

1 Muscle-evoked potentials after electrical stimulation to the brain in patients undergoing spinal
2 surgery are less affected by anesthetic fade with constant-voltage stimulation than with constant-
3 current stimulation

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Abstract

Study Design : A prospective, within-subject study was conducted.

Objective: We aimed to compare the influence of anesthetic fade under maximum stimulation conditions between constant-current and constant-voltage stimulation techniques.

Summary of Background Data: The monitoring of muscle-evoked potentials after electrical stimulation to the brain (Br(E)-M_SEP) is useful for assessing the integrity of spinal cord motor tracts during major spine surgery. Nonetheless, Br(E)-M_SEP responses are known to deteriorate over the duration of surgeries performed under general anesthesia. This phenomenon is known as anesthetic fade.

Methods: We recruited 117 patients undergoing various spinal surgeries from the cervical to the lumbar level. We excluded 29 cases with insufficient data. The decrease rate of the Br(E)-M_SEP amplitude for each muscle was examined. Br(E)-M_SEP monitoring with constant-current and constant-voltage stimulations at the C3 and C4 electrode positions was applied. Compound muscle action potentials (CMAPs) were bilaterally recorded from the abductor pollicis brevis, deltoid, abductor hallucis, tibialis anterior, gastrocnemius, and quadriceps muscles. We defined the decrease rate as follows: $(\text{initial CMAPs} - \text{final CMAPs}) / \text{initial CMAPs} \times 100$. Differences in the decrease rate were evaluated between stimulators, limbs (upper vs lower), and operative time group (lowest quartile vs highest quartile).

Results: The overall decrease rate (across all muscles) increased as the operative time increased, and the rate was higher in the lower limbs than in the upper limbs. In addition, the overall decrease rate was lower with constant-voltage stimulation than with constant-current stimulation. Furthermore, the decrease rate for constant-current stimulation was significantly higher than that for constant-voltage stimulation, regardless of the operative time.

Conclusions: The CMAP waveform with constant-voltage stimulation is less susceptible to anesthetic fade than that with constant-current stimulation, even during long surgeries.

Key Words: Br(E)-M_sEP, anesthetic fade, false positive, spine surgery, constant-current stimulation, constant-voltage stimulation, operative time, spinal cord motor tracts, lower limbs, upper limbs

Key Points (3-5 main points of the article)

- We evaluated anesthetic fade using the decrease rate of compound muscle action potentials (CMAPs).
- We examined the impact of different stimulation methods (constant-current vs constant-voltage) on anesthetic fade.
- CMAP waveform with constant-voltage stimulation is less susceptible to anesthetic fade than is constant-current stimulation, even during long surgeries.

Mini Abstract (50 words)

We examined the impact of different stimulation methods (constant-current vs constant-voltage) on anesthetic fade. The compound muscle action potential waveform with constant-voltage stimulation is less susceptible to anesthetic fade than that with constant-current stimulation, even during long surgeries.

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2 surgery are less affected by anesthetic fade with constant-voltage stimulation than with constant-
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5 **1 Abstract**
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8 **2 Study Design:** A prospective, within-subject study
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11 **3 Objective:** We aimed to compare the influence of anesthetic fade under maximum stimulation
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15 **4** conditions between constant-current and constant-voltage stimulation techniques.
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18 **5 Summary of Background Data:** The monitoring of muscle-evoked potentials after electrical
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21 **6** stimulation to the brain (Br(E)-M_sEP) is useful for assessing the integrity of spinal cord motor
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24 **7** tracts during major spine surgery. Nonetheless, Br(E)-M_sEP responses are known to deteriorate
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27 **8** over the duration of surgeries performed under general anesthesia. This phenomenon is known as
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30 **9** anesthetic fade.
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34 **10 Methods:** We recruited 117 patients undergoing various spinal surgeries from the cervical to the
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37 **11** lumbar level. We excluded 29 cases with insufficient data. The rate of the Br(E)-M_sEP
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40 **12** amplitude's decrease for each muscle was examined. Br(E)-M_sEP monitoring with constant-
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43 **13** current and constant-voltage stimulations at the C3 and C4 electrode positions was applied.
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46 **14** Compound muscle action potentials (CMAPs) were bilaterally recorded from the abductor
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49 **15** pollicis brevis, deltoid, abductor hallucis, tibialis anterior, gastrocnemius, and quadriceps
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52 **16** muscles. We defined the rate of decrease as follows: (initial CMAPs-final CMAPs)/initial
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55 **17** CMAPs×100. Differences in the rate of decrease were evaluated between stimulators (constant-
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58 **18** current vs. constant-voltage), limbs (upper vs. lower), and operative time groups (lowest quartile
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1 vs. highest quartile).

2 **Results:** The overall rate of decrease (across all muscles) increased as the operative time increased,
3 and the rate was higher in the lower limbs than in the upper limbs. In addition, the overall rate of
4 decrease was lower with constant-voltage stimulation than with constant-current stimulation.
5 Furthermore, the rate of decrease for constant-current stimulation was significantly higher than
6 that for constant-voltage stimulation, regardless of the operative time.

7 **Conclusions:** The CMAP waveform with constant-voltage stimulation is less susceptible to
8 anesthetic fade than with constant-current stimulation, even during long surgeries.

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11 **Key Words:** Br(E)-M_sEP, anesthetic fade, false positive, spine surgery, constant-current
12 stimulation, constant-voltage stimulation, operative time, spinal cord motor tracts, lower limbs,
13 upper limbs

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1 **Key Points**

2 • We evaluated anesthetic fade using the rate of decrease of compound muscle action
3 potentials (CMAPs).

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5 • We examined the impact of different stimulation methods (constant-current vs. constant-
6 voltage) on anesthetic fade.

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8 • The CMAP waveform with constant-voltage stimulation is less susceptible to anesthetic
9 fade than with constant-current stimulation, even during long surgeries.

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1 **Mini-abstract**

2 We examined the impact of different stimulation methods (constant-current vs. constant-voltage)
3 on anesthetic fade. The compound muscle action potential waveform with constant-voltage
4 stimulation is less susceptible to anesthetic fade than with constant-current stimulation, even
5 during long surgeries.

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1 Introduction

2 Intraoperative spinal cord monitoring of brain-evoked muscle-action potentials (Br(E)-MsEPs) is
3 widely used to avoid spinal cord injury during spinal surgery. By recording compound muscle
4 action potentials (CMAPs) from the muscles of the upper and lower limbs, Br(E)-MsEPs can be
5 used to monitor motor function.⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾ Performing spinal cord monitoring contributes not only
6 to the safety of surgery, but also to the surgical procedures, providing feedback to the surgeon.

7
8 Although Br(E)-MsEP monitoring has greater sensitivity than somatosensory-evoked potential
9 (SSEP) monitoring for the detection of changes in motor tract integrity during spinal surgery,
10 false positives are abundant.⁽⁵⁾ One cause of false positives is a phenomenon known as
11 “anesthetic fade”, which refers to the gradual decrease in the CMAP waveform over a long
12 period of time.⁽⁶⁾ MacDonald et al. also described this phenomenon as a “potential fade”.⁽⁷⁾ It is
13 critical to understand that gradual fading of muscle Br(E)-MsEP amplitude and threshold
14 increase is normal during stable intravenous or inhalational anesthesia without scalp edema.⁽⁷⁾
15 Lyon et al.⁽⁶⁾ analyzed the relationship between surgical time and Br(E)-MsEP threshold change
16 and reported that waveform attenuation is related to anesthesia time and myelopathy before
17 surgery. In their study, they used constant-voltage stimulation for Br(E)-MsEP monitoring.

1 To date, two types of stimulations have been used to generate Br(E)-M_sEPs, namely, constant-
2 voltage and constant-current. We previously reported that constant-voltage stimulation performs
3 better than constant-current stimulation in terms of the successful evocation of CMAPs.⁽⁸⁾
4 However, there are no reports on whether constant-voltage or constant-current stimulation is
5 more easily influenced by anesthetic fade at the maximum stimulation setting of the stimulation
6 device. Therefore, we aimed to identify the characteristics of anesthetic fade and to compare the
7 influence of anesthetic fade under maximum stimulation between constant-voltage and constant-
8 current stimulation techniques, and determine which stimulation method would better allow
9 continued monitoring that avoided anesthetic fade during long surgeries in terms of 1) the rate of
10 decrease of all muscles; 2) the rate of decrease according to operative time (short vs. long
11 surgeries); and 3) the rate of decrease according to limb (lower vs. upper limbs).

12 **Materials and methods**

13 This prospective, within-subjects study was approved by the local institutional review board. All
14 patients provided informed written consent, in accordance with ethical standards.

15 *Subjects*

16 The potential subject pool comprised 258 patients who underwent elective spine and spinal cord

1 surgeries with Br(E)-M_SEP monitoring between July 2014 and April 2016. Of these, 141 patients
2 declined to participate. In addition, 29 patients did not have sufficient clinical data. Thus, the final
3 study population comprised 88 patients (Fig. 1). The patients (46 male and 42 female) ranged in
4 age from 14 to 85 years (mean, 61 years). The patients had been diagnosed with cervical spinal
5 stenosis (n=15), cervical ossification of the posterior longitudinal ligament (n=3), cervical tumor
6 (n=2), lumbar canal stenosis (n=22), lumbar spondylolisthesis (n=5), lumbar spinal tumor (n=3),
7 thoracic tumor (n=7), scoliosis (n=3), or other spinal disorders (n=28). Preoperative mild to severe
8 motor weakness in any muscle (manual muscle test: 0–3) was present in 8 of the 88 patients (9%).
9 Postoperatively, there was no additional nerve injury in any of the patients.

10
11 The cases were divided according to operative-time quartiles. Cases with an operative time of less
12 than 81 minutes (the lowest quartile, n=22) were classified into the short-time group, and those
13 with an operative time of more 190 minutes (the highest quartile, n=22) were classified into the
14 long-time group (Fig.1).

15 16 *Anesthesia*

17 To minimize the suppressive effects of the anesthetic agents and neuromuscular blockades on
18 Br(E)-M_SEP waveforms, anesthesia was standardized for all patients as follows. No medication

1 was administered before anesthesia. Anesthesia was induced using 2–4 $\mu\text{g}/\text{kg}$ of fentanyl, 0.25–
2 0.5 $\mu\text{g}/[\text{kg}\cdot\text{min}]$ of remifentanyl, and 3.0–5.0 $\mu\text{g}/\text{mL}$ of propofol, administered via a target-
3 controlled infusion pump (TE-371; Terumo, Tokyo, Japan). After induction, tracheal intubation
4 was facilitated using 0.6 mg/kg of rocuronium. Anesthesia was maintained with a regimen of
5 propofol (2.0–3.0 $\mu\text{g}/\text{mL}$), fentanyl, and remifentanyl (0.20–0.5 $\text{g}/[\text{kg}\cdot\text{min}]$), administered via a
6 target-controlled infusion pump. The depth of anesthesia was adjusted to maintain the bispectral
7 index within a range of 40–60. No additional neuromuscular blockades were administered after
8 tracheal intubation to avoid pharmacologic reduction and the disappearance of the Br(E)-M_SEP
9 waveforms. Sugammadex was administered to reverse the profound residual neuromuscular
10 blockade induced by rocuronium only if the ratio of the fourth response to the first response in
11 the train-of-four monitoring at the timing of the control Br(E)-M_SEP recordings did not return to
12 at least 0.80. After the trachea was intubated, the lungs were ventilated mechanically to maintain
13 the partial pressure of end-tidal carbon dioxide level within 30 and 40 mmHg. A mixture of air
14 and oxygen was administered. The rectal temperature was maintained between 35.5°C and
15 37.0°C.

16 17 *Stimulators*

18 The parameters used for each stimulation type are summarized in Table 1. The constant-voltage

1 stimulator was a SEN-4100 (Nihon Kodan, Tokyo, Japan), and the constant current stimulator
2 was an MS-120B (Nihon Kodan). Both constant-voltage and constant-current stimulators were
3 used in all of the patients. In a preliminary study, the authors determined that a 2-minute interval
4 after the Br(E)-M_sEP recording did not affect subsequent responses; therefore, the interval
5 between Br(E)-M_sEP recordings was set at more than 2 minutes. Monophasic stimulation was
6 used, delivered via right-anode and left-cathode stimulating electrodes (Fig. 2). Briefly, a train of
7 five stimulating pulses was delivered at 500 Hz (2-ms interstimulus interval). The stimulating
8 electrodes consisted of a pair of 14.5-mm silver-plated disc electrodes at the C3 (cathode) and C4
9 (anode) locations of the international “10–20” system for the scalp (Fig. 3) and were affixed
10 using conductive paste. The intensity of the transcranial stimulation was determined at the outset
11 of the Br(E)-M_sEP recording, based on previously published data. Accordingly, our devices were
12 set to deliver the maximum stimulus in each case (500 V and 200 mA), which corresponded to
13 the maximum stimulation settings on the devices.

15 *Recording of CMAPs*

16 CMAPs were recorded on the first trial at baseline, after the disappearance of the effect of
17 muscle relaxation. CMAPs were bilaterally recorded from the skin over the abductor pollicis
18 brevis (APB), deltoid (Del), abductor hallucis, tibialis anterior, gastrocnemius, and quadriceps

1 muscles. A ground electrode was placed on the left or right upper limb, proximal to the elbow.

2 An intraoperative Br(E)-M_sEP measurement system (Neuromaster MEE1232, Nihon Kodan)

3 was used to collect CMAP data. When the intraoperative CMAP waveform declined, we checked

4 the blood pressure, depth of anesthesia, and amount of bleeding. When the waveforms deviated

5 from their control levels, we adjusted them with several rounds of stimulation and evaluation to

6 guarantee reproducibility.

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8 The influence of anesthetic fade was evaluated as the decrease rate of CMAPs, which was defined

9 as follows: decrease rate = (initial CMAPs - final CMAPs) / initial CMAPs × 100. If the initial

10 CMAPs could not be measured (i.e. zero μV), the muscle was excluded from analysis. As the

11 decrease rate is measured in the present study, the exclusion of muscles that could not be measured

12 at the initial time is considered to be a non-issue.

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14 *Statistical analysis*

15 All statistical analyses were performed using SPSS version 17.0 (IBM, Chicago, IL, USA).

16 Differences in the decrease rate between constant-voltage and constant-current stimulations

17 (overall and according to upper/lower limbs) were evaluated using the Wilcoxon signed-rank test.

18 Differences in the decrease rate between the long-time and short-time groups and between

1 constant-voltage and constant-current stimulations according to operative time were evaluated
2 using the Mann-Whitney U test. The threshold for statistical significance was set at $p < 0.05$.

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4 **Results**

5 Constant-voltage stimulation demonstrated a lower overall decrease rate (across all muscles) than
6 that for constant-current stimulation ($p < 0.01$) (Table 2). The decrease rate was significantly higher
7 in the long-time group than in the short-time group for both the constant-voltage and constant-
8 current stimulations (Table 3). Furthermore, the decrease rate was significantly lower for constant-
9 voltage stimulation than for constant-current stimulation in both the short-time and long-time
10 groups (Table 2). The decrease rate was significantly higher in the lower limbs than in the upper
11 limbs for both the constant-voltage and constant-current stimulations (Table 5).

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13 **Discussion**

14 The present study demonstrated that, across all muscles, constant-voltage stimulation is less
15 affected by anesthetic fade than constant-current stimulation. In addition, patients with long
16 operative times (the long-time group) were more affected by anesthetic fade than patients with
17 short operative times (the short-time group). Furthermore, it became clear that for both short and
18 long operative times, constant-voltage stimulation is less affected by anesthetic fade than constant-

1 current stimulation. Finally, in either stimulation method, the lower limbs muscles were more
2 affected by anesthetic fade than the upper limbs muscles.

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4 As we mentioned above, anesthetic fade was first reported by Lyon et al.⁽⁶⁾ The authors of this
5 previous study measured the amount of stimulation voltage required to obtain 50 μ V in the CMAP
6 waveform amplitude over time and found that the required stimulation voltage amount increased
7 gradually. Based on this result, the authors considered the suppression of anterior horn cell
8 excitability, accumulation of propofol, etc., as the causes of anesthetic fade with the passage of
9 time.⁽⁶⁾ Macdonald et al.⁽⁷⁾ reported that there is considerable individual variation in anesthetic
10 fade, from little or no fade to substantial fade, threatening false-positive results in practice. An
11 important feature of anesthetic fade is its gradual generalized evolution, which distinguishes this
12 phenomenon from more abrupt focal pathological decrements.⁽⁷⁾ The present study demonstrates
13 that anesthetic fade also differs according to the stimulation method.

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15 Currently, the Spinal Cord Monitoring Working Group of the Japanese Society for Spine Surgery
16 and Related Research recommends designating an alarm point of a 70% decrease in the
17 amplitude for routine spinal cord monitoring.⁽⁹⁾ Although there was no new paralysis after
18 surgery in the present study, we found that the muscles with a CMAP-amplitude decrease of 70%

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5 1 or more due to the influence of anesthetic fade occurred at a rate of 24% for constant-current
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8 2 stimulation and 7% for constant-voltage stimulation (Table 2). Therefore, constant-current
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11 3 stimulation is more likely to cause a false positive due to anesthetic fade than constant-voltage
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14 4 stimulation.

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21 6 Based on the present study results, constant-voltage stimulation appears to be more advantageous
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24 7 than constant-current stimulation for continued monitoring at the maximum stimulation setting of
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27 8 the device, as constant-voltage stimulation is not as easily influenced by anesthetic fade. However,
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30 9 waveform attenuation is observed over time with either stimulation method, and spine surgeons
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33 10 should be aware that it is important to compare the waveforms to those immediately before
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36 11 performing continuous monitoring, in order to prevent Br(E)-M_SEP false positives.

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43 13 The standardization of the degree of stimulation between constant-voltage and constant-current
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46 14 stimulations is difficult. Hausmann et al.⁽⁹⁾ reported that the charge required to record the
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49 15 equivalent amplitude of Br(E)-M_SEP using constant-voltage stimulation is 35% less than that for
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52 16 constant-current stimulation. MacDonald et al. reported that constant-voltage stimulators are now
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55 17 the most commonly used stimulators for Br(E)-M_SEP monitoring.⁽⁷⁾ However, the stimulating
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58 18 current depends on the resistance, which varies according to multiple factors during surgery. Since

1 charge is the most relevant parameter for stimulation, and threshold charge is linearly related to
2 pulse duration, a constant charge design would be logical.⁽¹⁰⁾ However, there is no stimulation
3 method that achieves a constant charge at present. In the present study, we found that the influence
4 of anesthetic fade was less with constant-voltage stimulation than with constant-current
5 stimulation at the maximum stimulation setting of the devices, and that it is possible to successfully
6 continue monitoring with constant-voltage stimulation, even during long surgeries.

7 Maintaining a constant blood concentration of the anesthetic is important when discussing
8 anesthetic fade. In this study, anesthesia was maintained with a regimen of propofol (2.0–3.0
9 $\mu\text{g/mL}$), administered via a target-controlled infusion pump. No significant difference between the
10 target-controlled infusion plasma concentration and the actual measured plasma concentration has
11 been reported.⁽¹¹⁾ ⁽¹²⁾ Thus, the target-controlled infusion concentration and the actual
12 concentration might have a minor difference without a significant clinical impact. Furthermore,
13 the depth of anesthesia was adjusted to maintain the bispectral index within a range of 40 to 60.
14 Liu et al. reported that the concentration of propofol is closely correlated to the bispectral index
15 value.⁽¹³⁾ Therefore, it is believed that the blood concentration of anesthesia can be kept constant
16 by administering propofol with target-controlled infusion and adjusting the bispectral index.

17 There are several reports on the difference in Br(E)-M_sEP amplitude between the upper and
18 lower limbs. MacDonald et al.⁽⁷⁾ reported that the muscle responses in the lower limbs may

1 sometimes be more affected by anesthetic fade than those in the upper limbs. Additionally,
2 Chong et al.⁽¹⁴⁾ evaluated the effect of incremental concentrations of desflurane vis-à-vis
3 sevoflurane on Br(E)-M_sEPs and found that the lower limbs are more sensitive to anesthetic-
4 induced depression than the upper limbs. In the present study, regardless of the stimulation
5 method, we found that the lower limbs were more affected by anesthetic fade than the upper
6 limbs. As there are no previous studies comparing the influence of anesthetic fade on responses
7 in the upper and lower limbs, the present study provides novel and clinically useful data for the
8 spine surgeon.

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10 The present study has several limitations. First, the present analysis did not take into account the
11 muscle weakness before surgery. Lyon et al.⁽⁶⁾ reported that patients with myelopathy have a
12 greater degree of fade than those who are neurologically intact. However, in the present study,
13 we investigated the changes in amplitude for individual cases over time; thus, we do not believe
14 the results would be affected by preoperative paralysis. Second, as there is no universal common
15 definition of anesthetic fade, we employed our own definition. Third, our cases included several
16 types of spinal disorders, which were distributed throughout the entire spinal cord. Furthermore,
17 we did not examine the variation in the amount of bleeding and anesthetic agents. However, we
18 believed that these factors would not significantly affect the observed differences because the

1 interval between the constant-voltage and constant-current stimulations was only 2 minutes.

2 Finally, we chose 500 V and 200 mA as the constant-voltage and constant-current stimulation
3 settings, respectively. Although these settings reflect the maximum stimulation of our devices,
4 whether our results can be generalized to other stimulation settings is unclear.

5

6 **Conclusions**

7 We compared the influence of anesthetic fade on the CMAP waveform between constant-current
8 and constant-voltage stimulations at the maximum stimulation. Although waveform attenuation is
9 observed over time with either stimulation method, the present study revealed that the CMAP
10 waveform with constant-voltage stimulation is less susceptible to anesthetic fade than with
11 constant-current stimulation, even during long surgeries. Spine surgeons should be aware of this
12 anesthetic fade phenomenon in Br(E)-M_sEP monitoring and keep it in mind, recording the CMAP
13 amplitude immediately before each key surgical procedure as a control waveform and comparing
14 it to the waveforms after each procedure in order to avoid anesthetic fade. Finally, based on our
15 results, the use of constant-voltage stimulation may reduce Br(E)-M_sEP false positives during long
16 surgeries.

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1 **Figure legends**

2 Figure 1. Flow diagram of patient enrollment and inclusion

3 The initial pool consisted of 258 patients; data from the final group of 88 individuals was
4 analyzed.

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6 Figure 2. The stimulation condition is depicted and the muscles recorded during the transcranial
7 electrical stimulation of motor-evoked potentials for monophasic stimulation are shown.

8 AH, abductor hallucis; APB, abductor pollicis brevis; Del, deltoid; GC, gastrocnemius; ISI,
9 interstimulus interval; Rt, right; Quad, quadriceps; TA, tibialis anterior

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11 Figure 3. Anatomical locations according to the international 10–20 system

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Tables

Table 1. Stimulation parameters in our hospital

	constant-current	constant-voltage
Stimulus count	5	5
Number of train	1	1
Stimulus interval (ms)	2	2
Stimulus rate (Hz)	500	500
Record time (ms)	100-200	100-200
Stimulus duration time	0.2 msec	50 μ sec
Filter (kHz)	2-3	2-3
Stimulus voltage	200 mA	500 V

Table 2. The decrease rates (%) for the constant-voltage and constant-current stimulations(across all total muscles and each time group). The operative time of short-time group is less than 81 minutes, and that of long-time group is more190 minutes.

Muscle	Number of muscles	Constant-current		Number of muscles	Constant-voltage		p Value
		Median	Interquartile Range		Median	Interquartile Range	
Total muscles	851	26	2 – 67	992	8	-21 – 33	<0.01
Short-time group	191	23	-6 – 57	233	3	-34 – 27	<0.01
Long-time group	230	51	16 – 84	254	22	-6 – 56	<0.01

Table 3. The decrease rates (%) for the long-time and short-time groups

Number of muscles	Short-time group		Number of muscles	Long-time group		p Value
	Median	Interquartile Range		Median	Interquartile Range	
424	11	-20 – 41	484	35	4 – 71	<0.01

Table 4. The decrease rates (%) for the constant-voltage and constant-current stimulations, according to limb (upper and lower limbs)

	Number of muscles	Constant-current		Number of muscles	Constant-voltage		p Value
		Median	Interquartile Range		Median	Interquartile Range	
Short-time group	191	23	-6 – 57	233	3	-34 – 27	<0.01
Long-time group	230	51	16 – 84	254	22	-6 – 56	<0.01

Upper limb=deltoid+abductor pollicis brevis muscles.

Lower limb=quadriceps+tibialis anterior+gastrocnemius+abductor hallucis muscles.

Table 5. The comparison of the number of muscles whose amplitude at final CMAPs was beyond the alarm point (less than 70% of initial CMAPs) between constant-current and constant-voltage

	Number of total muscles	Less than 70% of initial CMAPs		p value
		Number of muscles	Rate(%)	
Constant-current	851	201	24	<0.01
Constant-voltage	992	69	7	

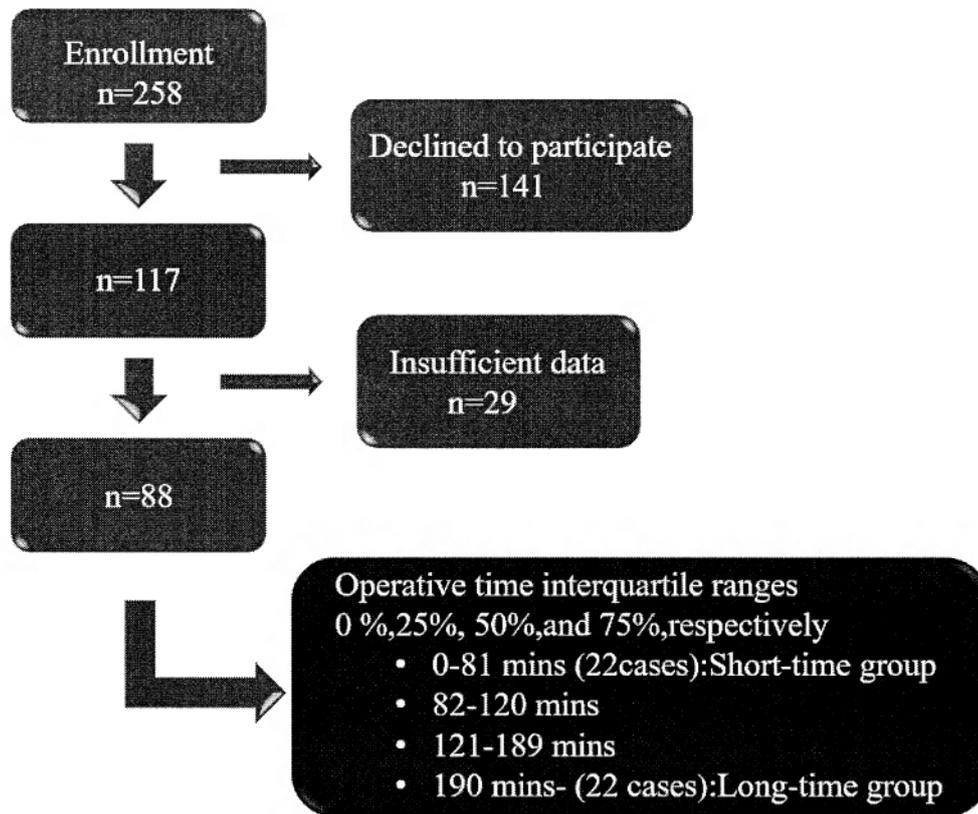


Figure 1. Flow diagram of patient enrollment and inclusion. The initial pool consisted of 258 patients; data from the final group of 88 individuals was analyzed.

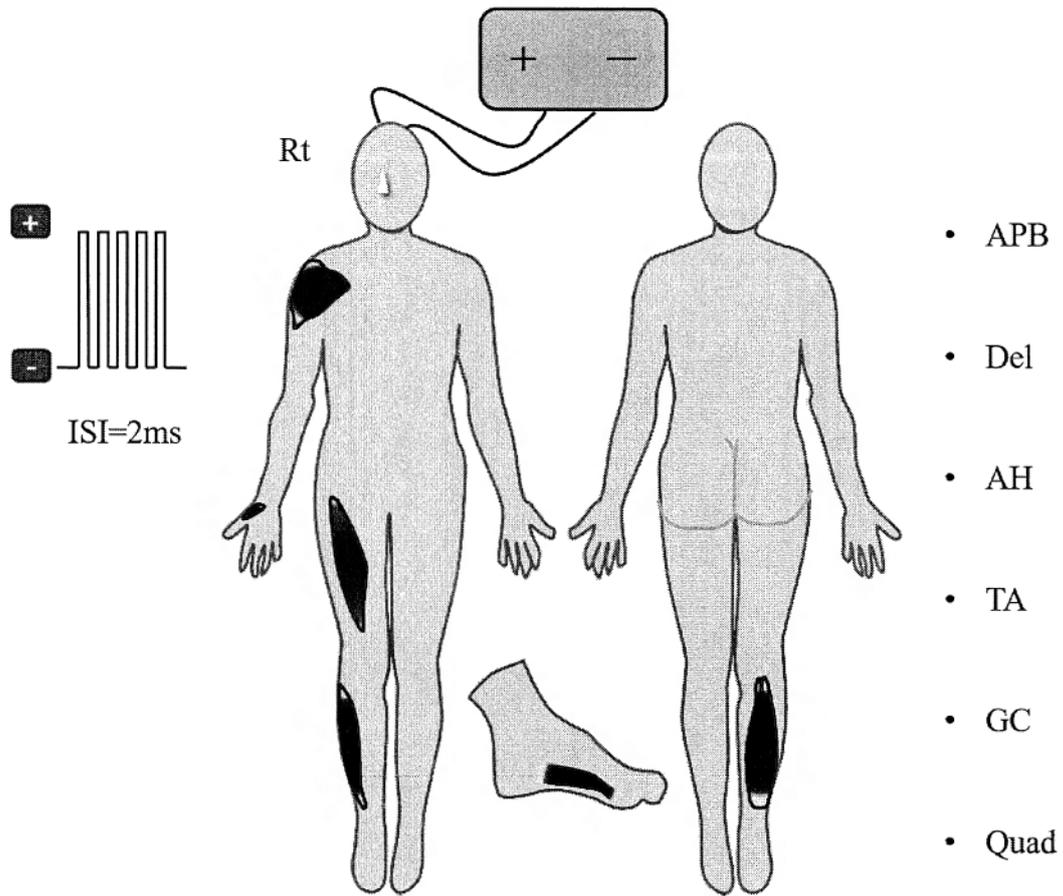


Figure 2. The stimulation condition is depicted and the muscles recorded during the transcranial electrical stimulation of motor-evoked potentials for monophasic stimulation are shown.

AH, abductor hallucis; APB, abductor pollicis brevis; Del, deltoid; GC, gastrocnemius;

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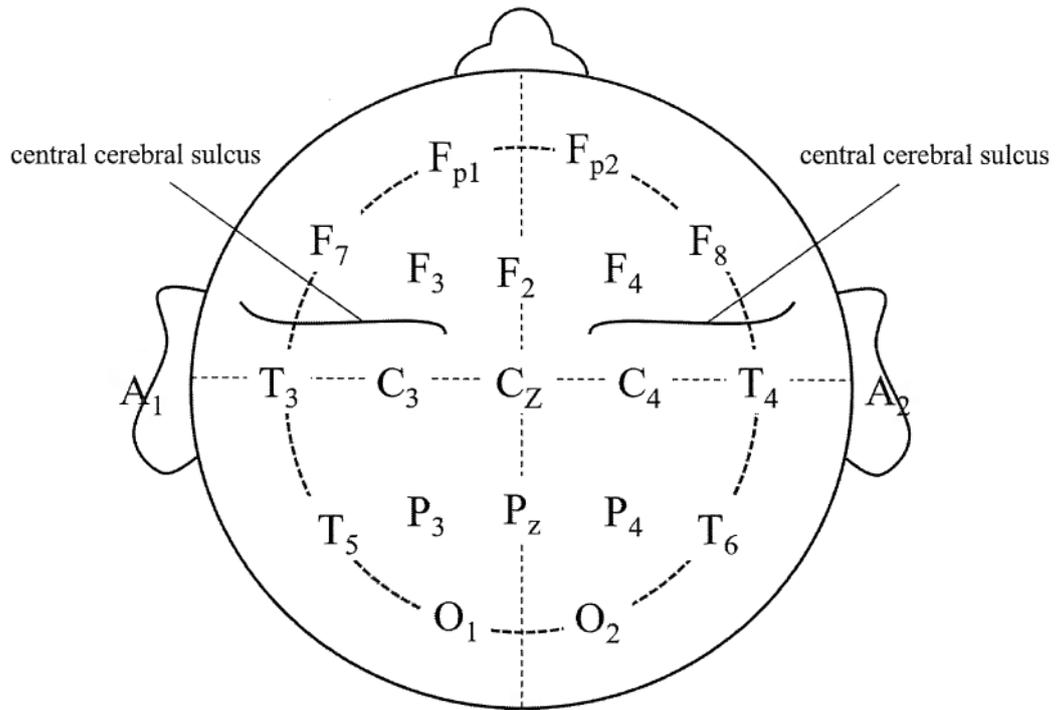


Fig. 3. Anatomical locations according to the international 10–20 system.