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Original Article

Predictive Value of Motor Evoked Potential Monitoring during Surgery of Unruptured Anterior Circulation Cerebral Aneurysms

Abstract

Objective and Background: Surgery of unruptured aneurysms is always a great challenge to neurovascular surgeons because no postoperative neurological deficits should be expected postoperatively as the patients are fully asymptomatic before the surgery. Here, we present our experience with selective motor evoked potential (MEP) monitoring of our patients in a 2-year time window. **Patients and Methods:** From 2012 to 2014, 27 patients with unruptured intracranial aneurysms were operated in our institute with the help of MEP monitoring. All patients underwent endoscope-assisted microsurgery with pre- and post-clipping indocyanine green angiography. **Results:** In this period, no mortality was observed, but 18.5% of the patients developed postoperative deficits which showed good recovery in all cases. Overall, MEP showed about 90% accuracy in predicting postoperative deficits. **Conclusions:** MEP as a part of multimodality monitoring of aneurysm surgeries is a valuable tool to improve the outcome. However, we should know its limitations as its results are not always consistent with the outcome.

Keywords: *Brain, clipping, monitoring, motor evoked potential, unruptured aneurysm*

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Introduction

Multimodality monitoring during aneurysm surgery has improved surgical outcome in the last decades.[1,2] Indocyanine green (ICG) videoangiography (VA), intraoperative conventional angiography, neuroendoscopy, Doppler ultrasound, and electrophysiologic monitoring have all been described to check for anatomical or functional abnormalities during the surgery and reduce any possible postoperative complication.[3,4] There are some case series considering some role for motor evoked potential (MEP) monitoring during the surgery and its correlation with the postoperative outcome.[5] However, a more pool of data is required to better clarify sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of MEP changes during aneurysm surgery. In this study, we reviewed patients operated in our department for the past 3 years to understand the predictive role of MEP monitoring in aneurysm surgeries.

Patients and Methods

Profiles of all cases of unruptured cerebral aneurysms operated in our department using intraoperative MEP monitoring from 2012 to 2014 were reviewed retrospectively. Patients' demographic data, site of aneurysm, operation notes, and postoperative morbidities or mortalities were recorded.

Since 2010, all neurovascular surgeries have been performed with OPMI Pentero microscope with INFRARED 800 camera and FLOW 800 software (Carl Zeiss, Oberkochen, Germany) in our hospital. This will help us with intraoperative ICG-VA both before and after clipping and calculate hemodynamic properties of the blood flow in the adjacent vessels. For all patients, we use a rigid endoscope (Machida, Japan) under microscope to check for the exact location of the perforators and their relation to aneurysm as well as the clip before and after its placement. Other technical tips of aneurysm surgery have been discussed elsewhere and are beyond the scope of this paper.[6] One thing worthy to be mentioned here is that although we dissect proximal vessels to aneurysm, we avoid inserting temporary clips as much as possible. Whenever concerned for a disturbed distal blood flow, we use Doppler ultrasound (DVM 4300, Hadeco, Japan) and FLOW 800 software to measure the flow.

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Postoperatively, patients are kept for at least one night in neurosurgical intensive care unit under cardiac and neurological monitoring where any new neurological deficit is evaluated by computed tomography angiography and/or magnetic resonance imaging according to which necessary interventions are performed. Transcranial MEP monitoring of the abductor pollicis brevis, abductor digiti minimi, flexor pollicis brevis, brachioradialis, and/or deltoid muscles in the upper limb and tibialis anterior, abductor hallucis muscle, and/or gastrocnemius muscles in the lower limb is performed when necessary. We do not use MEP monitoring on a regular basis, and it is implemented in patients where aneurysm is surrounded by important perforating arteries to the motor areas (e.g., M1 aneurysms) or in occasions, in which a distal blood flow compromise is likely.

Results

Twenty-seven unruptured aneurysm patients were identified during this period who underwent clip ligation using MEP monitoring. M1 segment of middle cerebral artery (MCA) was the single most common location of the aneurysms for which we used MEP monitoring [Table 1]. Of all cases, new postoperative motor deficits occurred in five patients, but all patients recovered with good functional outcome on their follow-up [Table 2]. Intraoperative MEP monitoring was disturbed in two patients where amplitude decreased in one and was lost in the other one transiently. MEP amplitude recovered in both cases within 10 min after clip adjustment. We did not use temporary clipping in any of these cases. Both patients showed transient postoperative deficits. The other three patients with postoperative deficits had an uneventful surgery with normal MEP waves throughout the surgery. In other words, of twenty-two patients with normal MEP monitoring, three patients developed postoperative new deficits. ICG-VA and endoscopy had normal findings in all cases. This datum translates into 40.0% sensitivity, 100% specificity, 80.0% NPV, 100% PPV, and 88.88% accuracy for MEP findings during surgery to predict postoperative neurological deficits.

Table 1: Distribution of the aneurysms according to their location

Location of the aneurysm	Number of cases (%)
ICA	
IC-Oph	1 (3.7)
IC-PC	4 (14.8)
IC-Ach	4 (14.8)
IC-tip	2 (7.4)
ACA	
ACom	2 (7.4)
Distal ACA	0
MCA	
M1	10 (37.1)
MCA bifurcation	4 (14.8)
Total	27 (100.0)

ACA – Anterior cerebral artery; ACom – Anterior communicating artery; ICA – Internal carotid artery; IC-Ach – Choroidal segment of the internal carotid artery; IC-Oph – Ophthalmic segment of the internal carotid artery; IC-PC – Postcommunicating segment of the internal carotid artery; MCA – Middle cerebral artery; M1 – First division of the middle cerebral artery; IC-tip – Internal carotid-tip

Discussion

Multimodality intraoperative monitoring has helped the surgeons to improve the outcome of the aneurysm patients.[1] Based on the results of intraoperative ICG-VA, endoscopy, and MEP monitoring, the surgeon may decide to change his/her strategy of clipping.[1,7] Despite all the monitoring techniques, a postoperative morbidity is always a real threat which might be explained by distal emboli during vascular manipulation, brain infarction or ischemia due to proximal closure, or damage to the perforating arteries by the temporary or permanent clips. With the addition of MEP, we try to discover some of these subtle changes intraoperatively though we are still not sure if their discovery and timely treatment will improve the outcome.

Utility of the evoked potentials

Irie *et al*. proposed that all anterior choroidal artery (AchA) aneurysms should be monitored by MEP as MEP could predict their neurological outcome very well with limited false-negative (FN) results.[8] In consistent with their findings, all four AchA aneurysms in our series had normal MEP monitoring, and none of them developed postoperative deficits (no FN results). Furthermore, it has been showed that ischemia due to subtle changes in blood flow during AchA coiling not demonstrated on digital subtraction angiography can be detected by MEP monitoring and

Table 2: Characteristics of the cases who developed postoperative neurological deficits

Case	Age/sex	Location	MEP	Postoperative course	Outcome
Case 1	64/female	IC-Oph	NL	Transient paralysis develops in 4 h after surgery	GR
Case 2	44/male	M1	NL	Transient paralysis develops in the day after surgery	GR
Case 3	36/female	M1	NL	Transient paralysis develops in 1 h after the surgery	GR
Case 4	66/female	M1	Amplitude drop	Transient paralysis develops after awakening	GR
Case 5	64/female	M1	Amplitude loss	Transient paralysis develops after awakening	GR

GR – Good recovery; IC-Oph – Ophthalmic segment of the internal carotid artery; MEP – Motor evoked potential; M1 – First division of the middle cerebral artery; NL – Normal reversed by prompt withdrawal of the coils.[9] In another study by Suzuki *et al*., the authors find no FN results with MEP monitoring of the hand muscles, to check for AchA blood flow, to predict any postoperative neurological deficit.[10] Furthermore, they noticed that some transient postoperative deficits might happen after reversible MEP changes whereas permanent MEP changes accompanied severe postoperative plegia. On the other hand, some authors claim that MEP is not sensitive enough to detect all ischemia due to temporary AchA occlusion and advocate awake craniotomy in these patients.[11] However, due to the limited number of cases in their study (only three patients with AchA aneurysms with one FN), these results should be interpreted with cautious and in the context of data pool from other studies. Considering our results and other studies on the whole, we want to underlie the importance of physiologic monitoring for AchA aneurysm surgeries.

Horiuchi *et al*. showed the efficacy of MEP monitoring during MCA aneurysm surgeries where MEP could detect postoperative deficits with good sensitivity.[12] This has been suggested by some case reports that MEP loss has a good predictive value for postoperative subcortical infarction in aneurysms of the MCA.[13] In our series, four of the M1 aneurysms developed postoperative deficits. These findings require special attention: MEP changes were able to predict postoperative deficits in two cases. In the other two patients with normal MEP during the surgery, deficits developed hours after awakening from anesthesia. This indicates a late event such as hypotension or vasospasm which was not present during anesthesia. The same finding was observed in the study by Irie *et al*. where two of their six patients with FN results had late developing of postoperative paresis.[8] This means that "FN" results of MEP are not "truly" FN as ischemia had not happened, most likely, at the time of the operation. In case where the surgeon works closely around the small perforators (e.g., AchA or M1 aneurysms) measures to keep the blood pressure high enough to prevent any late ischemia should be started as soon as securing the aneurysm.

On the other hand, in spite of an uneventful aneurysm clipping, postoperative deficits due to vasospasm of major or perforating arteries may happen. Isolated vasospasm of perforators has been reported which can result in neurological deficits.[14] Unfortunately, most of these spasms happen in the postoperative course which cannot be detected or even predicted by current monitoring facilities. Noticeably, all three patients with FN intraoperative MEPs who showed some postoperative deficits developed their symptoms hours after recovery from anesthesia which further underlies the importance of the vasospasm mechanism. In fact, we should not consider these results as "FN" as the MEP results were correlated with the function of the brain during the operation (patients recovered asymptomatic), and the false results are due to the inability of the MEPs to predict the postoperative vasospasm. Although aggressive medical management of vasospasm is recommended in such scenarios, the final result is usually disappointing without any functional recovery. In case of any change in MEP, prompt action to correct reversible causes such as hypotension or ischemia due to permanent or temporary clipping should be taken.[15]

Accuracy of motor evoked potential in aneurysm surgeries

Abnormal MEP findings during aneurysm surgeries are observed in 5.4%–25% of surgeries.[8,16,17] In a report by Shi *et al*. in 2012, postoperative deficits were observed only in patients who despite therapeutic strategies did not show improvement in their MEP monitoring. All six patients whose MEP changes normalized, even after 40 min, recovered from anesthesia without any deficit.[16] Other authors claimed the same findings that measures to reverse the MEP changes are not associated with any postoperative deficits.[8,15] However, some other studies as well as our results showed that even transient changes in MEP curves for about 6 min could be associated with immediate postoperative deficits.[10,12] It seems that we still require more data, but for the time being, it is advisable to reverse any change in MEP recording as soon as possible and preferably <5 min.[17,18] Permanent loss of MEP is believed to be associated with severe irreversible postoperative ischemia and paralysis.[10,12]

In another study with 64 aneurysm patients, intraoperative MEP changes showed a sensitivity of 100%, specificity of 78.7%, PPV of 18.8%, and NPV of 100%.[17] Although they did not have any FN patient, our results as wells as other studies showed that expecting FN result (i.e., postoperative motor deficits despite normal intraoperative MEP) is a routine rather than an exception[8] (see above). Although there are some concerns that transcranial electrical stimulation (TES) MEP may produce FN results by stimulating subcortical tissues and therefore bypassing the cortical ischemia, its results are not essentially different from direct cortical stimulation technique for aneurysm surgeries.[19] It can be explained by the fact that motor deficits in aneurysm surgeries are mostly due to injuries to the perforators contributing to the subcortical tract, not the main feeders of the cortex. Hence, it seems that TES MEP is an acceptable technique for monitoring of aneurysm surgeries.[19]

Indications of motor evoked potentials

We do not use MEP monitoring for all patients although it has been advocated by some authors.[5] In our experience, we recommend intraoperative MEP monitoring when there is a high risk of distal emboli in the context of atherosclerosis of the parent vessels or when aneurysm is located in proximity to the perforating arteries such as proximal MCA aneurysms. There are reports showing a more difficult clipping and worse outcome for calcified aneurysms.[20,21] As muscle relaxants are not used for anesthesia in patients undergoing MEP monitoring, excessive or nociception-induced movements of the limb may prevent monitoring.[22] However, with proper anesthetic techniques, this problem can be resolved, and we did not find such a problem to prevent monitoring in any of our patients.

Based on the results of our study and current literature, MEP predicts the neurological deficits after anterior circulation aneurysm surgeries with good accuracy. FN results can develop which are usually late onset deficits and most likely due to vasospasms. We still require more data on any certain location of aneurysms to define the sensitivity and specificity of MEP monitoring to predict the functional outcome.

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Conflicts of interest

There are no conflicts of interest.

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