



Research paper

Multi-channel motor evoked potential monitoring during anterior cervical discectomy and fusion



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ABSTRACT

Objectives: Anterior cervical discectomy and fusion (ACDF) surgery is the most common surgical procedure for the cervical spine with low complication rate. Despite the potential prognostic benefit, intraoperative neurophysiological monitoring (IONM), a method for detecting impending neurological compromise, is not routinely used in ACDF surgery. The present study aimed to identify the potential benefits of monitoring multi-channel motor evoked potentials (MEPs) during ACDF surgery.

Methods: We retrospectively reviewed 200 consecutive patients who received IONM with multi-channel MEPs and somatosensory evoked potentials (SSEPs). On average, 9.2 muscles per patient were evaluated under MEP monitoring.

Results: The rate of MEP change during surgery in the multi-level ACDF group was significantly higher than the single-level group. Two patients from the single-level ACDF group (1.7%) and four patients from the multi-level ACDF group (4.9%) experienced post-operative motor deficits. Multi-channel MEPs monitoring during single and multi-level ACDF surgery demonstrated higher sensitivity, specificity, positive predictive and negative predictive value than SSEP monitoring.

Conclusions: Multi-channel MEP monitoring might be beneficial for the detection of segmental injury as well as long tract injury during single- and multi-level ACDF surgery.

Significance: This is first large scale study to identify the usefulness of multi-channel MEPs in monitoring ACDF surgery.

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1. Introduction

Anterior cervical discectomy and fusion (ACDF) is one of the most common surgical procedures for decompression of spinal cord and roots of the cervical spine with low complication rate (Marawar et al., 2010). Intraoperative neurophysiological monitoring (IONM) is a method employed to determine the likelihood of post-operative motor deficits (Macdonald et al., 2013). However, the rate of IONM usage during ACDF surgery in the United States is as low as 6.9%, possibly due to the limited risk of the surgery (Ney et al., 2015).

Relatively few studies have investigated the influence of IONM on ACDF prognosis. Studies employing the use of IONM techniques, such as somatosensory evoked potentials (SSEPs) have reported no significant correlation with postoperative motor deficits or prognostic outcome (Taunt et al., 2005; Khan et al., 2006; Smith et al., 2007; Cole et al., 2014). Notwithstanding unfavorable results of intraoperative SSEP monitoring, a national study demonstrated that the use of IONM produced a better clinical outcome in low risk spinal procedures that included ACDF surgery (Ney et al., 2015).

Supporting this, a previous study recorded SSEPs and motor evoked potentials (MEPs) from the abductor hallucis, tibialis anterior, and abductor pollicis brevis during ACDF surgery, and demonstrated sensitivity and specificity in the detection of postoperative motor deficits (Xu et al., 2011). Recent studies have provided additional evidence for the usefulness of Multi-channel MEPs (at least 8 muscles) during spinal surgery (Ito et al., 2013), and other studies suggested that MEPs demonstrated greater sensitivity during ACDF

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surgery than SSEPs (Lee et al., 2006; Xu et al., 2011). However, since no previous studies have investigated multi-channel MEPs during ACDF surgery, the current study aims to evaluate the usefulness of multi-channel MEPs monitoring on post-operative motor deficits of ACDF surgery.

2. Methods

2.1. Patients

A consecutive series of 200 ACDF surgeries conducted at Seoul National University Bundang Hospital between June 2012 and October 2015 was retrospectively analyzed. The mean subject age of 200 patients (Male, 123; female, 77) was 53.7 ± 12.6 years. Patients presented with foraminal stenosis ($n = 175$; 87.5%), and severe central canal stenosis ($n = 116$; 58%) (Kang et al., 2011). Almost all patients ($n = 198$, 99%) featured herniated intervertebral discs, while 21% of patients ($n = 42$) demonstrated the combined ossification of posterior longitudinal ligaments. Of these, 59% of patients ($n = 118$) had undergone single level ACDF surgery, while 33.5% ($n = 67$) had received 2-level ACDF surgery. The remaining 15 patients had undergone 3-level ACDF surgery (Table 1). The present study was approved by the Institutional Review Board at Seoul National University Bundang Hospital.

2.2. Anesthesia

To avoid confounding effects in MEP monitoring, a neuromuscular blocker (rocuronium 0.5–1.0 mg/kg) was applied prior to intubation. Pre-medication was 2 mg of midazolam, and intravenous lidocaine (0.3–0.5 mg/kg) was administered for the induction of anesthesia. Total intravenous anesthesia was achieved using propofol (3.0–4.0 $\mu\text{g}/\text{mL}$) and remifentanyl (1.5–4.0 $\mu\text{g}/\text{mL}$) was used to maintain anesthesia. The anesthesiologist maintained end-tidal CO_2 in the normal range throughout surgery.

2.3. Surgical procedures

ACDF surgery involved regions C3–4 to the C7–T1 intervertebral disc. The C5–C6 intervertebral disc was the most common site ($n = 117$) for both single-level ($n = 51$) and multi-level ACDF surgery ($n = 66$). Accordingly, C7–T1 was the least involved site ($n = 9$) for both single-level ($n = 2$) and multi-level ACDF ($n = 7$; Table 1).

2.4. Intraoperative neurophysiological monitoring

2.4.1. Transcranial electrical stimulation

Transcranial electrical stimulation was delivered using needle electrodes inserted at C3 and C4 according to the international 10–20 electrode placement system. The C3 anode and C4 cathode pair was used to stimulate the left hemisphere, and the reverse arrangement was used to stimulate the right hemisphere. Multi-pulse transcranial electrical stimulation was performed using a commercially available IONM electrical stimulator (Xltek protektor 32 IOM system; Natus Medical Inc., Oakville, Canada). Five square-wave stimuli were delivered, with individual pulse durations of 0.05 ms, interstimulus intervals of 1–2 ms, intensity of 250–500 V, 10–1000 Hz filter, and a time base of 100 ms. MEPs were recorded approximately every 10 min in all patients. We checked MEPs before and after discectomy and foraminotomy as well as when surgeons requested.

2.4.2. Multi-channel recording for MEPs

On average, MEPs were recorded in 9.2 muscles per patient in the upper and lower extremities using subdermal needle electrodes. Electrodes were placed in the trapezius (to represent the C4 spinal nerve root), the deltoid and/or biceps brachii (C5 and C6), the triceps brachii (C7), and the abductor pollicis brevis (C8) for the upper extremities. In the lower extremities, MEPs were recorded from the tibialis anterior (TA) and abductor hallucis (AH) muscles. Several muscles were selected in the upper extremity to identify segmental injury as well as long tract injury. The lower extremity muscles (TA and AH) were used to identify corticospinal tract (long tract) injury.

2.4.3. Somatosensory evoked potentials

In order to obtain SSEPs, square-wave electrical pulses of 0.3 ms duration and approximately 10–20 mA intensity were used for the upper extremities at a frequency of 2.31 Hz. Pulses of approximately 20–30 mA intensity were used for the lower extremities at a frequency of 2.31 Hz. Stimulating needle electrodes were placed at the wrist and ankle for the evaluation of the median and tibial nerves, respectively. SSEPs were recorded using scalp electrodes for recording at C3' (2 cm posterior to C3), C4' (2 cm posterior to C4), and Cz' (2 cm posterior to Cz) against a reference electrode at the Fpz. The low pass cut-off filter was 30 Hz, and the high pass filter was 1000 Hz. SSEPs were recorded every 60 s in all patients.

Table 1

Demographics and radiologic findings of the patients.

	Overall ACDF	Single-level ACDF	Multi-level ACDF	p-Value
Number	200	118	82	
Sex (M:F)	123:77	81:37	42:40	<0.05
Age (years \pm SD)	53.7 ± 12.6	53.8 ± 12.6	53.4 ± 12.7	0.76
Extent of surgery				
Single level	118	118		
Two level	67		67	
Three level	15		15	
Radiological finding				
Foraminal stenosis	175	100	75	0.2
Central canal stenosis	195	115	80	0.67
Grade 0 (no stenosis)	5	3	2	
Grade 1	21	14	7	
Grade 2	58	31	27	
Grade 3 (severe stenosis)	116	70	46	
HIVD	198	116	82	0.51
OPLL	42	20	22	0.11

*p-Value between single-level ACDF and multi-level ACDF surgeries.

ACDF = anterior cervical discectomy and fusion; HIVD = herniated intervertebral disc; OPLL = ossifications of posterior longitudinal ligament.

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