Neurophysiological intraoperative monitoring in neurosurgery: aid or handicap?

An international survey

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Object. Neurophysiological intraoperative monitoring (IOM) is regarded as a useful tool to provide information about physiological changes during surgery in eloquent areas of the nervous system, to increase safety and reduce morbidity. Nevertheless, numerous older studies report that very few patients benefit from IOM, and that there are high rates of false-positive and false-negative changes of neurophysiological parameters during surgery. There is an ongoing discussion about the effectiveness of neurophysiological IOM. This questionnaire study was performed to evaluate the attitude of neurosurgeons toward neurophysiological IOM and the availability of this tool.

Methods. One hundred fifty neurosurgeons from 60 institutions in 16 countries were asked to answer anonymously a questionnaire with 11 questions. The questionnaire covered aspects of personal experience, the neurosurgical institution, and availability of neurophysiological IOM as well as asking the surgeon's opinion of the procedure.

Results. One hundred nine questionnaires were returned (73%). Seven questionnaires were excluded because of failure to complete the form correctly or completely, leaving 102 respondents from 44 institutions in 16 countries in the study; 79.5% of the included institutions provided neurophysiological IOM. Young neurosurgeons did not put more trust in IOM than experienced neurosurgeons. With growing IOM experience, surgeons seem to allow less influence of the findings on the course of their operation. At large institutions in which > 1500 operations per year are done, IOM is performed by the neurosurgeons themselves in most cases. In institutions with fewer operations, the IOM team consists mostly of nonneurosurgeons. Regardless of the availability of neurophysiological IOM, all surgeons stated that IOM is gaining increasing importance.

Conclusions. Neurophysiological IOM represents an established tool in neurosurgery. Although the importance of IOM is emphasized by the majority of neurosurgeons, the relevance of this tool to the course of the operation changes with increasing neurophysiological IOM experience. (DOI: 10.3171/2009.7.FOCUS0969)

KEY WORDS • eloquent cortex • central nervous system • neurophysiological monitoring

NEUROPHYSIOLOGICAL IOM represents a diagnostic tool to monitor the functional integrity of neural structures during surgery by electrophysiological methods. Although there are several studies indicating that it represents a useful tool to increase safety and prevent neurological deterioration during surgery,^{9,13,15–21,27,29–31,34–37,39,41} there are no existing controlled randomized studies that show a superior effect of neurophysiological IOM on neurological outcome after surgery in eloquent areas of the CNS. Thus, due to problems with the prognostic value and the lack of reliability in exact prediction of neurological outcome as well as false-negative findings during IOM, as reported in older studies,^{7,20,28,39,42,43} many surgeons do not rely on this technique. The use of IOM also depends on personal experience, availability, and training background.²⁵ Whereas

younger neurosurgeons might welcome additional information to feel safer during surgery, experienced neurosurgeons might regard the neurophysiological information as a handicap, due to their knowledge of the disadvantages of this technique and after years of successful surgery without IOM. These assumptions were tested as a hypothesis. Differences also exist regarding the IOM team. According to the American Association of Neuromuscular and Electrophysiological Medicine^{3–5} and the Academy of Neurology,² the team should consist of surgeons with a fundamental background in neurophysiology, an IOM team with a fundamental background in this type of monitoring, and of course experienced anesthesiologists. Recommendations detailing which type of operation should be performed under IOM also exist.^{6,26} Nevertheless, these recommendations represent no obligatory standard. Consequently, many differences exist regarding the meaning of IOM findings, availability of this tool, techniques for its performance, and the composition of the operating room team.

Abbreviation used in this paper: IOM = intraoperative monitoring.

FIG. 1. Bar graph showing the influence of IOM during the course of surgery in comparison with surgeons' experience with IOM. Allowing an influence only sometimes was interpreted as a minor influence.

The aim of the survey presented here was to evaluate the attitude of neurosurgeons toward IOM, its availability, and composition of the operating room team in various institutions worldwide.

Methods

The data were generated from a simple questionnaire containing 11 questions (see *Appendix*), which covered aspects of personal experience and of the neurosurgical institution.

The neurosurgeons were asked to respond anonymously about their experience with IOM and answered questions about the impact of the information provided by IOM on the course of their operations. Furthermore, the questionnaire included questions about the estimated number of operations performed in general and with the aid of IOM in particular, as well as who provides the IOM service. Finally, the participants rated the importance of IOM in the future.

The questionnaire was distributed personally during a European Association of Neurosurgical Societies meeting in Opatija, Croatia, in 2008, and in most cases by email to neurosurgeons worldwide. One hundred fifty neurosurgeons with various levels of experience from 60 institutions in 16 countries were addressed.

The different IOM modalities were not specified, to avoid a ranking between the hospitals and to avoid any suggestion of standards. Thus, the data had been collected, analyzed, and stored without mention of the hospital's name.

For statistical analysis we dichotomized the surgeons into groups of experienced neurosurgeons (> 10 years of neurosurgery) and less experienced neurosurgeons (< 10 years of neurosurgery), and neurosurgeons with long experience with IOM (> 5 years) and with less experience with IOM (< 5 years).

The Fisher exact test was performed using GraphPad Prism version 5.00 for Windows (GraphPad Software, www.graphpad.com).

FIG. 2. Bar graph showing the influence of IOM during the course of surgery in comparison with surgeons' experience with IOM. Allowing an influence "sometimes" was interpreted as a high influence during these occasions.

Results

Questionnaires from 109 neurosurgeons at 46 institutions in 16 countries were returned (in order of most forms received: Germany, the Netherlands, United Kingdom, Switzerland, France, Poland, US, Brazil, Argentina, Croatia, Serbia, Spain, Turkey, Luxembourg, China, and Australia). Seven questionnaires had to be excluded due to incomplete information, leaving 102 respondents at 44 institutions in 16 countries in the study.

The highest percentage of the participating institutions (40.9%) were large neurosurgical centers in which > 1500 operations are performed yearly and IOM is provided. In most institutions (79.5%) IOM is available. The number of operations performed with the aid of IOM ranges from < 10 per year in smaller neurosurgical units to > 50 per year in larger departments. Most of the large centers (66%) perform > 50 operations yearly with the aid of IOM. There are also smaller departments with < 1000 operations per year that provide a comparably large number of operations with IOM. Only 2 large centers do not provide IOM. Interestingly, 43% of the small neurosurgical units that perform < 500 operations yearly provide IOM as well. At large institutions performing > 1500 operations per year, IOM is provided by other neurosurgeons in most of the cases (66.67%). In institutions with fewer operations, the IOM team consists of nonneurosurgeons in the majority of cases (88%); they are mostly neurophysiologists (42.3%). In 40% of all participating institutions with IOM, the neurosurgeons provide IOM themselves.

The questionnaire was returned by experienced neurosurgeons in the majority of cases (47%); 18.6% of participating neurosurgeons stated a long experience with IOM of > 5 years. In contrast, 32 neurosurgeons (31.4%) stated that they had no experience with IOM, although 12 of these 32 were from institutions at which IOM was available. Therefore, 15% of neurosurgeons at institutions with IOM have no experience with this monitoring method, despite its availability.

Independently from IOM availability, all surgeons stated that IOM is gaining increasing importance now

Availability and influence of intraoperative monitoring

TABLE 1: Institutions with and without IOM, classified by estimated number of operations performed yearly*

Parameter	No. of Ops/Yr at Institutions W/ IOM (%)				No. of Ops/Yr at Institutions W/o IOM (%)			
	<500	500–999	1000–1500	>1500	<500	500–999	1000–1500	>1500
no. of surveyed institutions	3 (6.8)	7 (15.9)	7 (15.9)	18 (40.9)	4 (9)	1 (2.3)	2 (4.5)	2 (4.5)
no. of ops performed w/ IOM at institution								
<10/yr	2 (4.5)	—	—	—				
10–20/yr	1 (2.3)	2 (4.5)	4 (9)	3 (6.8)				
21–50/yr	—	4 (9)	2 (4.5)	3 (6.8)				
>50/yr	—	1 (2.3)	1 (2.3)	12 (27.3)				
who provides IOM at institution								
neurosurgeon	—	—	2 (4.5)	12 (27.3)				
(neuro)anesthesiologist	—	1 (2.3)	—	1 (2.3)				
neurophysiologist/neurologist	2 (4.5)	3 (6.8)	5 (11.4)	2 (4.5)				
nurse/technician	1 (2.3)	3 (6.8)	—	3 (6.8)				

* Total and relative numbers for all 44 participating institutions (IOM was available in 35 institutions, and unavailable in 9).

and that this will continue in the future. Nevertheless, according to surgical experience and experience with IOM, different results could be found regarding the influence of this method. Of all participating neurosurgeons, 76% regard IOM as a very important diagnostic tool for identifying risky surgical maneuvers. Only 6% of surgeons saw no importance of IOM at all.

Regardless of the practitioner's experience in the field of neurosurgery and regardless of the team that provides IOM, no difference was observed between neurosurgeons when asked what influence the information provided by IOM has on the course of surgery ($p = 0.47$). Interestingly, the neurosurgeons with IOM experience of > 5 years state less influence of the monitoring on the course of their surgery than did the surgeons with less experience with this tool, who stated a higher influence on the course of their operation ($p = 0.001$; Fig. 1). Surgeons with less IOM experience mostly stated a high influence of IOM on the course of their surgery. Surgeons with long experience with IOM most often stated that IOM would influence their course of operation only "sometimes" ($p = 0.001$), but never did surgeons with IOM experience state that the monitoring results would have no influence at all (Fig. 2). In institutions without IOM, surgeons with various levels of experience stated that IOM would have no influence on the course of their surgery, and only 4 experienced surgeons would give IOM an influence on the course of their surgery. Consistently, these 4 neurosurgeons believed that IOM would expand the range or extent of their surgery.

Eighty-eight percent of neurosurgeons from institutions at which IOM was available confirmed that this method extends the range of operations at their department. Fifty-five percent of neurosurgeons from institutions without IOM estimated that this tool would extend the range of operations at their department. The data obtained are shown in Tables 1 and 2.

Discussion

We have presented an international survey on the

availability and importance of IOM that involves more than 100 neurosurgeons from 16 countries. Most of the participating neurosurgeons regard IOM as an important diagnostic tool to identify risky surgical maneuvers and guide the surgery in eloquent areas of the nervous system, which extends the range of surgical procedures. Therefore, most institutions provide IOM. The large number of operations performed with IOM in comparatively small departments indicates a high specialization and high academic interest. Experience in neurosurgery does not influence the estimation of the importance of IOM, but with growing IOM experience, surgeons seem to analyze the results of this method more critically. It is interesting that even in centers that provide IOM, 15% of neurosurgeons do not have any experience with this tool. At large institutions the IOM team consists mostly of neurosurgeons, whereas neurophysiologists provide IOM at the majority of smaller institutions.

Neurophysiological IOM is regarded as a useful tool to provide information about physiological changes during surgery in eloquent areas of the nervous system to increase safety and reduce morbidity.^{9,13,14,18–20,29–31,34,36,37,39,41,42} Nevertheless, when changes in neurophysiological parameters are of importance, the exact data underlying multifactorial interindividual parameters are unknown, and due to ethical reasons cannot be assessed in prospective studies. Numerous older studies and case reports exist that show a low rate of patients benefitting from IOM, and rates of false-positive and false-negative changes in neurophysiological parameters between 2 and 28% during surgery.^{8,10–12,37,42} One reason for dissenting opinions might be the poor definition of when and how the surgeon should react to a neurophysiological event during surgery. Although false-negative and false-positive findings might make an adequate decision difficult, even in true-positive IOM events the surgeon often cannot react adequately or in time to the information obtained from IOM.⁴² However, there are various events that can be easily addressed to avoid neurological deterioration, such as a break in tissue dissection, brain retraction, or replacement of a clip dur-

TABLE 2: Data divided into years of experience in the field of neurosurgery for the 102 neurosurgeons whose response was included*

Parameter	Yrs of Experience & No. of Surgeons at Institutions W/ IOM (%)			Yrs of Experience & No. of Surgeons at Institutions W/o IOM (%)		
	6–7 Yrs	8–10 Yrs	>10 Yrs	6–7 Yrs	8–10 Yrs	>10 Yrs
no. of neurosurgeons interviewed	34 (33.3)	10 (9.8)	36 (35.3)	4 (3.9)	6 (5.9)	12 (11.8)
personal experience w/ IOM						
none	8 (7.8)	—	4 (3.9)	4 (3.9)	6 (5.9)	10 (9.8)
<2 yrs	10 (9.8)	2 (1.9)	5 (4.9)	—	—	2 (1.9)
2–5 yrs	8 (7.8)	2 (1.9)	8 (7.8)	—	—	—
>5 yrs	8 (7.8)	6 (5.9)	19 (18.6)	—	—	—
estimated importance of IOM						
not important	2 (1.9)	—	—	—	—	4 (3.9)
very important	26 (25.5)	8 (7.8)	30 (29.4)	2 (1.9)	6 (5.9)	6 (5.9)
nice to have it	4 (3.9)	2 (1.9)	4 (3.9)	2 (1.9)	—	2 (1.9)
may protect me from lawyers	2 (1.9)	—	2 (1.9)	—	—	—
influence of IOM on the course of op						
none	—	—	4 (3.9)	4 (3.9)	6 (5.9)	8 (7.8)
high	21 (20.6)	6 (5.9)	22 (21.5)	—	—	2 (1.9)
sometimes	13 (12.7)	4 (3.9)	10 (9.8)	—	—	2 (1.9)
would/does IOM extend your op range						
yes	26 (25.5)	10 (9.8)	34 (33.3)	—	4 (3.9)	8 (7.8)
no	8 (7.8)	—	2 (1.9)	4 (3.9)	2 (1.9)	4 (3.9)
future of IOM						
no future	—	—	—	—	—	—
increasing importance	34 (33.3)	10 (9.8)	36 (35.3)	4 (3.9)	6 (5.9)	12 (11.8)

* Total and relative numbers of all 102 participating surgeons.

ing intracranial aneurysm surgery.^{12,22,28,36,37,40,42} Furthermore, the rate of false-negative or false-positive findings during surgery can be reduced by multimodal IOM.^{23,24,33} In the field of spine surgery, combined neurophysiological IOM with electromyography, somatosensory evoked potentials, and motor evoked potentials shows a high sensitivity of 97–100%. Therefore, IOM is of substantial benefit in cervical spine surgery,¹⁷ correction of spinal deformity,^{15,21,35} and can help to guide the extent of intradural spinal cord surgery.²⁷ Especially in regard to spinal deformity in pediatric patients, a growing need for IOM and trained staff can be observed.³² Furthermore, multimodal IOM can help to recognize perioperative spinal cord injury in time and possibly attenuate the extent of this debilitating complication by prompting specific treatment, such as immediate surgery, application of steroids, and maintenance of adequate blood pressure and blood sugar.¹

Another important aspect is that expenses for IOM, including staff and technical equipment, are not compensated adequately in different countries, making IOM uneconomical or restricting it to academic purposes only. There is an ongoing discussion about the effectiveness and utility of IOM.

The data we obtained leaves a wide range of interpretation resulting from a nonspecific questionnaire that intentionally does not go into detail. This has been done deliberately to avoid a ranking or classification of “safe” departments that offer large-scale IOM and “less safe”

departments with rudimentary or no IOM at all. Furthermore, the purpose of the study was not to suggest or imply any standards, because even the availability of different IOM tools (that is, electromyography, motor evoked potentials, or somatosensory evoked potentials) shows a great variability.²⁵ The study has another potential bias, due to the fact that a large number of questionnaires (41) was gathered during an European Association of Neurosurgical Societies meeting, which might reflect the opinion of surgeons with particular academic interests.

Neurophysiological IOM of various kinds is available in most of the participating institutions. A previous survey study of the availability of IOM in the field of spine surgery could show similar high rates of availability in orthopedic and neurosurgical institutions.²⁵ Larger academic centers more often offer IOM, and thus surgeons trained at such centers more often prefer IOM during surgery.²⁵

In smaller centers without IOM, patients with pathological entities in eloquent areas of the CNS are probably not treated surgically. Therefore, neurosurgeons from units without IOM state that this tool would extend the range of operative procedures. Avoiding surgery in eloquent areas when operating without IOM might resemble the results when these neurosurgeons operate with IOM. Nevertheless, in a few departments the lack of IOM does not seem to influence the decision to perform surgery in eloquent areas of the nervous system. Consistently, most of the neurosurgeons from these departments stated that

Availability and influence of intraoperative monitoring

IOM would not extend the range of surgery. Surgery in eloquent areas of the nervous system in these departments is probably performed by the most experienced surgeons only. It is not clear from the data we obtained whether the number of cases regarded as “nonoperable” is higher in these departments than in departments offering IOM, and whether these patients are sent to nonoperative care such as radiation, chemotherapy, and so on. However, although only 4 experienced neurosurgeons from institutions without IOM stated that this tool would have an influence on the course of their surgery, 4 more experienced surgeons who stated no influence of IOM on the course of their operation indicated later that IOM would extend the operative range at their institution. Many interpretations are imaginable: IOM might extend the radicality of their surgery, maybe some “nonoperable” lesions would become “operable” as suggested before, or maybe the statements were aimed at the younger neurosurgeons who might hone their skills with that additional information.

Younger neurosurgeons do not put more trust in IOM according to our study, as was also found in a previous questionnaire study conducted among spine surgeons.²⁵ In contrast, with growing experience with IOM, regardless of surgical experience, the influence of the neurophysiological IOM data on the surgeon’s decision changes. Whereas surgeons with less IOM experience allow mostly a high influence of IOM-acquired data on the course of their surgery, the ones with more IOM experience only allow this “sometimes.” We interpret this as a critical analysis of the IOM data by the experienced surgeon, who decides whether he or she should allow this influence, whereas the less experienced surgeon depends on another opinion and would rather follow IOM data analysis than to risk neurological deterioration of the patient. This is not a proof, but might be a support of both our hypotheses. Furthermore, there are expert neurosurgeons who acknowledge the importance of IOM, but who, even with the availability of IOM, do not require this additional support to perform safe surgery. We found that 15% of neurosurgeons at institutions that provide IOM do not have any experience with this tool. It is not clear whether they do not perform surgery in the eloquent areas of the nervous system or do not want the additional information during surgery.

All of the participating neurosurgeons noted that IOM will gain increasing importance in the future, supporting impressions from the literature.³⁸ It would be interesting to see if the consequent use of IOM in all neurosurgical units in which operations in eloquent areas are performed would increase safety and reduce complications of surgery in these areas of the CNS. Furthermore, it would also be interesting to see if becoming an experienced neurosurgeon without using IOM would result in comparable numbers of complications during a learning period as with a neurosurgeon who learns these operative techniques with the aid of IOM. Without the support of IOM, the surgeon can learn only from the experience of his teacher and from the clinical outcome, whereas with the aid of IOM, the outcome can possibly be directly influenced during the operation by changes in the procedure due to the neurophysiological findings. Even if a

direct influence of a monitoring event is not possible, the information about it can help the surgeon to learn which step of the operation caused an injury and help to refine the surgical procedure.⁴²

Recently, physicians from other medical branches besides neurophysiology and neurosurgery, such as anesthesiology, have been advancing to the field of IOM. Many neurosurgeons might regard neurophysiologists as too unfamiliar with the surgeon’s daily practice to offer useful information that does not handicap the surgeon during the operation. In large neurosurgical centers, IOM is mostly performed by neurosurgeons. This might imply that large neurosurgical centers have more staff and can afford to task a neurosurgeon with IOM. Consequently, the units might have fewer problems in coordinating IOM with surgery. Nevertheless, neurosurgical residents might possibly regard IOM duty as competing with surgical training, despite good scientific possibilities for research, which is reflected in the existence of numerous distinguished journals, such as the *Journal of Clinical Neurophysiology*, dealing with this particular subject. This might result in less expertise of neurosurgeons in the field of IOM. This potential problem leads to the question whether IOM personnel should undergo certification tests to offer a basic standard independent of medical background. The American Society of Neurophysiological Monitoring (<http://www.asnm.org/>) develops quality standards, as do other national organizations such as the German neurophysiological society DGKN (Deutsche Gesellschaft für klinische Neurophysiologie, <http://www.dgkn.de/>). Electrophysiological subsections of national neurosurgical societies are providing similar curricula or are about to develop them. The International Society of Intraoperative Neurophysiology was founded to promote interdisciplinary communication and collaboration between surgeons, neurologists, neurophysiologists, and anesthesiologists (<http://www.ptstroma.it/isin>). Regardless of who provides IOM, cooperation must grow, and the partners must learn from each other to achieve effective cooperation. The experience of the person who provides IOM, along with good cooperation between the surgeon, IOM team (regardless of medical discipline), and neuroanesthesiologist, are of fundamental importance.

Conclusions

Neurophysiological IOM represents an established tool in the field of neurosurgery and in surgery in general. Although the importance of IOM is emphasized by the majority of neurosurgeons, in those with more experience with IOM, the impact of this monitoring method on the course of the operation changes toward only an occasional influence.

Appendix

Questionnaire on IOM given to neurosurgeons worldwide:

- 1) Country: _____
- 2) Personal experience in neurosurgery
 - a. 6–7 years
 - b. 8–10 years
 - c. >10 years

- 3) Estimated number of operations at your institution
 - a. <500/year
 - b. 500–999/year
 - c. 1000–1500/year
 - d. >1500/year
- 4) Availability of intraoperative monitoring (IOM) at your institution
 - a. Yes
 - b. No
- 5) Estimated number of operations with the aid of IOM at your institution
 - a. None
 - b. <10/year
 - c. 10–20/year
 - d. 21–50/year
 - e. >50/year
- 6) Personal experience with IOM
 - a. None
 - b. <2 years
 - c. 2–5 years
 - d. >5 years
- 7) Who provides IOM at your institution?
 - a. Nobody
 - b. Neurosurgeon
 - c. Neurologist/Neurophysiologist
 - d. Nurse/Technician
 - e. Anesthesiologist
- 8) How do you regard the importance of IOM for operations in eloquent areas?
 - a. Not important
 - b. Very important
 - c. Nice to have it
 - d. May protect me from lawyers
- 9) Influence of IOM on the course of your operation
 - a. None
 - b. High
 - c. Sometimes
 - d. Depends on daily practice
- 10) Would IOM extend the range of operations at your department?
 - a. Yes
 - b. No
- 11) How do you regard the future of IOM?
 - a. No future
 - b. Increasing importance

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Availability and influence of intraoperative monitoring

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