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Review / Derleme

Intraoperative Neuromonitoring

Ameliyatta Nörofizyolojik İzleme

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Summary

Principal aim of "intraoperative neuromonitoring" (IN) is to prevent the potential neurlogical deficits may caused by surgical process, which is very appropriate to the principal rule of medicine "primum non nocere". In addition to reducing the neurological deficits, monitoring of the neurological structures, also provides very valuable knowledge about anatomy and physiology of central nervous system. IN become almost routine technique during the surgeries concerned to the central and/or peripheral neurological structures. The used monitoring technique varies according to the involving neurological structure, and the aim of the surgical intervention. Because of this, the stuff who runs the monitoring, must be well trained and experienced. As it similar in the other countries, there are serious controversies on the IN in our country by means of training, price, legal aspects. Before the problems hard to be solve, all the sides of the neuromonitoring must be together to regulate the all aspects of the issue.

Keywords: Intraoperative neuromonitoring, somatosensory evoked potential, motor evoked potential

Öz

"Önce zarar verme" ilkesinin, cerrahi girişimlere uygulanması olarak kabul edilebilecek olan, "ameliyatta nörofizyolojik izleme" (ANİ) tekniğinin temel amacı; ameliyatta risk altında olan nörolojik dokuların korunması veya en az hasarla girişimin bitirilmesini sağlamaktır. Bunun yanında ameliyatta izleme, başlangıçtan beri, santral sinir sistemi anatomisi ve fizyolojisinin anlaşılmasında da çok önemli katkılarda bulunmuştur. Son yıllarda merkezi ve periferik sinir sistemini ilgilendiren tüm ameliyatlarda neredeyse rutin uygulamaya giren, ANİ için, girişimin yeri ve hedefine göre değişmek üzere son derece değişik teknikler uygulanmaktadır. Bu nedenle, bu girişimi yapanların son derece eğitimli ve tecrübeli olmaları gerekmektedir. Ülkemizde de son yıllarda uygulamanın yaygınlaşması ile eğitim, uygulama, ücretlendirme ve uygulayıcılar açısından bazı sorunlar ortaya çıkmaktadır. Uygulamanın tüm tarafları bir araya gelerek, sorunlar çözülmez olmadan konu bütün boyutları ile ele alınmalı ve düzenlemeler yapılmalıdır.

Anahtar Kelimeler: İntraoperatif nörofizyolojik izleme, somatosensoryel uyarılmış potansiyel, motor uyarılmış potansiyel

Introduction

Intraoperative neuromonitoring (IN), which contains measurements of blood pressure, electrocardiogram, and other monitoring, is an effort to practice "primum non nocere," one of the principal rules of medicine written in the Hippocratic Oath, with the help of the latest computing and electronic technology. Monitoring of vital signs during surgery has been performed for many years. Developments in computing and electronic technology have led to progress in monitoring basic neurophysiologic systems and saving data intraoperatively and thus creating the modern technique of IN. The aims of IN are to predict dangers by monitoring tissues and systems at risk moment-by-moment and to decrease the effects of malicious insults when they are still reversible. IN should be considered as a medical-technological effort that can improve personal and social joy and decrease economic losses by avoiding or decreasing postoperative morbidity, which is also in line with professional principles. IN

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was first performed in operating rooms of some universities in the 1970s and quickly became routine practice. Early IN practices were electrophysiologic investigations performed in operating rooms and these had a long history. Wilder Penfield, a neurosurgeon, who had a good electrophysiology education is known as the founder of IN. He performed studies with Boldrey about somatic motor and sensory representation using electrical stimulation in 1937 and with Rasmussen on mapping epileptogenic areas using electrical stimulation of the cortex (1,2). He defined areas of cortical function and sensory and motor homunculus in these well-known studies. Another neurosurgeon, Ojeman (3), followed Penfield. He mapped the temporal lobe in patients on which he operated using electrical stimulation of the cortex and defined areas of memory and speech in awake patients during operations. In later years, the auditory cortex, dorsal column nuclei, cochlear nucleus, and inferior colliculus were defined by electrical stimulation (4,5). All these studies were precursors of IN and with the help of improvements in computing and electronic technology, IN became routine practice in operating rooms in the 1970s. In the late 1960s, monitoring of the facial nerve was routine practice (6) and it was followed by monitoring of the trigeminal nerve during microvascular decompression surgery for hemifacial spasm (7), monitoring of the auditory potentials (8), and monitoring of multiple cranial nerves at the same time during skull base operations in the late 1980s (9). With the development of magnetic and electrical stimulation of the cortex, cortical and spinal motor systems could be monitored intraoperatively (10,11). IN techniques then began to be used all over the world and performed in all operations of the central nervous system. Many neurosurgeons became pioneers of IN techniques in Turkey (12).

Intraoperative Neuromonitoring Techniques

All modalities used in clinical electrophysiology laboratories can also be used for IN. The types of IN techniques that would be used in an operation depends on the type of operation and the part of nervous system that is under risk. In addition to methods used in electrophysiology laboratories, awake anesthesia and uncovered nervous system provide fascinating investigations and monitoring including corticography, mapping, and detection of speech areas can be performed that cannot usually be performed in daily practice. Table 1 shows electrophysiologic monitoring and research methods that can be used intraoperatively.

One of the most commonly used IN techniques is "somatosensorial-evoked potentials" (SEP). SEP is commonly used in carotid endarterectomy because of its high sensitivity to cerebral blood flow (13); it is also used in scoliosis surgery (14). However, use of SEP alone has two disadvantages. First, averaging of many stimuli to get a clear SEP response takes a long time and instantaneous events can be missed or artefacts caused by cautery prevent obtaining a clear SEP response and cause more delay. Second, monitoring with SEP alone has a high percentage of false negative results - SEP responses are normal but the operation results in neurologic deficit (15). The percentage of false negativity dramatically decreased after transcortical electrical stimulation was used in operating rooms. Also, getting a response with one stimulation causes instantaneous monitoring and also makes performing mapping technique easier. Using compound techniques for IN (Figure 1) including SEP, motor-evoked potentials (MEPs), and spinal motor potentials (D and I waves) have also reduced the percentage of false negativity nearly to zero, and decreased the risk of postoperative neurologic deficit and results with 92% specificity and 99% sensitivity (16).

IN contributes to detecting surgical borders sensitively with many aspects. The use of IN techniques including mappings of cortex, spinal cord and brainstem, electrocorticography, phase change studies in cerebellopontine angle tumors, cauda equina and tethered cord operations decreases morbidity and protects patient's functional health by helping to detect nerves (Figure 2, 3). Visual evoked potentials and brainstem auditory evoked potentials (BAEP) especially in "cerebellopontine angle tumors" operations are used but less mentioned. We use BAEP in "cerebellopontine angle tumors" operations in our clinical practice.

Intraoperative Neuromonitoring Cost and Efficiency

Efficiency of IN is well studied. IN is, no doubt, efficient in monitoring of cerebral blood flow, detecting the margins of tumor resection and cortical ablation, fixating cranial nerves in operations of cerebellopontine angle and brainstem, securing hearing, functional mapping, fixating nerves and filum terminale in operations of

Table 1. Intraoperative neuromonitoring techniques
Somatosensory Evoked Potentials
Somatosensory cortical evoked potentials by peripheral nerve stimulation
Spinal cord evoked potentials by peripheral nerve stimulation
Spinal cord evoked potentials by spinal cord stimulation
Phase change studies
Motor Evoked Potentials
Spinal evoked potentials by motor cortex stimulation (spinal MEP/D-I waves)
Muscle evoked potentials by motor cortex stimulation (brain-muscle MEP)
Muscle and/or sensory potentials by peripheral nerve stimulation
Motor cortex/brainstem/spinal cord mappings
Spinal Cord Stimulation
Muscle evoked potentials (spinal-muscle MEP) (myogenic MEP)
Peripheral nerve evoked potentials (neurogenic MEP)
Visual Evoked Potentials
Brainstem Auditory Evoked Potentials
Free-run EMG
Reflex Studies
F wave
H reflex
Pudental reflex
Electroencephalography
Scalp EEG
Electrocorticography

MEP: Motor-evoked potential, EEG: Electroencephalogram, EMG: Electromyogram tethered cord and cauda equina (9). But some believe that efficiency and essentiality of IN are overestimated. They argue that IN increases the expenses of operations, its importance is overestimated and decrease in percentage of complications is due to improvements in surgical technology. These arguments are partly true.

IN definitely imposes additional cast upon operations. But its cost can easily be measured. On the other hand, calculating the cost of a neurological complication is very hard. Toleikis (17) showed that the cost of a complication in pedicle screw surgery is equal to the cost of 50 patients' IN for the same surgery. Personal expanses, effects on quality of life, effects on family members are not counted in calculation of the cost of IN in patients who had a complication because physical and psychological costs can't be counted. IN can increase the cost in one patient but it doesn't increase public health costs (18).

Intraoperative Neuromonitoring in Turkey and the World

Practice of IN in Turkey is problematic. IN is used in orthopedic and neurosurgical operations but in small numbers considering the development of medical practice in Turkey. In many developed countries, IN became a "sine qua non" practice in orthopedic and neurosurgical operations and the number of studies about IN exceeded thousands (19). But practice of IN and studies about IN are in very small numbers in Turkey.

Social Security Institution, the buyer and payer of health services in Turkey determine in which operations a payment is made when IN is used (20). But this must not mean only in these operations, IN can bu used. Surgeons can use IN in every kind of operation when they need. The amounts of payment for INs are determined in "guide for budget implementations". These amounts were changed many times because they were not determined realistically. On the other hand, amounts of payment that will be made to doctors are very small and because of this, neurologists who are only allowed to use IN by laws (21,22,23), are not interested in IN. Therefore, IN is used by someone who doesn't have an education about it. IN performed by someone who doesn't have an education about electrophysiology, doesn't have a scientific value and won't give reliable information. Because of this, practice of IN is limited by administrators. As shown in Table 1, all IN modalities performed in operations are modalities that are performed in clinical neurophysiology laboratories. Only neurologists are authorized to perform IN (21). Letting anyone to perform these procedures which are more complicated than ones performed in clinical neurophysiology laboratories and may require immediate decision, must be unacceptable for surgeons. Not to make an IN is better than making a bad IN. There are also problems about peforming IN and education of IN performers abroad but at least some rules are edited for IN performers ın United States and Canada. Unfortunately, suggestions of Turkish Clinical Neurophysiology Electroencephalogram-Electromyogram Society about education, authority, pricing and legal infrastructure for IN, hasn't been accepted until now. All sides must come together and discuss to find solutions and make decisions before problems get bigger.

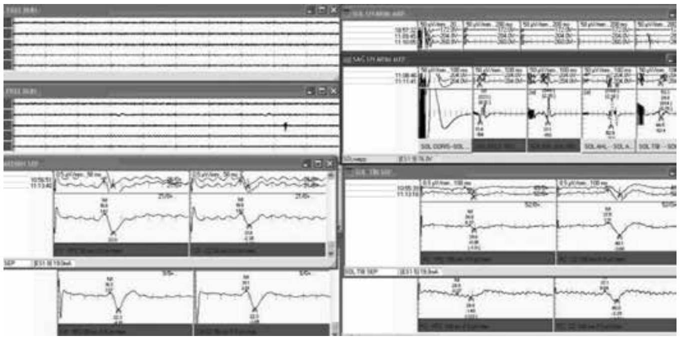

Figure 1. A multimodal monitoring during a temporal mass excision (bilateral tibial somatosensorial-evoked potential, median somatosensorial-evoked potential, motor-evoked potential by transcortical electrical stimulation, free-run electromyogram)

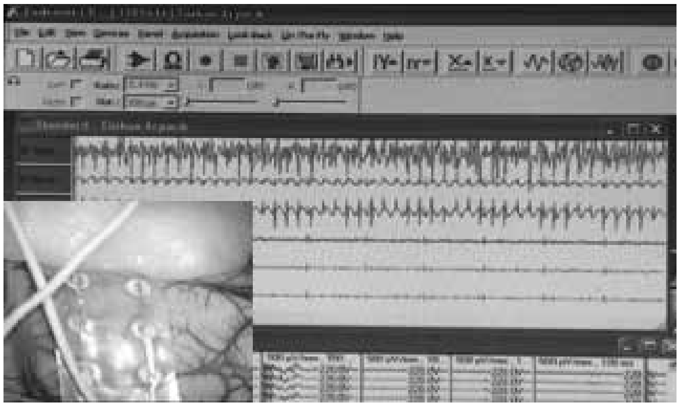

Figure 2. Cortical stimulation, electrocorticography and phase change studies can be performed with the use of sequential cortical electrodes (in this image, cortical area is being investigated by cortical stimulation induced speech cessation)

Ethics

Peer-rewieved: Internal peer-reviewed.

Figure 3. Investigation of whether facial or trigeminal nerve is stimulated with the use of direct nerve stimulation during a cerebellopontine angle tumor operation

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