcortical functional mapping for resection of brain tumors. Clinical article. Journal of neurosurgery 2011;114:719-726.
27. Maesawa S, Fujii M, Nakahara N, Watanabe T, Wakabayashi T, Yoshida J. Intraoperative tractography and motor evoked potential (MEP) monitoring in surgery for gliomas around the corticospinal tract. World neurosurgery 2010;74:153-161.
28. Seidel K, Beck J, Stieglitz L, Schucht P, Raabe A. Low-threshold monopolar motor mapping for resection of primary motor cortex tumors. Neurosurgery 2012;71:104-114; discussion 114-105.
29. Landazuri P, Eccher M. Simultaneous Direct Cortical Motor Evoked Potential Monitoring and Subcortical Mapping for Motor Pathway Preservation During Brain Tumor Surgery: Is it Useful? Journal of clinical neurophysiology : official publication of the American Electroencephalographic Society 2013;30:623-625.
30. Schucht P, Seidel K, Beck J, et al. Intraoperative monopolar mapping during 5-ALA-guided resections of glioblastomas adjacent to motor eloquent areas: evaluation of resection rates and neurological outcome. Neurosurgical focus 2014;37:E16.
31. Shiban E, Krieg SM, Obermueller T, Wostrack M, Meyer B, Ringel F. Continuous subcortical motor evoked potential stimulation using the tip of an ultrasonic aspirator for the resection of motor eloquent lesions. Journal of neurosurgery 2015;123:301-306.
32. Roth J, Korn A, Bitan-Talmor Y, Kaufman R, Ekstein M, Constantini S. Subcortical Mapping Using an Electrified Cavitron UltraSonic Aspirator in Pediatric Supratentorial Surgery. World Neurosurgery 2017;101:357-364.
33. Moiyadi A, Velayutham P, Shetty P, et al. Combined Motor Evoked Potential Monitoring and Subcortical Dynamic Mapping in Motor Eloquent Tumors Allows Safer and Extended Resections. World neurosurgery 2018.

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