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Significance of multimodal intraoperative monitoring for the posterior cervical spine surgery

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ABSTRACT

Objective: The aim of this study was to evaluate the efficacy of multimodal neurophysiologic intra-operative monitoring (IOM) in a cohort of patients who underwent posterior cervical surgery.
Material and methods: A total 182 patients were included in this study. Multi-modal intraoperative monitoring (MIOM, somatosensory-evoked potentials: SSEP/transcranial motor-evoked potentials: TCe-MEP/spontaneous-electromyography: S-EMG) was performed in a consecutive series of 129 patients and the other 53 patients (control group) did not. We classified all patients into a high-cervical (H-C) operation group or a low-cervical (L-C) operation group, based on the level of the surgery and analyzed respectively.
Results: One hundred-eleven cases (86%) showed true negative results. Fourteen patients (9 cases- H-C operation, 5 cases- L-C operation) met the criteria of neurophysiologic changes during operation. Of these, 10 cases were restored to normal during operation spontaneously (7cases) or with surgical manipulation (all 3 cases were related to H-C operation). All unrestored neurophysiologic cases ($n = 4$) showed new post-operative neurological deficits. Four patients showed neurological deficits without any changes in MIOM (false negative, 3 cases—delayed onset C5 palsy, 1 case—C8 palsy).
Conclusions: Proper application of MIOM may be useful to detect intraoperative neurological injury during the posterior cervical operations and improve surgical outcomes especially in subgroup of H-C operation. However, the efficacy of MIOM may be restricted to detect and prevent the delayed onset C5 palsy.

1. Introduction

Neurophysiologic intra-operative monitoring (IOM) provides an opportunity to assess the functional integrity of the spinal cord, allowing early detection and reversal of neurological deficits. Therefore, IOM has become a routine part of many spine surgeries and its use has been shown to be effective in minimizing neurological deficits in a thoracolumbar deformity surgery. However, its usefulness remains still debatable especially during cervical spine surgery. We have therefore assessed the impact of IOM on neurological outcomes in posterior cervical spinal surgery. Several IOM modalities are currently available for spinal surgeries. Somatosensory-evoked potentials (SSEP), transcranial motor-evoked potentials (TCe-MEP), and spontaneous-electroymyography (S-EMG) are representative IOM modalities. Generally, combined or multimodal IOM (MIOM) is preferred during spine surgery to maximize diagnostic efficacy. The aim of this study was to evaluate the efficacy of multimodal IOM in a cohort of patients who underwent posterior cervical surgery. We also evaluated the risk factors which are related to the significant intra-operative neurophysiological change.

2. Materials and methods

2.1. Study patients

This study was approved by the Institutional Review Board (IRB) of the Catholic University of Korea.

We retrospectively reviewed the collected data of posterior cervical spine surgery. From January 2009 to July 2012, we performed 182 consecutive posterior cervical spine surgeries (M:F = 113:69; age, mean age 58.1 ± 13.9 years) in a single institution. MIOM (TCe-MEP/SSEP/S-EMG) was performed during surgery in a consecutive series of 129 patients (MIOM group). Although we attempted to conduct MIOM in all posterior cervical operations, this was impossible in some cases (non-MIOM group). These situations included

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the absence of a neurophysiologist, an unstable patient who could not endure a total intravenous protocol (TIVA), or the lack of time to coordinate between the surgical team and other counterparts during an emergency situation.

The clinical diagnoses for posterior cervical operations were classified as degenerative (atlantoaxial subluxation, subaxial subluxation, ossification posterior longitudinal ligament, or spondylotic cervical myelopathy) or traumatic (cervical spine fracture or cervical cord injury). Tumor lesions, congenital deformities, and intra-dural pathologies were excluded.

We classified all patients into a high-cervical (H-C) operation group or a low-cervical (L-C) operation group, based on the cervical spine level. The H-C group included cranio-vertebral junction (CVJ) lesions involving the occiput-atlas-axis. L-C operations were subdivided into three smaller groups. The first group is the low cervical long-segment (LL) decompression group, which involved more than three levels of the cervical spine. The second group is the low cervical short segment (LS) decompression group, which involved less than two levels of the cervical spine. Posterior cervical decompression surgery included laminectomy or laminoplasty (LL or LS group). The third group is the low cervical fusion only (FO) group, which did not involve decompression procedures.

Underlying comorbidity (diabetes, vascular disease and hypertension) and age of the patients were analyzed to identify the risk factors of MIOM abnormalities during surgery.

2.2. MIOM and anesthesia protocol

All patients (MIOM group) received general anesthesia based on TIVA with a continuous infusion of propofol (2–4 mg/kg/hr) and remifentanyl (0.25 μg/kg/min) according to pain response. The level of neuromuscular block was monitored by recording the compound muscle action potentials (CMAPs) in response to a train of four stimuli. Anesthesia was maintained with a 50/50 oxygen/nitrous oxide ratio and an intermittent fentanyl bolus was used for intraoperative analgesia. Multiple confounding systemic factors (arterial pressure, body temperature, end-tidal CO2, blood loss, metabolic derangements) were also recorded.

We recorded a baseline SSEP and measured changes every few minutes with a new SSEP recording. Stimulation consisted of trains of five pulses at 200–400 V for supramaximal response using an Eclipse® Neurological Workstation (AXON systems). The duration of each stimulation was 50 μs and the inter-pulse interval was 2 ms. Electrodes are placed on the scalp in accordance with the International 10–20 system, and a needle was placed in the muscles of interest (bilateral trapezius, deltoid, biceps, triceps, flexor hallucis brevis, or abductor digit minimi) based on the structures at risk for corresponding spinal segments.

During the operation, a decrease of more than 50% in amplitude or an increase of more than 10% in latency was defined as an abnormal SSEP neurophysiologic change, and the criteria for abnormal TCe-MEP was defined as a decrease of more than 80%. Spontaneous spike activity and sustained bursting or train activity of S-EMG waves were also defined as neurophysiologic change. We defined neurological events as the new onset of post-operative neurological deficits, or a neurophysiologic change in MIOM during the operation [1].

2.3. Statistical analysis

A true positive result was defined confirmed neurophysiologic change in MIOM along with persistent changes in MIOM and new post-operative neurological deficits. Cases in which MIOM changes persisted without post-operative neurologic deficits were defined as false-positive results. A true negative result occurred when there was no persistent neurophysiologic change in MIOM and patients

Table 1
Demographic and surgical data for all patients.

	MIOM group (n = 129)	Control group (n = 53)	p value
Age (years)	57.8 ± 14	55.5 ± 14.4	0.33
Sex (female/male)	57/72	11/42	<0.01[a]
Traumatic origin (n)	27 (20.9%)	16 (30.2%)	0.18
Degenerative origin (n)	102 (79.1%)	37 (69.8%)	
H-C operation (n)	54 (41.1%)	9 (17%)	<0.01[a]
L-C operation (n)	75 (58.9%)	44 (83%)	
LL vs LS and FO (n)	58 vs 12 and 5	20 vs 11 and 13	<0.01[a]

Abbreviations: LL, low cervical long segments; LS, low cervical short segments; FO, fusion only; vs, versus
[a] Statistically significant.

showed no post-operative neurological deficits. Any case in which persistent neurophysiologic changes in MIOM were not detected during surgery, but new post-operative neurological deficit was found, was defined as a false-negative result. The sensitivity, specificity and positive and negative predictive values were calculated. Data analyses were done using SAS System for Windows V 9.0. A p-value less than 0.05 was considered statistically significant.

3. Results

There was no statistical difference in age between the MIOM group (57.8 ± 14 years) and the non-MIOM group (55.5 ± 14.4 years). In the MIOM group, 54 (41.8%) patients underwent H-C operations (occiput-C1-C2) and 75 (58.2%) patients underwent L-C operations. In the non-MIOM group, nine (17%) patients underwent H-C operations and 44 (83%) patients underwent L-C operations. Statistically, the MIOM group had more H-C operations than the non-MIOM group (P < 0.01). The incidence of traumatic origin was not statistically different between the MIOM and non-MIOM group (P = 0.18) (Table 1).

No patients had post-operative neurologic deficits in the non-MIOM group. 18 patients showed MIOM changes during surgery or postoperative neurological deficit in the MIOM group (Table 2). Of these 18 patients, 14 patients (10.9%, 14/129) met the criteria of neurophysiologic changes during operation. Of these 14 patients, nine cases (16.7%, 9/54) were included in the H-C group and five cases (6.7%, 5/75) were included in the L-C group. Of the patients in the H-C group, four cases showed TCe-MEP changes, four cases showed S-EMG changes, and two cases showed SSEP changes. One case showed Tce-MEP and SSEP change simultaneously. Of the five cases in the L-C group, three cases showed TCe-MEP changes, two cases showed S-EMG changes, and one case showed SSEP changes during operation. One case showed Tce-MEP and SSEP change simultaneously.

Four patients who did not show the neurophysiologic changes during surgery developed cervical fifth nerve (C5) palsy (n = 3) or C8 palsy (n = 1) after surgery in the MIOM group (false negative). Two cases showed delayed C5 palsy weakness (case 9, 18) and the other case presented C5 palsy immediately after the surgery (case 11). The patient with hand grip weakness (case 16) was diagnosed with a C7-T1 fracture and dislocation, and we performed intra-operative reduction of the C7-T1 locked facet and cervico-thoracic fusion (C6-C7-T1-T2).

Four patients who showed persistent neurophysiologic changes during MIOM suffered from postoperative neurological deficits (three patients had C5 palsy, and one patient had hand paresthesia) (true positive). All three patients with C5 palsy showed immediate weakness, and TCe-MEP (cases 12, 17) and EMG (case10) showed persistent signal changes during surgery (Fig. 1). The remainder showed persistent decreased SSEP amplitude during surgery and subsequently presented with post-operative hand paresthesia (case 7).