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The Monitoring of Somatosensory Evoked Potentials and Neurologic Complications in Aneurysm Surgery

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Somatosensory evoked potential (SSEP) changes during cerebral aneurysm surgery and their relationship to postoperative neurologic complications have been studied on many occasions. However, it is still a matter of debate whether SSEP monitoring is really helpful in detecting or preventing neurologic complications. We studied 87 patients undergoing aneurysm surgery of the anterior cerebral circulation and SSEPs were monitored in 60 of these patients. All patients were grade 2 by the subarachnoid hemorrhage (SAH) grading system. Median nerve SSEP was monitored for middle cerebral or internal carotid artery aneurysms and posterior tibial nerve SSEP for anterior cerebral artery aneurysms. A decrease in the cortical amplitude of more than 50%, compared with control, was considered significant and interventions were then taken to reverse the SSEP. The pre- and postoperative neurologic deficits of each patient were evaluated immediately before and after surgery. No significant difference was found in the incidence of postoperative neurologic complications in the SSEP monitored (15% [9/60]) and unmonitored patients (22% [6/27]). In the SSEP monitored patients, the amplitudes of SSEPs decreased significantly in 14 patients and 4 of these showed neurologic complications. However, SSEP amplitudes were not significantly changed in 46 patients, and 5 of these showed neurologic complications. Significant changes in the amplitude of SSEP might represent neuronal injury, but the absence of change in the SSEP cannot guarantee patient safety. Our results suggest that SSEP monitoring may be useful for detecting the danger of neuronal injury, but that it does not reduce the incidence of neurologic complications in aneurysm surgery.

Key Words: Somatosensory evoked potentials, cerebral aneurysm surgery

INTRODUCTION

During cerebral aneurysm surgery, there are many risk factors of brain damage such as direct mechanical injury by surgical instruments, or ischemia caused by vessel occlusion. Somatosensory evoked potentials (SSEPs) have been used to monitor brains at risk of damage.[1-3] Changes of SSEPs during cerebral aneurysm surgery and their relationship to postoperative neurologic deficit have also been studied.[4,5] However, because false positive and false negative rates were relatively high, and most of the deficits were transient or very mild, it remains a matter of debate whether SSEP monitoring is helpful at detecting neurologic complications. Therefore, we designed this study to evaluate the value of SSEP monitoring in terms of detecting postoperative neurologic deficits and the outcome of aneurysm surgery.

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MATERIALS AND METHODS

We studied 87 adult patients that underwent clipping of cerebral aneurysms of the anterior cerebral circulation. Aneurysms located in the posterior circulation were excluded. Whenever the SSEP recorder was available, SSEPs were measured throughout the operations and 60 patients were monitored in total. All patients were categorized as ASA grade I or II, and SAH grade 2 using the subarachnoid hemorrhage grading system as modified by Hunt and Hess.[6]

Anesthesia was induced with fentanyl, thiopental sodium, vecuronium bromide and isoflurane, and maintained with isoflurane (1.2 - 1.4 end-tidal vol% until dural incision, and then 0.8 - 1.0%), 50% oxygen and 50% air. Total fresh gas flow was 2 L/min. Arterial carbon dioxide tension was maintained at 32 - 33 mmHg with alpha-stat management throughout the operation. Thiopental sodium 5 mg/kg was injected intravenously immediately prior to temporary clipping and phenylephrine 0.1 mg was injected intermittently to maintain mean blood pressure at 20 - 25% above the patient's control level.

SSEPs were recorded using a Neuropack 8 (MEB-4200K, Nihon Kohden, Tokyo, Japan). The median nerve SSEP (M-SSEP) was used for the temporary clipping of the internal carotid artery (ICA) or the middle cerebral artery (MCA), and the posterior tibial nerve SSEP (P-SSEP) for the temporary clipping of the anterior cerebral artery (ACA). The median nerve and the posterior tibial nerve were stimulated using a saddle-type of bipolar electrode. The recording electrodes were placed at C3 or C4 for the M-SSEP and at Cz for the P-SSEP. The reference electrode was placed at Fpz according to the international 10 - 20 system. For stimulation, a square wave was applied at 30 mA, for 0.2 msec, at 5 Hz, and 500 responses were averaged to obtain the signal. The amplitude of N20 (the negative peak appearing 20 msec after stimulation) - P23 (the positive peak appearing 23 msec after stimulation) for M-SSEP and the amplitude of P40 - N50 for P-SSEP were measured (Fig. 1 and 2). SSEPs were continuously recorded following the induction of anesthesia (Fig. 3). The average amplitude of SSEPs measured after incision of the dura and cerebrospinal fluid drainage was considered as a control value and more than a 50% decrease in amplitude was considered to be a significant change. If a significant change of SSEP occurred, the surgeon was notified by the anesthesiologist. After notification, brain retraction and/or, temporary or permanent arterial clips were removed if possible and changes of SSEP were observed. If the removal was impossible, blood pressure was elevated further and additional thiopental was administered.

A preoperative neurologic evaluation was performed on the day prior to the operation and postoperative status was evaluated as soon as practically possible after emergence from anesthesia. A newly developed deficit or a worsening of a preoperative deficit was considered as a postoperative neurologic complication. The outcome of surgery was checked at least 3 months after operation, and graded as follows:- good,

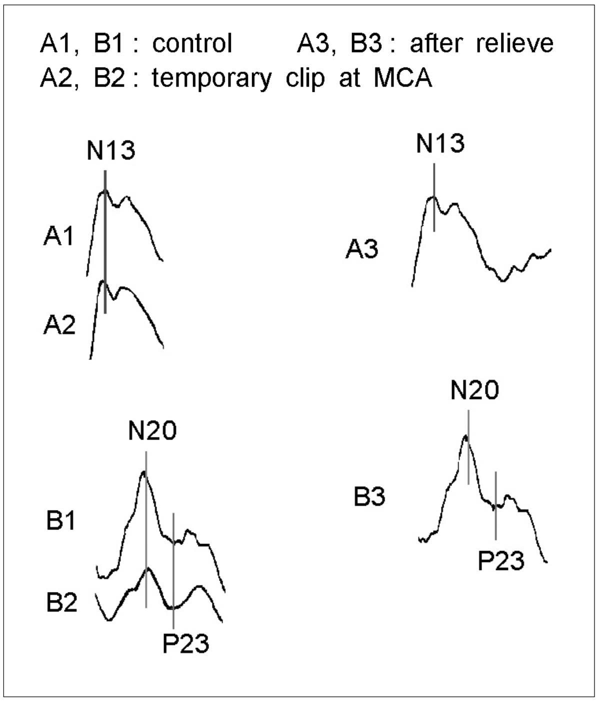

Fig. 1. An example of median nerve SSEP during MCA bifurcation aneurysm surgery. Note the decrease in amplitude between N20 and P23 during the temporary clipping of the MCA. N13 was recorded at the level of the 5th cervical vertebrae.

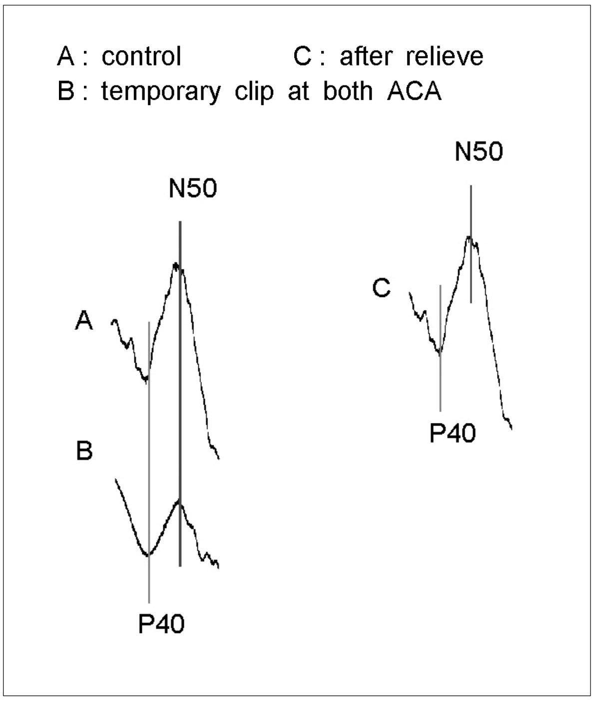

Fig. 2. An example of posterior tibial nerve SSEP during anterior communicating artery aneurysm surgery. Note the decrease in amplitude between P40 and N50 during the temporary clipping at both ACAs.

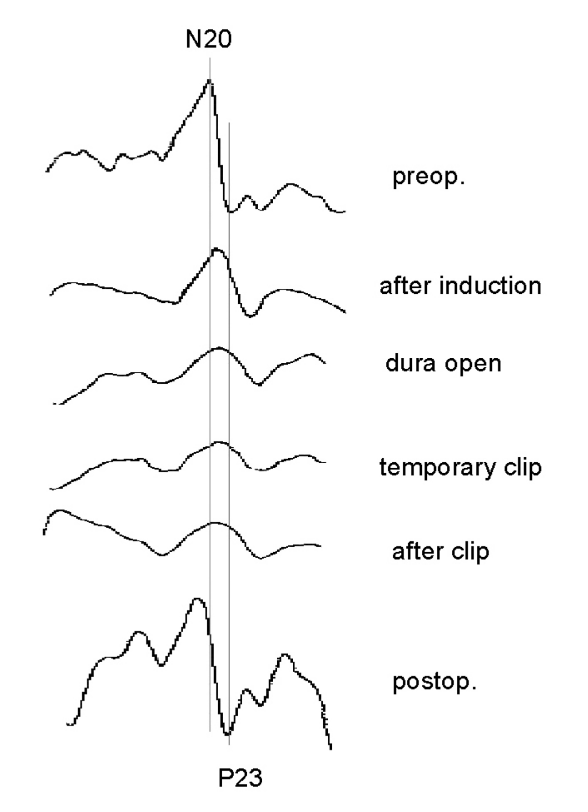

Fig. 3. An example of changes of median nerve SSEP during the perioperative period. Note the decrease in amplitude between N20 and P23 after the opening of the dura mater.

return to normal life without deficit; fair, return to normal life with mild deficit; poor, severe deficit, vegetative state; and death.

Patients baseline data were analyzed using the unpaired Student's *t*-tests. The Chi Square-test was used to compare the postoperative neurologic complication and the outcome of surgery between the SSEP monitored and unmonitored groups, and between the SSEP changed and unchanged groups. A probability value of < 0.05 was considered significant.

RESULTS

Baseline patient characteristics were similar for the two groups (Table 1). 15% of SSEP monitored patients and 22% of SSEP unmonitored patients showed postoperative neurologic complications, but no significant difference was found in the incidences of the two groups (Table 2). In SSEP monitored patients, the amplitude of SSEPs decreased significantly in 14 patients, and 4 of the 14 (29%) showed neurologic complications. The amplitude of SSEPs did not change significantly in 46 patients, and 5 of these patients (11%) showed neurologic complications, but this was not statistically significant (Table 3).

Results obtained on aneurysm and temporary clipping, neurologic complications, SSEP changes

Table 1. Characteristics of Patients

	SSEP	No SSEP
Age	51 ± 9	48 ± 12
Sex (male/female)	25/35	11/16
Number of aneurysms of 1 patient	1.2 ± 0.4	1.1 ± 0.3
Location of aneurysms (ICA/MCA/ACA)	27/10/23	08/07/12
Interval between rupture and surgery (days)	5.5 ± 3.8	5.3 ± 5.1
Duration of temporary clip (minutes)	10.2 ± 5.7	10.8 ± 6.3

Values, except sex and location of aneurysms, are mean ± standard deviation.
ICA, internal carotid artery; MCA, middle cerebral artery; ACA, anterior cerebral artery.

Table 2. SSEP Monitoring and Neurologic Complications of Patients

	No complication	Complication
SSEP-monitored patients	51	9
SSEP-not monitored patients	21	6

The difference in the incidence of neurologic complication in the two groups was not significant.

Table 3. SSEP Changes and Neurologic Complications of Patients

	No complication	Complication
Significant SSEP change	10	4
No or insignificant SSEP change	41	5

Differences were not statistically significant.

Table 4. Neurologic Complication of Individual Patient

Age	Sex	Location	TC Location	TC Duration (min)	Neurologic Complication	SSEP Changes	Final Outcome
47	M	ACOM	Both A1	27.3	Infarction in right frontal lobe, dysphasia	Reversible	Good
51	F	ACOM	L A1	23.5	Lethargic	No change	Good
54	M	R M1	R M1	11.9	Left hemiparesis	Irreversible	Good
61	F	L IC PCOM	L IC PCOM	9.4	Infarction in left frontal lobe	No change	Good
53	M	R IC	R IC PCOM A1 M1	17.5	Left hemiparesis	Reversible	Good
30	M	ACOM	Both A1 A2	13.0	Left frontal lobe swelling, lethargic	Reversible	Good
48	F	L M BIF	L IC A1 M1	9.0	Left hemiparesis, thalamic infarction	No change	Fair
55	F	L IC PCOM	L IC PCOM A1 M1	11.0	Contusional hemorrhage in right frontal lobe	No change	Good
40	F	R IC PCOM	R IC	4.9	Infarction in right frontal lobe, coma	No change	Death
42	F	R IC	R IC	15.0	Right hemiparesis	Unmonitored	Good
61	F	ACOM	Both A1	20.0	Right hemiparesis	Unmonitored	Fair
59	F	ACOM	Both A1	16.4	Infarction in right frontal lobe	Unmonitored	Good
50	M	ACOM	Both A1	20.9	Hemorrhage and infarction in right frontal lobe	Unmonitored	Good
66	F	ACOM	L A1	5.0	Infarction in right parietal lobe	Unmonitored	Good
46	F	R IC PCOM	R IC A1	10.5	Infarction in right internal capsule	Unmonitored	Poor

TC, temporary clip; ACOM, anterior communicating artery; A1, first portion of anterior cerebral artery; L, left; R, right; M1, first portion of middle cerebral artery; IC, internal carotid artery; PCOM, posterior communicating artery; BIF, bifurcation; Reversible, complete recovery of decreased SSEP amplitude to control level; Irreversible, incomplete recovery of decreased SSEP amplitude to control level.

and final outcome are summarized in Table 4.

DISCUSSION

According to our results, 29% of patients, whose SSEP changes were significant, showed neurologic complications, but when there were no or only insignificant SSEP changes, 11% of patients experienced complications. Although no statistically significant difference was found using the Chi Square-test, the odds ratio suggested that SSEP changes are associated with a 2.6 fold increase in the risk of a neurologic complication, which indicates that SSEP monitoring may be useful at detecting the danger of neuronal injury. However, no statistical difference was found in the incidence of neurologic complications of the SSEP monitored and unmonitored patients that received aneurysm surgery. Therefore, the usefulness of SSEP needs to be reconsidered.

M-SSEP is generated by the primary somatosensory cortex, which subserves the arms and receives its blood supply from the MCA. Thus, M-SSEP has been considered to be an useful means of monitoring the ischemic insults associated with cerebral aneurysm surgery, especially during temporary occlusion of the MCA or ICA.[7,8] For the same reason, P-SSEP has been considered to monitor ischemic insults associated with ACA occlusion.[9] However, many reports have indicated that SSEP changes do not always reflect neurologic damage, which suggests that SSEP is incapable of ensuring the adequate surveillance of neurologic complications.

Cortical SSEP is generated by the primary somatosensory cortex, but many strokes which occur during temporary clipping occur in the area of deep perforating arterial branches, which supply the subcortical area.[10,11] Because the vascular distribution of the motor pathway is separated from the sensory pathway at this level, motor pathway damage may not provoke SSEP changes.[12] Even if there is an infarction in the sensory pathway, SSEP may not be affected if the impulse pathway of SSEP is located out of the infarction area. In this study, one patient showed thalamic infarction, but the SSEP did not change (Table 4).

The amount of the cerebral cortex that is monitored by SSEP is very small, and many patients may develop neurologic damage in the absence of SSEP changes. During temporary clipping, the affected area of the brain is supplied by the collateral circulation via the circle of Willis or the extracranial circulation. If the blood supply through the collateral circulation is not even, ischemic damage may occur in some area of brain, as the SSEP monitored area may be well supplied. SSEP changes during temporary clipping do not always indicate neurologic injury. Among those patients that showed significant SSEP changes, postoperative neurologic deficits only occurred in 50 - 60%.[7,8,13] All patients showed neurologic deficits only when SSEP changes did not recover after relieving the temporary clip.[13] According to our data published in non-English journal, only 2 of 18 patients that showed significant SSEP changes developed neurologic deficit.[14] Induced hypertension during temporary clipping may be another factor that affects neurologic outcome. Induced hypertension may enhance more collateral circulation to overcome the neurologic deficit, though it did not reverse the decreased SSEP amplitude. In the rat MCA occlusion model, hypertension induced by phenylephrine reduced the ischemic area of the brain.[15]

SSEPs are mainly used for monitoring sensory pathways during temporary clipping, but temporary clipping may not be the only reason for neurologic complications. All surgical procedures may cause brain injuries and many of these cannot be monitored by SSEPs. If significant changes in the amplitudes of SSEP are observed, this might represent neuronal injury, but in many cases, such changes do not match clinical observations, and even when no change in SSEPs is observed, the safety of patients cannot be guaranteed. Our results suggest that SSEP monitoring may be useful to detect the danger of neuronal injury, but it is questionable if SSEP monitoring can reduce the incidence of neurologic complications in aneurysm surgery. We believe that further studies are needed to elicit the usefulness of SSEP monitoring.

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