Evaluation of Combined Use of Transcranial and Direct Cortical Motor Evoked Potential Monitoring During Unruptured Aneurysm Surgery

Yasushi MOTOYAMA,1 Masahiko KAWAGUCHI,2 Shuichi YAMADA,1 Ichiro NAKAGAWA,1 Fumihiko NISHIMURA,1 Yasuo HIRONAKA,1 Young-Su PARK,1 Hironobu HAYASHI,2 Ryuichi ABE,2 and Hiroyuki NAKASE1

Departments of 1Neurosurgery, and 2Anesthesiology, Nara Medical University, Kashihara, Nara

Abstract

The feasibility and reliability of combined use of transcranial and direct cortical motor evoked potential (MEP) monitoring during unruptured aneurysm surgery were evaluated. Forty-eight patients with unruptured cerebral aneurysms underwent craniotomy and neck clipping accompanied by muscle MEP monitoring. MEPs were elicited successfully by transcranial electrical stimulation in all patients. Direct cortical stimulation elicited MEPs in 44 patients. Reduction in MEP amplitude to less than 50% of baseline was considered significant. No postoperative motor paresis occurred in 39 patients in whom transcranial and direct MEPs remained unchanged. Four patients in whom direct MEPs could not be recorded had no intraoperative abnormality in transcranial MEPs and no postoperative motor dysfunction. Four of the other 5 patients manifested significant transient direct MEP changes without transcranial MEP changes. The transient MEP changes were observed in 3 patients during temporary clipping of the parent artery and in one patient with inadequate clipping of an middle cerebral artery aneurysm, and were considered due to insufficiency of blood flow. Decrease or disappearance of direct MEP waves recovered immediately after re-application of the clip and release of the temporary clip. Direct MEP waves disappeared and did not recover until the end of microsurgical procedures in one patient, although transcranial MEP amplitude remained at less than 50% of baseline. She developed hemiparesis postoperatively, which recovered within 6 hours. The duration of temporary occlusion in patients with direct MEP changes was significantly longer than that in patients without (p < 0.05). Direct MEP was sensitive in detecting ischemic stress to descending motor pathways during aneurysm surgery. Transcranial MEPs could be elicited in patients in whom direct MEPs could not be obtained, and during periods such as craniotomy or after dural closure, in which direct MEPs could not be recorded. These findings suggest that combined transcranial and direct cortical MEP recording may improve the feasibility and reliability of MEP monitoring during unruptured aneurysm surgery.

Key words: motor evoked potential, direct cortical stimulation, transcranial electrical stimulation, cerebral aneurysm, intraoperative monitoring

Introduction

Recent improvements in neuroradiological techniques have resulted in more frequent detection of unruptured aneurysms. Current management of unruptured cerebral aneurysms includes microsurgical clipping, endovascular treatment, and observation. Treatment of unruptured aneurysms should be advocated for patients with lower risk of management-related morbidity. However, careful follow up should be considered on an outpatient basis if the intervention risk outweighs that of observation. Accurate intraoperative monitoring may help to prevent postoperative deterioration. Recent advances in anesthesiology and techniques for stimulation devices have made motor evoked potential (MEP) monitoring possible in patients undergoing surgery under general anesthesia. MEP recording has been introduced to detect ischemic injury to descending motor pathways during aneurysm surgery, and may minimize the incidence of ischemic complications attributable to prolonged temporary occlusion or unexpected perforator occlusion.
Two methods, direct cortical stimulation and transcranial electrical stimulation, are currently used for MEP monitoring. Direct cortical stimulation MEP has recently been shown to have high sensitivity and reliability. Intraoperative changes in MEPs were evaluated by direct electrical stimulation and somatosensory evoked potentials (SEPs) in 56 patients with middle cerebral artery (MCA) aneurysms, showing that MEPs are more reliable than SEPs for the detection of insufficiency of blood flow in the MCA branches and the lenticulostrate artery. However, installation of specially designed grid electrode strips is required in the subdural space to elicit direct MEPs, so subdural adhesions due to previous surgery may cause interference resulting in injury of the bridging veins. In addition, MEPs elicited by direct cortical stimulation can only be recorded during microsurgery, when the brain surface is exposed. In contrast, transcranial MEP can be performed without insertion of grid electrodes on the brain surface and throughout the course of surgery, and is therefore widely used not only in brain surgery but also in spine and aortic surgery. Direct recording of MEPs from the spinal cord (D waves) after transcranial stimulation demonstrated that high-intensity stimulation can activate the corticospinal tract as deep as the pyramidal decussation.

To compensate for the weaknesses of direct MEP, we have used transcranial electrical stimulation combined with direct cortical stimulation to elicit MEPs for intraoperative monitoring. This study evaluated the feasibility and reliability of combined use of transcranial and direct cortical MEP monitoring during unruptured aneurysm surgery.

Materials and Methods

A total of 48 patients with unruptured aneurysms in the anterior circulation were treated and underwent neurophysiological monitoring using both direct and transcranial MEP recording between April 2007 and November 2009. There were 10 male and 38 female patients, aged from 42 to 79 years (mean age 62.1 ± 8.9 yrs, median age 64 yrs, mean age of male patients 58.5 ± 9.2 yrs, mean age of female patients 64.2 ± 4.4 yrs). The aneurysms were located in the internal carotid artery (ICA) (19 patients), the MCA (25 patients), and the anterior cerebral artery (4 patients). No patients had motor paresis preoperatively. Patients with a history of epileptic seizures or implanted devices such as cardiac pacemakers were excluded to allow performance of transcranial electrical stimulation and direct cortical stimulation to elicit MEPs. All protocols were approved by the Nara Medical University Ethics Review Committee, and written informed consent was obtained from each patient.

Anesthesia was standardized for all patients. Anesthesia was induced with a bolus injection of propofol (1–2 mg/kg), fentanyl (2 μg/kg), and vecuronium (0.1 mg/kg) or rocuronium (0.5–0.6 mg/kg), and maintained with 40% oxygen, propofol (2.3–3.0 g/ml of target-controlled infusion), fentanyl (total doses of 0.3–0.5 mg), and remifentanil (0.05–0.2 mcg/kg/min). No muscle relaxant agents were used after induction and intubation. After the trachea was intubated, the lungs were ventilated mechanically to maintain the partial pressure of arterial carbon dioxide between 35 and 40 mmHg. The rectal temperature was maintained between 35.5 and 37.0°C. Physiological monitoring included electrocardiography, intraarterial pressure, oxygen saturation measurement by pulse oximetry, end-tidal carbon dioxide concentration, and rectal temperature.

Transcranial electrical stimulation used a pair of silver-plated discs placed on the scalp at the C3-anode/C4-cathode positions for left hemispheric stimulation and C4-anode/C3-cathode positions for right hemispheric stimulation (according to the International 10–20 Electroencephalography System), with the anode serving as the active electrode. To elicit MEPs, transcranial electrical stimulation was performed using a multipulse stimulator (D-185; Digitimer, Welwyn Garden City, UK). Stimulation intensity was decreased gradually until MEP amplitudes could not be obtained from the ipsilateral abductor pollicis brevis (APB) muscle to determine the threshold voltage. Intraoperatively, stimulation intensity was set at 20 V above the threshold level to ensure that MEPs of at least 50 μV in amplitude could be stably obtained.

Direct cortical stimulation used a grid electrode strip with 16 electrodes (Unique Medical, Tokyo) was inserted into the subdural space after standard front-temporal craniotomy to facilitate electrical stimulation of the hand portion of the motor cortex. The electrode providing the largest MEP amplitude was chosen for stimulation. The placement of the electrodes was guided by the surgeon's understanding of anatomy. The stimulation parameters used for transcranial electrical stimulation were also used for direct cortical stimulation. The contact electrode requiring the lowest stimulation intensity to elicit a contralateral muscle response was chosen for continuous monitoring. The intensity of direct cortical stimulation was initially set at 8 mA and was increased in 1- or 2-mA steps to determine the
th-threshold level. Intraoperatively, the motor cortex was stimulated at 2 mA above the threshold level, but the intensity did not exceed 30 mA. If a motor response was not obtained with the first strip electrode position, the strip was repositioned until a motor response could be obtained.

Compound muscle action potentials were recorded from the skin over the bilateral APB muscles. The ground electrode was placed on the left or right arm proximal to the elbow. Evoked myographic responses were amplified with a 0.3- to 3-kHz band-pass filter and were displayed on oscilloscopes (Neupack; Nihon Kohden, Tokyo). MEP amplitude was defined as the range between the maximum positive and negative peaks of the polyphasic waveforms. The highest value obtained after completion of craniotomy was recorded as the baseline response. The surgeon received a warning when MEPs disappeared or decreased in amplitude to less than 50% of the baseline level over the course of three or more consecutive recordings, since responses produced different amplitudes and waveforms. During microsurgical procedures, MEPs were checked during aneurysm dissection (every 3 to 5 minutes), before temporary and permanent clip applications, and within 15 minutes after such clip applications, mainly by direct cortical stimulation. Transcranial MEPs were also checked repeatedly. Additional recordings were performed every 3 to 5 minutes up to dural closure even after clip application. After removal of the grid electrode for direct MEP, transcranial MEPs were recorded up to skin closure.

Intraoperative findings from operation records in all patients were retrospectively reviewed and the patients in whom temporary clipping was performed were divided into a group with MEP changes and a group without MEP changes. Mean occlusion time of each group was analyzed statistically with Student’s t-test and reported as mean ± standard deviation. p Values <0.05 were considered statistically significant.

Results

Transcranial electrical stimulation was performed in all patients. The mean stimulation intensity required to elicit MEPs from the APB muscle was 210 ± 37.6 V (range 140–250 V). Usually, the responses were recorded as a group of positive and negative deflections. The amplitude and onset latencies of the MEPs were 1025.1 ± 542.2 μV (range 180–1750 μV) and 21.6 ± 1.8 msec (range 19–24.6 msec), respectively. Transcranial MEPs could be recorded from the APB muscle in all patients (Table 1). Transcranial MEPs did not decrease in amplitude to less than 50% of the baseline level during surgery in any patient. Complications including biting injuries of the tongue, and infection at the site of insertion of the needle electrode, but no seizures occurred.

A subdural grid electrode was placed in 46 of the 48 patients, but could not be inserted in 2 patients because of subdural adhesions resulting from previous surgery and an incidental small meningioma of the convexity. Muscle MEPs could be elicited by direct cortical stimulation during surgery in 44 of the 46 patients, and were estimated with the strip electrode not ideally positioned over the motor strip or moved from the correct position due to sinking of the brain with reduction of cerebrospinal fluid volume in 2 patients. MEPs from the APB muscle could be elicited with direct cortical stimulation in 44 of 48 patients. The mean stimulation intensity required to elicit direct MEPs from the APB muscle was 21.7 ± 5.6 mA (range 12 to 30 mA). The mean amplitude and onset latency of the MEPs were 966.4 ± 761.4 μV (200–2240 μV) and 21.9 ± 1.4 msec (19.8–23.9 msec), respectively.

Direct MEP waves disappeared and did not recover until the end of microsurgical procedures in one patient. The waveforms of transcranial MEPs remained at less than 50% of the baseline value. After awaking from anesthesia, the patient developed left hemiparesis (3/5 in severity at the level of the manual muscle testing), but had no neurological deficits within 6 hours (illustrative Case 1). Transient MEP disappearance and/or decrease in MEP amplitude to less than 50% of the baseline level were observed in 4 patients. The transient MEP changes were considered due to insufficiency of blood flow resulting from temporary clipping of the parent ar-

Table 1  Success rate and parameters of motor evoked potential (MEP) recording at baseline

<table>
<thead>
<tr>
<th></th>
<th>Stimulation intensity (mA)</th>
<th>Amplitude (μV)</th>
<th>Latency (msec)</th>
<th>Success rate of recording MEP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
<td>Mean ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>Direct MEP</td>
<td>21.7 ± 5.6</td>
<td>12–30</td>
<td>966.4 ± 761.4</td>
<td>200–2240</td>
</tr>
<tr>
<td>Transcranial MEP</td>
<td>210.3 ± 37.6</td>
<td>140–250</td>
<td>1025.1 ± 542.2</td>
<td>180–1750</td>
</tr>
</tbody>
</table>

SD: standard deviation.

Neurol Med Chir (Tokyo) 51, January, 2011
Table 2 Characteristics of 5 patients in whom the motor evoked potentials (MEPs) disappeared or decreased in amplitude

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)/Sex</th>
<th>Aneurysm location</th>
<th>Direct MEP</th>
<th>Transcranial MEP</th>
<th>Causal procedure</th>
<th>Duration of occlusion (min)</th>
<th>Postoperative motor paresis (MMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43/F</td>
<td>rt MCA</td>
<td>disappeared</td>
<td>normalized</td>
<td>none</td>
<td>temporary + inadequate clip</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>64/F</td>
<td>rt ICA C1, medial large</td>
<td>disappeared</td>
<td>disappeared</td>
<td>40% decrease</td>
<td>temporary trap</td>
<td>10</td>
</tr>
<tr>
<td>33</td>
<td>53/F</td>
<td>lt ICA ophthalmic</td>
<td>50% decrease</td>
<td>normalized</td>
<td>none</td>
<td>temporary clip</td>
<td>8</td>
</tr>
<tr>
<td>38</td>
<td>63/F</td>
<td>lt MCA</td>
<td>50% decrease</td>
<td>normalized</td>
<td>none</td>
<td>temporary clip</td>
<td>6</td>
</tr>
<tr>
<td>42</td>
<td>60/F</td>
<td>rt MCA</td>
<td>disappeared</td>
<td>normalized</td>
<td>none</td>
<td>temporary clip</td>
<td>5</td>
</tr>
</tbody>
</table>


tery in 3 patients and inadequate clipping of an MCA aneurysm in one patient (illustrative Case 1). Temporary clips were applied to the M1 artery in 2 patients and to the ICA in one patient. Decrease or disappearance of direct MEP waves recovered to normal baseline level within 10 minutes after re-application of the clip and release of the temporary clip (Table 2).

Twenty-eight patients underwent standard frontotemporal craniotomy on the right, and the other 20 patients on the left. Aneurysms were approached through the standard pterional route in all 48 patients, and neck clipping was performed for all aneurysms. Obliteration of aneurysms was confirmed by postoperative angiography or three-dimensional computed tomography (CT) angiography. No evidence of hemiparesis on emergence from anesthesia was detected in 47 of 48 patients. Only one patient, in whom temporary trapping of the ICA had continued for over 10 minutes, had transient hemiparesis, which disappeared within 6 hours postoperatively (illustrative Case 2). Other neurological deficits including aphasia, visual field disturbance, and anosmia could not be detected in any patient postoperatively.

Temporary clipping of the parent artery was applied during surgery in 15 of 48 patients, in the M1 portion in 8 patients and in the ICA proximal to the origin of the posterior communicating artery in 5 patients. Temporary clipping was applied to the dominant A1 artery in 2 patients with anterior communicating artery aneurysms. Transient greater than 50% decreases in MEP amplitude were recorded on direct cortical stimulation in 5 of the 15 patients. These changes immediately recovered to normal after release of the temporary clip or reapplication of the clip in all patients except one (illustrative Case 2). These 14 patients did not develop motor paresis postoperatively, regardless of observation of transient MEP changes.

The five patients with greater than 50% decrease in MEP amplitude underwent temporary clipping for 5 to 10 minutes (mean 7.8 ± 2.3 min). The 10 patients without greater than 50% decrease in MEP amplitude underwent temporary clipping for 1.5 to 7 minutes (mean 3 ± 1.58 min). The duration of temporary clipping in the group with MEP change was significantly longer than that in the group without MEP change (p = 0.00035).

Illustrative Cases

Case 1: A 43-year-old woman presented with transient left hemiparesis. Right carotid angiography revealed an aneurysm in the right MCA (Fig. 1A). After craniotomy, the aneurysm was dissected and exposed. First, a temporary clip was applied to the M1 trunk. To reduce tension in the aneurysm, a standard straight clip was applied to the neck of the aneurysm perpendicular to the M2 branch. Five minutes after release of the temporary clip, direct MEP waveforms disappeared completely, although transcranial MEPs remained unchanged. Thorough inspection revealed kinking of the M2 branch (Fig. 1B). The clip applied to the aneurysm neck was removed 10 minutes after application. About 10 minutes after release of the clip applied to the neck, MEPs recovered to within the normal range. Further arachnoid dissection around the MCA and aneurysm was added to provide mobilization of the M2 branches. Then a second L-shaped clip was applied to the aneurysm neck parallel to M2. After confirmation of no flow deficiency around the clipped aneurysm and no abnormal findings on either direct or transcranial MEP recording, the microsurgical procedure was finished (Fig. 2). She recovered from anesthesia without motor deficits. The postoperative course was uneventful.
Fig. 1 Case 1. A: Right carotid angiogram, right anterior oblique view, showing an aneurysm located in the superior trunk of the middle cerebral artery. B: Intraoperative photograph revealing kinking of the M2 branch near the clip (arrow).

Fig. 2 Case 1. Intraoperative direct (left column) and transcranial (right column) motor evoked potential (MEP) findings. Direct MEPs decreased after application of the first clip. After release of the temporary clip, direct MEPs disappeared. Kinking of the M2 branch near the neck was detected. The aneurysm clip was then removed. Ten minutes after removal of the aneurysm clip, direct MEPs recovered. A second clip was applied with care taken to prevent kinking. Transcranial MEPs remained unchanged throughout the procedure.

Fig. 3 Case 2. A: Right carotid angiogram showing an aneurysm projecting medially in the right C2 portion. B: Intraoperative photograph showing the anterior clinoid process and optic canal were drilled out. The aneurysm was occluded using multiple fenestrated clips in tandem fashion under temporary trapping of the internal carotid artery. C: Postoperative right carotid angiogram demonstrating complete obliteration of the aneurysm and patency of the right internal carotid artery.

Discussion

MEPs elicited by stimulation of the medulla oblongata would not be useful in intraoperative monitoring for surgery of intracranial aneurysms. To avoid false-negative findings, adjustment of stimulation intensity is important. Generally the stimulus intensity of transcranial stimulation in spine and aortic surgery is determined at the beginning of MEP recording and is set just supramaximal to each stimulus (approximately 500 V). In this study, the intensity of stimulus was 210 ± 37.6 V (range 140–250 V). Initially we identified the threshold level, at which the MEP waveform was elicited from only the contralateral APB. Then the stimulation intensity was set supra-minimally to stably elicit MEPs of at least 50 μV in amplitude. Use of the weakest electrical stimulation possible allowed monitoring for blood
Fig. 4 Case 2. Intraoperative direct (left column) and transcranial (right column) motor evoked potential (MEP) findings. During the clip application procedure, direct MEPs became impossible to record. The clips applied for trapping were removed 10 minutes from the beginning of internal carotid artery (ICA) occlusion. However, direct MEPs did not recover even though transcranial MEPs remained above 50% of baseline amplitude. Patency of the parent artery and obliteration of the aneurysm were confirmed by both ultrasound sonography and intraoperative angiography. There was no evidence of ICA stenosis or perforating artery occlusion. Microscopic procedures were completed after confirmation of hemostasis. The patient developed left hemiparesis postoperatively. Postoperative computed tomography revealed no new low density areas, and she recovered completely by 6 hours after surgery.

flow insufficiency in the internal capsule.8)

Transcranial MEPs could not be recorded before completion of craniotomy in some cases. The causes of inability to record MEPs, such as overdose of anesthetic agent or electrode disconnection, were all determined and resolved before the intracranial procedure started. Solving such problems did not prolong the time of operation. Finally, transcranial MEPs remained above 50% of baseline amplitude. Patency of the parent artery and obliteration of the aneurysm were confirmed by both ultrasound sonography and intraoperative angiography. There was no evidence of ICA stenosis or perforating artery occlusion. Microscopic procedures were completed after confirmation of hemostasis. The patient developed left hemiparesis postoperatively. Postoperative computed tomography revealed no new low density areas, and she recovered completely by 6 hours after surgery.

The development of subdural grid implanted 4 × 4 electrodes with adequate width has made direct MEP recording feasible.2) Optimally, the strip electrode would be placed parallel to and over the motor cortex. However, the placement of the electrodes in this study was guided by the surgeon’s understanding of anatomy. The electrode providing the largest MEP amplitude for stimulation can be chosen from among the 16 electrodes. Microsurgical procedures can be initiated immediately after positioning of the grid electrode.

In this study, significant changes of MEP were recorded in 5 patients by direct cortical stimulation. The causes of MEP change were temporary clipping and/or inadequate aneurysm clipping resulting in ischemic stress on the descending motor pathway. Temporary clipping of the parent artery of the aneurysm was performed in 15 patients. Mean time of occlusion in five patients with MEP change was significantly longer than that of the other 10 patients without MEP change. Direct MEP did not recover until the procedure was finished in one patient (illustrative Case 2). The time of occlusion of ICA was 10 minutes. For 20 minutes after release of the temporary clip, direct MEP did not recover but transcranial MEP showed less than 50% decrease of amplitude. Micro-Doppler sonography and intraoperative angiography confirmed patency of the ICA and anterior choroidal artery, and transcranial MEP demonstrated waveforms of more than 50% of control level, so we did not release the applied multiple clips. As a result, she had hemiparesis, which recovered 6 hours postoperatively. Such findings of MEP change represent irreversible injury of the corticospinal tract. In this patient, we postulated perforators including the anterior choroidal artery near the large aneurysm might be stressed by distal temporary clipping of the ICA or the multiple clip application procedure.

Many authors have investigated the permissible time of temporary occlusion of the parent artery during aneurysm surgery.6,7,9,10) The general guideline for safe, temporary occlusion of the MCA is occlusion for less than 10 minutes.6) However, development of collateral flow, time and intensity of brain retraction, and sacrifice of veins all influence the tolerance to ischemic stress of the descending motor pathway. Temporarily occluded arteries with perforators have poor tolerance to ischemic stress.9) The MEP could evaluate the actual physiological condition of the corticospinal tract. However, few findings are yet available concerning the relationship between the extent of MEP changes and irreversible ischemic insult or clinical motor dysfunction. Further studies regarding the relationship between MEP changes and motor function are needed.

Our five patients with MEP change included three with aneurysm in the MCA (Table 2). Intraoperative MEP monitoring elicited by direct cortical stimulation is useful during surgery for MCA aneurysm. In our study, MEP changes were detected in the patients with MCA aneurysm by direct cortical stimulation. However, transcranial MEP did not reveal any significant change in these patients.

Direct MEP recording is thought to stimulate a
more superficial site of the corticospinal tract than transcranial MEP recording.\(^\text{13}\) If direct MEP recording can reveal ischemia in both the deep white matter and internal capsule but also the cortex on the brain surface, it should be useful in surgery with usual MCA bifurcation aneurysms in addition to ICA-anterior choroidal artery aneurysms or early MCA aneurysms associated with the lenticulostriate artery. On the other hand, this advantage of direct cortical stimulation is difficult to obtain in surgery for anterior communicating artery aneurysm, because the cortical representation of the leg area is located at the midline and the foot area is hidden in the sagittal plane, so this area is less accessible to strip electrodes, especially through pterional craniotomy. Insertion of the subdural grid electrode is necessary to elicit direct MEPs. We could not insert the grid electrode in 2 patients because of subdural adhesion due to previous surgery and incidental small meningioma. Furthermore, we sometimes encountered unstable changes in direct MEP recording, including abrupt vanishing of waveforms and intermittent changes in amplitude which could not be explained by the surgical procedures used. We considered these findings attributable to disturbance of contact between the brain surface and electrode, and inferred that the cause of this disturbance might have been shift of the electrode caused by sinking of the brain due to cerebrospinal fluid reduction or drying of the superficial arachnoid membrane. This is the reason why waveforms often recovered with repositioning of the electrode or refilling of the subarachnoid space with saline solution from the cranial window. However, we could not obtain reliable MEP waveforms in 2 patients despite these procedures such as saline refilling or electrode repositioning. In our study, the success rate of recording direct MEPs was 91%, which is lower than that of transcranial MEPs (100%).

The advantages of combined use of transcranial and direct MEP monitoring can be summarized as follows. First, the advantages of each method can be obtained, including the feasibility of transcranial MEP and sensitivity of direct MEP recording. Second, simultaneous monitoring can compensate for the disadvantages of the two techniques; MEP can be obtained by transcranial stimulation even in the patients with difficulty to insert subdural grid electrode caused by adhesion due to previous surgery, and superficial ischemia of the cortical branch and transient ischemia due to temporary clipping cannot be detected by transcranial MEP recording but can with direct MEP recording. Third, simultaneous monitoring provides synergy in feasibility and reliability of monitoring. Initial transcranial MEP monitoring can function as pilot monitoring to exclude technical errors such as overdose of anesthetic agent or mistakes in set-up of recording apparatus. Furthermore, after microsurgical procedures, transcranial MEPs can be monitored until skin closure to detect possible delayed complications caused by ischemia due to clip deviation or kinking.\(^\text{13-15}\)

The feasibility and reliability of combined use of transcranial and direct MEP recording were evaluated in 48 patients with unruptured aneurysm. The success rate of MEP monitoring was improved if transcranial MEP was combined with direct MEP. Direct MEP was sensitive to transient ischemic stress on the descending motor pathways. Use of transcranial MEP in addition to direct MEP recording not only yielded secure intraoperative monitoring but also pilot and backup monitoring. These findings suggest that combined transcranial and direct cortical MEP recording may improve the feasibility and reliability of MEP monitoring during unruptured aneurysm surgery.

Acknowledgment

The authors thank T. Takatani and T. Imai for help with preparation, setting up, and assisting in recording of MEPs.

References


Address reprint requests to: Yasushi Motoyama, MD, Department of Neurosurgery, Nara Medical University, 840 Shijo-cho, Kashihara, Nara 634-8522, Japan.

E-mail: myasushi@naramed-u.ac.jp