Effectiveness and Limitations of Intraoperative Monitoring with Combined Motor and Somatosensory Evoked Potentials During Surgical Clipping of Unruptured Intracranial Aneurysms

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■ OBJECTIVE: **Postoperative neurologic deficits are one of the devastating complications that can result from surgical clipping of unruptured intracranial aneurysms. Intraoperative monitoring (IOM) of motor and somatosensory evoked potentials (EPs) has been used to reduce neurologic sequelae. We evaluated the effectiveness and limitations of IOM in prevention of surgical complications during aneurysm clipping.**

■ METHODS: **A retrospective analysis was performed, involving 386 operations for 429 unruptured intracranial aneurysms in 386 patients with consecutively collected IOM data.**

■ RESULTS: **Significant EP changes were detected during clipping of 23 aneurysms in 23 patients (5.4% of aneurysms). Among them, 8 patients (accounting for 2.1% of operations and 1.9% of aneurysms) experienced postoperative motor deficits, including 3 permanent and 5 temporary motor deficits with corresponding radiologic lesions. In detecting postoperative motor deficits, the sensitivity and specificity of motor EP monitoring were 0.38 and 0.99, respectively, and those of somatosensory EP monitoring were 0.25 and 0.96, respectively. Seven patients (1.8% of operations) with unchanged EPs had other kinds of postoperative neurologic complications, including altered mentality in 5 cases, motor aphasia in 1, and gaze limitation in 1, with corresponding radiologic abnormalities. However, all 7 patients with other neurologic symptoms recovered within 6 months after surgery.**

■ CONCLUSIONS: **IOM of motor and somatosensory EPs was useful and reliable in predicting and preventing postoperative motor deficits. However, it also showed some limitations in the significance of positive EP changes and detection of neurologic deficits other than motor function.**

INTRODUCTION

Surgical clipping of unruptured intracranial aneurysms (UIAs) is one of the major treatment modalities to eliminate the possibility of rupture and subsequent subarachnoid hemorrhage or, rarely, a mass effect, either of which would lead to catastrophic outcomes. However, despite the recent improvement in microsurgical techniques, ischemic brain injury caused by surgical manipulation remains one of the significant perioperative complications. Considering the 0.25%–1% annual risk of spontaneous aneurysm rupture,[1-3] the perioperative complication rate should be reduced lower than that of the natural course of UIAs to justify preventive aneurysm treatment.

Surgical manipulation carries a substantial risk of brain injury by retraction and compromise of the small perforators and parent arteries.[4,5] To prevent irreversible ischemic damage, early detection of the impending ischemic situations and prompt

Key words
- Clipping
- Intraoperative monitoring
- Postoperative neurologic deficits
- Unruptured intracranial aneurysms

Abbreviations and Acronyms
CT: Computed tomography
EP: Evoked potentials
IOM: Intraoperative monitoring
MCA: Middle cerebral artery
MEPs: Motor evoked potentials
SSEPs: Somatosensory evoked potentials
UIAs: Unruptured intracranial aneurysms

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adjustment of surgical procedures, including relief of the brain retractor, discontinuation of dissection, and removal or repositioning of the aneurysm clips, are important. Intraoperative monitoring (IOM) of parameters such as motor evoked potentials (MEPs) and somatosensory evoked potentials (SSEPs) has recently been used to detect the subsequent change in nerve conduction caused by decreased blood flow and structural injury in the reversible phase and prevent permanent neurologic deficits.[6,7] Previous studies have reported the effectiveness of IOM in aneurysm clipping; however, the numbers of cases are small, and neurologic functions other than motor function are rarely described.[6-13] In this study, we analyzed clinical and neurophysiologic data about the surgical clipping of UIAs to evaluate the effectiveness and limitations of IOM in preventing postoperative neurologic deficits.

METHODS

Patient Selection

With the approval of the institutional board, we reviewed the medical records of 386 patients who underwent surgical clipping for 429 UIAs under MEP and SSEP monitoring from January 2010 to May 2015 in our institute. The numbers of male and female patients were 131 and 255, respectively, with a mean age at surgery of 57.5 ± 9.3 years (range, 27–86 years). The locations of the UIAs were the middle cerebral artery (MCA) for 307 aneurysms (71.6%), the anterior cerebral artery in 83 (19.4%), and the internal carotid artery in 38 (8.8%). The baseline characteristics of the patients and aneurysms are summarized in Table 1.

Table 1. Basal Characteristics of Patients and Aneurysms

Characteristics	Values
Unruptured intracranial aneurysms/patients, n	429/386
Age, years, mean ± standard deviation (range)	57.5 ± 9.3 (27–86)
Male/female, n	131:255
Single/multiple, n	350/36
Right/left/central, n	189:165:74
Locations of aneurysms, n (%)	
Anterior cerebral artery	83 (19.4)
A1	5 (1.2)
Anterior communicating artery	66 (15.4)
A2 and A3	12 (2.8)
Middle cerebral artery	307 (71.6)
M1	34 (7.9)
Bifurcation	265 (61.8)
M2	8 (1.9)
Internal carotid artery	38 (8.8)
Posterior communicating artery	12 (2.8)
Anterior choroidal artery	19 (4.4)
Others	7 (1.6)
Posterior cerebral artery	1 (0.2)

Surgical and Anesthetic Techniques

The surgical approach was decided based on the characteristics of the aneurysms (size, location, and direction) and surrounding structures, the surgeons' preference (J.E.K., H.S.K., and W.S.C.) and the patients' wishes. We used the pterional approach in 280 patients, the supraorbital keyhole approach in 93, and the interhemispheric approach in 13. Surgeons generally used brain retractors to obtain a sufficient surgical field. Temporary clipping was occasionally used in cases with a high risk of intraoperative aneurysm rupture. When significant changes in MEP and SSEP monitoring were detected, we halted the surgical manipulation and promptly made procedural adjustments, including relief of the brain retractor, discontinuation of dissection, and removal or reposition of the aneurysm clips. After the recovery of baseline IOM, we performed subsequent surgical procedures.

Total intravenous general anesthesia was maintained by continuous infusion of propofol (3.5 μg/mL) and remifentanyl (3.5 ng/mL) in the absence of all inhalational agents. A bolus of nondepolarizing muscle relaxant was given during induction and tracheal intubation. No additional neuromuscular junction–blocking agents were administered after induction and tracheal intubation unless the patients woke up from the anesthesia during surgical clipping or seizurelike movement repeated. Thereafter, the baseline values of MEP/SSEP were checked before dural incision and immediately after arachnoid dissection and drainage of the cerebrospinal fluid.

IOM with MEP and SSEP

Multipulse transcranial electric stimulation was produced using a D-185 constant voltage stimulator (Digitimier, Welwyn Garden City, United Kingdom). MEP was produced by a repetitive train of 5 pulses delivered at 300–350 V to 4 sites (Oc1, Oc2, Ocz, and Cz) on the basis of the International 10–20 system of electrode placement. MEP was recorded bilaterally by patch electrodes at the deltoid and thenar muscles for the upper extremities, and the tibialis anterior and abductor hallucis muscles on each side were recorded for the lower extremities. After anesthetic induction and intubation, SSEP and MEP values were checked a few times before skin incision, dural incision, and intracranial vessel manipulation. MEPs were frequently obtained under various circumstances, such as the application of the brain retractor, dissection of arachnoid membrane and aneurysms, before and after the application of temporary and permanent clips, unexpected surgical events (intraoperative aneurysm rupture and vein injury), and after dural closure. Surface stimulating electrodes were positioned over the median nerve of each wrist and the posterior tibial nerve of each ankle. SSEPs in the median nerve were stimulated with a maximum intensity of 18 mA at a frequency of 2.9 Hz. For the posterior tibial nerve, a maximum intensity of 31 mA at 2.9 Hz was applied. One cortical channel was used for evoked potentials (EPs) recording. A significant MEP and SSEP change was defined as a decrease in amplitude of >50% of the baseline value or an increase in latency of >10% of the baseline value.[14]

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