Intraoperative Neurophysiologic Monitoring

M Dinkel, U Beese, M Messner

Citation

M Dinkel, U Beese, M Messner. *Intraoperative Neurophysiologic Monitoring*. The Internet Journal of Neurosurgery. 2000 Volume 1 Number 2.

Abstract

In order to avoid neurologic impairment the primary objectives of intraoperative electrophysiologic monitoring are the identification and localisation of morphologically uncertain tissue as well as monitoring CNS structures whose function is threatened either directly by surgical trauma or indirectly by ischemia. Depending on the objectives of monitoring different techniques are employed. Electromyographic recording of muscle activity after stimulation of cranial and peripheral motor nerves is helpful in detecting all of these nerves as important landmarks especially during posterior fossa surgery and thyroidectomy. Continuous monitoring of CNS stuctures at risk is primarily done by means of recording EEG which assesses the spontaneous activity of the cortex and by means of somatosensory evoked potentials (SSEP) which are used to detect neurologic impairment during spinal cord surgery or during procedures with the risk of hypoperfusion in the territory of middle cerebral artery.

Neurologic deficits are serious complications of surgical procedures endangering the functional integrity of the brain, spinal cord and cranial or peripheral nerves. They are dreaded due to the desasterous effect on the individual patient and due to a high incidence.

The rate of permanent recurrent laryngeal nerve paresis after thyroidectomy for instance comes up to 9%. Almost 40% of patients with acute dissection of the thoracoabdominal aorta suffer from paraplegia after aneurysm repair. Despite a wake-up test 0.7 to 1.6% are paraplegic after corrective procedures for scoliosis. After cardiac procedures with extracorporal circulation there is a 1 to 3% incidence of severe neurologic deficits and an incidence of cognitive deficits running up to 80%. Finally the stroke rate after carotid endarterectomy comes to 7% in well documented series [2, 3, 4,5,7].

OBJECTIVES AND METHODS

In order to avoid neurologic impairment the primary objectives of intraoperative electrophysiologic monitoring are the identification and localisation of morphologically uncertain tissue as well as monitoring CNS structures whose function is threatened either directly by surgical trauma or indirectly by ischemia. Another objective that is not a topic of this survey is the assessment of depth of anesthesia.

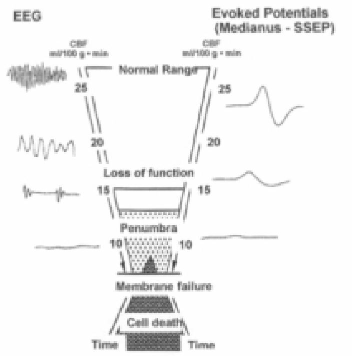
Depending on the objectives of monitoring different techniques are employed. Electromyographic recording of muscle activity after stimulation of cranial and peripheral motor nerves is helpful in detecting all of these nerves as important landmarks especially during posterior fossa surgery and thyroidectomy. Using a surface electrode attached to an endotracheal tube vocal cords` electromyographic activity can be recorded after stimulation of an intact laryngeal nerve.

Continuous monitoring of CNS stuctures at risk is primarily done by means of recording EEG which assesses the spontaneous activity of the cortex and by means of somatosensory evoked potentials (SSEP) which are used to detect neurologic impairment during spinal cord surgery or during procedures with the risk of hypoperfusion in the territory of middle cerebral artery. In contrast to the EEG SSEP offer the opportunity to monitor subcortical areas feeded by the small perforating arteries which are particularly prone to ischemia during carotid artery cross clamping [2,8].

EEG and SSEP are well suited for intraoperative monitoring because they indicate critical thresholds of CNS hypoperfusion before irreversible cell death has occurred (Fig 1) [8].

Figure 1

Figure 1: Neurophysiologic changes indicating critical thresholds of cerebral hypoperfusion.



CONTROVERSIES

Despite this and the fact that it is possible to monitor all important CNS functions even during general anaesthesia when clinical neurologic examination is not available, electrophysiologic monitoring is still a point of controversy culminating in the question: Is intraoperative neurophysiologic monitoring a luxury or a necessity?

One reason for the controversial debate is the fact, that the essentials of neurophysiologic monitoring are not always fulfilled. In order to achieve a high sensitivity knowledge of CNS anatomy and possible pathomechanisms of neurologic deficits as well as correct indication and application of different monitoring techniques are necessary. In order to increase specificity the anaesthetist has to control physiologic parameters and to maintain an anaesthetic steady state during critical periods to reliably distinguish between physiologic and pathologic findings. In a word a close cooperation between surgeon, anaesthetist and neurophysiologist is the most important prerequisite for a successful intraoperative neurophysiologic monitoring.

The main reason for the controversial discussion on electrophysiologic monitoring is the fact, that so far no prospective, randomized study has been undertaken to proof its efficacy. However I doubt that such a study will be undertaken in the future because it would be unethical to ignore pathologic neurophysiologic findings in an individual patient and because there is strong evidence for efficacy in certain procedures endangering peripheral nerves, the spinal cord and the brain.

EFFICACIOUS APPLICATIONS

During 97 resection of the thyroid gland we quickly and safely could identify recurrent laryngeal nerves, whenever there was a no preexisting defect. In 41% of all cases our surgeons stated neurophysiological stimulation useful and in 21% of all cases even necessary to identify the recurrent laryngeal nerve. Only one patient demonstrated a new permanent vocal paresis. In this patient the recurrent nerve had to be cut in order to remove a carcinoma of the thyreoid gland totally. Confirmed by the results of other groups we can summarize that monitoring of the laryngeal nerve is easy to handle, carries low risk and helps the surgeon to preserve normal vocal cord function [5].

Neurophysiologic monitoring has also proved effective for spinal cord monitoring during corrective procedures for scoliosis. For this type of spinal surgery monitoring SSEP is an obvious standard of care. As a review of more than 50.000 cases by the scoliosis research society revealed the incidence of neurologic deficits without pathologic EP finding is 0.6%. This report also indicated that surgical teams with great experience in monitoring had a rate of neurologic deficits less than half of the rate of less experienced teams (0.46% vs. 1.04%) [7].

By means of epidurally stimulated and recorded SSEP critical spinal ischemia during thoracoabdominal aortic repair can be detected reliably as could be shown by the group of Stühmeier and Grabitz. Neurologic deficits have to be expected when epidural EP disappear within 15 minutes after aortic crossclamping, when the duration of SSEP loss is more than 40 minutes and when the potential does not recover within 20 minutes after declamping.

With the use of SSEP monitoring the group noticed a reduction of paraplegia from 33% to 10% and a reduction of mortality from 22% to 5%. Although based on historical controls which needs to be evaluated with caution the application of this invasive technique is justified as long as motor evoked potentials that allow direct monitoring of particularly ischemia prone motor pathways cannot be recorded successfully during every procedure under general anaesthesia [4, 6].

In cardiac surgery the use of intraoperative neuromonitoring is evolving. No doubt, the EEG is a sensitive indicator of cerebral functional state during these procedures. But in order to overcome its major shortcoming a lack of specificity (EEG slowing can be a sign of cerebral well-being due to anaesthesia and hypothermia as well as a sign of cerebral impairment due to ischemia) it has to be combined with additional monitoring modalities. In this respect transcranial

Doppler sonography (TCD) and trancranial near infrared spectroscopy (NIRS) offer the chance to detect hazardous conditions like cerebral hypoperfusion, embolization or a serious imbalance between oxygen delivery and consumption during different states of cardiac surgery (Tab. 1). However further investigations have to establish reliable critera for intervention and to evaluate whether neurologic and neuropsychologic outcome can really be improved by such a sophisticated monitoring [3].

Figure 2

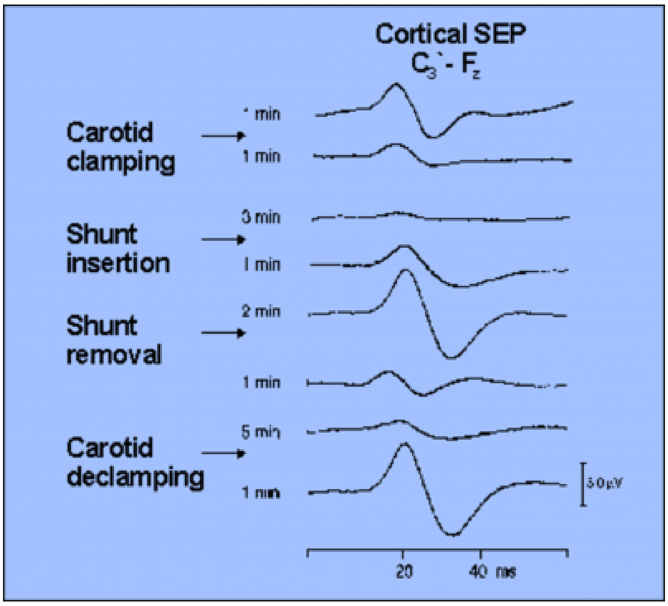
Table 1: Causes of EEG slowing and correct interventions at different stages during cardiac procedures determined by means of body temperature, blood pressure, transcranial Doppler ultrasonography and near infrared spectroscopy.

Time	BT	BP	TCD	rSO_2	Cause	Intervention
Anytime	-	-(↓)	-(↓)	↑	$CMRO_2$↓	Decrease anaesth. level
Cannulation	-	-	↓	↓	Malposition	Reposition
Bypass onset	-	-	-	↓	Hemodilution	Transfusion
Bypass	-	-	Emboli	-	Embolisation	Source?
Bypass	↓	-	-	↑	$CMRO_2$↓	Control BT
Postbypass	↑	-	-	↓	$CMRO_2$↑	Relaxation

Finally neurophysiologic monitoring is effective during carotid artery surgery. Loss of the median nerve evoked cortical SSEP after carotid cross clamping as can be taken from the example is a safe index of critical cerebral hypoperfusion. Sufficient shunt function is just as reliably indicated by SSEP recovery (Fig. 2). We could proof that in a prospective study of meanwhile more than 1800 procedures. The high sensitivity (99-100%) and specificity (84-100%) of SSEP monitoring in detecting clamp related ischemia is confirmed by many other groups [2, 9].

Figure 3

Figure 2: Typical SSEP recording during carotid artery surgery.



SSEP monitoring fitts the essential requirements of a suitable neuromonitor and holds among the clinical available monitors like EEG, TCD and NIRS an outstanding position not only for its ease of application but especially for its high sensitivity and high specifity which offer various advantages (Tab.2) [1, 2,9].

Figure 4

Table 2: Comparison of somatosensory evoked potentials, electroencephalography, carotid stump pressure, transcranial Doppler sonography, jugular bulb oximetry and near infrared spectroscopy during carotid artery surgery for monitoring clamp related ischemia during carotid artery surgery.

Requirement	SSEP	EEG	CSP	TCD	SjO_2	NIRS
Ease of application	+	0	+	-	0	+
Low rate of failure	0	-	+	-	0	+
Continuous monitoring	+	+	-	+	+	+
Ease of interpretation	+	-	+	+	+	+
Unimpeded surgery	+	0	0	-	0	+
No risks	+	+	+	+	+	+
Affordable costs	+	+	+	+	-	0
High sensitivity	+	0	+	0	-	0
High specificity	+	0	-	0	-	-

Requirement: + = fulfilled, 0 = partly fulfilled, - = not fulfilled

The high sensitivity reliably prevents ischemic neurologic deficits.The high specificity minimizes the risks of unnecessary shunt placement. As long as the cortical response can be evoked there is no need for induced hypertension. This facilitates protection of heart and brain. SSEP monitoring enables the surgeon to perform technically perfect surgery without undue haste. Finally the underlying mechanisms of neurologic deficits are identified. A new postoperative neurologic deficit without intraoperative SSEP loss points towards a source of embolism meaning that there is a clear indication for surgical reexploration without further delay.

In summary SSEP recording should be recomended as a routine monitor because it contributes to a comparatively low rate of perioperative strokes (1,3%) in our own group of patients.

This paper was presented at the 23rd Annual Meeting of the European Academy of Anaesthesiology (EAA): Molecular Biology, Ethics and the Future of Anaesthesia Research. August 30 - September 1, 2001, Graz, Austria

References

1. Beese U, Langer H, Lang W, Dinkel M (1998) Comparison of near-infrared spectroscopy and somatosensory evoked potentials for the detection of cerebral ischemia during carotid endarterectomy. Stroke 29:2032-2037
2. Dinkel M (1995) Funktionelles, h□dynamisches und metabolisches Neuromonitoring in der Karotischirurgie. Wissenschaftliche Verlagsabteilung Abbott GmbH, Wiesbaden
3. Edmonds HL, Rodriguez RA, Audenaert SM, Austin EH, Pollock SB, Ganzel BL (1996) The role of neuromonitoring in cardiovascular surgery. J Cardiothorac Vasc Anesth 10:15-23
4. Grabitz K, Sandmann W, St□r K, Mainzer B, Godehardt E, Ohle B, Hartwich U (1996) The risk of ischemic spinal cord injury in patients undergoing graft replacement for thoracoabdominal aortic aneurysms. J Vasc Surg 23:230-240
5. Hemmerling TM, Schurr C, Dern S, Schmidt J, Braun GG, Klein P (2000) Intraoperative elektromyographische Recurrensidentifizierung als Routinema□ahme. Chirurg 71 :545-550
6. Kalkman CJ (1997) Motor Evoked Potentials. Seminars in Anesthesia 16:28-35
7. Nuwer MR, Dawson EG, Carlson LG, Kanim LEA, Sherman JE (1995) Somatosensory evoked potential spinal cord monitoring reduces neurologic deficits after scoliosis surgery: results of a large multicenter survey. Electroencephalography and clinical Neurophysiology 96:6-11
8. Shapiro HM (1986) Anesthesia effects upon cerebral blood flow, cerebral metabolism, electroencephalogram, and evoked potentials. In: Miller RD, Anesthesia; 2nd Ed., pp. 1276
9. Schwarz G., Litscher G (1998) Neuromonitoring in An □hesie und Intensivmedizin. Wissenschaftliche Verlagsabteilung Abbott GmbH, Wiesbaden

Author Information

Michael Dinkel, M.D.
Department of Anaesthesiology , Frankenwaldklinik

Ulrich Beese, M.D.
Department of Anaesthesiology , University of Erlangen-Nuremberg

Michael Messner, M.D.
Department of Anaesthesiology , University of Erlangen-Nuremberg