Power spectral analysis of the electroencephalogram during induced total spinal block

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Abstract

Purpose. To evaluate the effects of total spinal block (TSB) on brain function, TSB-induced changes in cortical electrical activities were analyzed using power spectral analysis of an electroencephalogram (EEG).

Methods. Six patients suffering from chronic pain who were undergoing TSB therapy were studied. TSB was established with intrathecal 1% lidocaine (0.3ml·kg⁻¹) injected through the C1–2 lateral intervertebral space. Mechanical ventilation was continued via a laryngeal mask until the recovery of respiration. The EEG recording was started before TSB induction and continued until 10min after extubation. The following processed EEG parameters were monitored: spectral edge frequency-90% (SEF90), spectral median frequency (SMF), and relative power in the frequency bands of δ, θ, α, β, and the δ ratio [(α + β)/δ].

Results. TSB induced an unconscious state more than 40min in all patients. During TSB, 12–13Hz in SEF90 and 6–7Hz in SMF were observed. These values are consistent with the previously reported prearousal threshold from general anesthesia. The other EEG descriptors did not change during the TSB-induced unconscious state.

Conclusion. The dissociation of cortical electrical activities and the clinical coma-like condition may be characteristic of the TSB-induced unconscious state.

Key words Total spinal block · Electroencephalogram · Power spectral analysis · Chronic pain

Introduction

Induced total spinal block (TSB) was historically used for anesthesia during surgical procedures in the upper part of the body, including the neck, head, and thorax [1]. Since Tsumura et al. first described the resulting relief of pain in posttraumatic cervical syndrome in 1971 [2], TSB has been applied to relieve various types of neck- or head-related persistent pain that do not respond to conventional pharmacological or nonpharmacological treatment. In general, TSB is induced with the injection of 1%–1.5% mepivacaine or lidocaine at a volume of 0.3–0.4ml·kg⁻¹ into the cervical subarachnoidal space. The injection of the local anesthetic immediately produces a coma-like condition in the patient, so that adequate ventilatory support is necessary until the recovery of consciousness. Although the Ministry of Public Welfare in Japan has accepted TSB as a standard therapy for persistent pain, the underlying mechanism of pain relief in this procedure still remains unclear.

Recent evidence has strongly suggested the supraspinal modulation of pain perception [3–5]. Various clinical interventions that target the central nervous system (CNS) have been reported to relieve intractable pain [6–9]. Since TSB clearly targets supraspinal organs and produces the characteristic “coma-like” unconscious state in patients, we assumed that the impact of TSB on the brain is involved in the mechanism of pain relief. The aim of the present study was, therefore, to evaluate the TSB-induced changes in central nervous activities. To achieve this purpose, we used power spectral analysis of an electroencephalogram (EEG). This analysis has been applied to evaluate the changes in the cortical electrical activities induced by general anesthetics and is reported to have high sensitivity and specificity for the prediction of arousal from anesthesia [10–12].

Patients and methods

After we had obtained the approval of our institutional ethical committee and written informed consent from the patients, six patients (three women and three men, aged 22–52 years) undergoing TSB therapy were enrolled in this study. All of the patients suffered from
chronic pain in various upper body parts, including the head, neck, and limbs. Multiple medications and nerve-blocking interventions applied in our pain clinic provided only limited pain relief. The present intensity of pain in each patient was evaluated by using a visual analog scale (VAS) ranging from 0 (no pain) to 100 (the worst pain imaginable) before TSB induction without any daily medication or intervention. VASs were also recorded a day after TSB and subsequently in the follow-up period.

The patients were premedicated with intramuscular atropine (0.01 mg·kg⁻¹) 30–45 min prior to TSB. An intravenous catheter was inserted into the unaffected forearm vein before the treatment. The patients were placed in the supine position. An electrocardiogram, SpO₂, and noninvasive blood pressure were continuously monitored before the induction of TSB and until the full recovery of the patients. TSB was established with an intrathecal injection of 1% lidocaine at a volume of 0.3ml·kg⁻¹ using a 23-G needle advanced through the C1–2 lateral intervertebral space under X-ray vision. This approach, with a safe access to the subarachnoidal space, has been used for transcutaneus cordotomy [13]. To avoid possible discomfort before the complete loss of consciousness, the patients were given propofol intravenously at the minimal sleeping dose (0.8–1.4 mg·kg⁻¹) simultaneously with the injection of lidocaine. A laryngeal mask was placed immediately after the patients lost consciousness, and artificial ventilation was maintained until the recovery of sufficient spontaneous breathing.

For two-channel continuous recording of the EEG, silver/silver chloride cup electrodes were placed at C3–4 (positive) and A1–2 (negative) against the forehead as a common ground (FPZ), according to the international 10–20 system. The impedance of all electrodes was maintained at less than 3000Ω. The EEG was recorded, analyzed, and stored by a p-EEG monitor system (Dräger, Lübeck, Germany). Bandpass filters were set at 0.5–30Hz, and the amplifier sensitivity was 200μV. On-line power spectral analysis was performed by fast Fourier transformation. The epoch length for EEG acquisition was 2s. The power spectrum was displayed as density spectral array. The following quantitative EEG parameters were generated by the p-EEG system: spectral edge frequency-90% (SEF90), spectral median frequency (SMF), and relative power in the frequency bands of δ (0.5–4Hz), θ (4–8Hz), α (8–13Hz), β (13–30Hz), and the δ-ratio [(α + β)/δ]. The EEG recording was started before the induction of TSB and continued until 10min after the removal of the laryngeal mask. Data from 30 consecutive epochs, excluding artifacts, were averaged in each of the generated parameters at the following time points: before TSB induction; 5, 15, and 30min after the induction; at eye opening; and 5min after extubation.

Data were expressed as means ± SD. The changes in the parameters during TSB were analyzed with repeated-measure analysis of variance (ANOVA), and the Wilcoxon signed-ranks test was used to compare values between each time point. P values less than 0.05 were considered to indicate statistically significance.

Results

The clinical profiles of the six patients are summarized in Table 1. Needle access to the C1–2 intrathecal space was achieved under local anesthesia without serious bleeding or paresthesia in all patients. During TSB, bradycardia (heart rate <50bpm) occurred in four of the six patients close to eye opening. They were successfully treated with intravenous atropine, and no other critical arrhythmia was observed throughout the procedure. Blood pressure and SpO₂ were stable throughout TSB (data not shown). The laryngeal mask was removed when each patient showed a full response to verbal commands. The mean time from the injection of

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age/Sex</th>
<th>Diagnosis</th>
<th>VAS change (pre/post-TSB)</th>
<th>Duration of VAS &lt; 50 (mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25/F</td>
<td>CR</td>
<td>78/8</td>
<td>3</td>
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<tr>
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<td>22/F</td>
<td>UK</td>
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<td>CHD</td>
<td>85/40</td>
<td>8</td>
</tr>
<tr>
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<td>52/M</td>
<td>CRPS I</td>
<td>72/34</td>
<td>0</td>
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<tr>
<td>5</td>
<td>42/M</td>
<td>PTCS</td>
<td>77/21</td>
<td>14b</td>
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<tr>
<td>6</td>
<td>46/F</td>
<td>CRPS I</td>
<td>91/84</td>
<td>NA</td>
</tr>
</tbody>
</table>

CR, Cervical radiculopathy; UK, unknown source; CDH, chronic daily headache; CRPS I, complex regional pain syndrome type I; PTCS, posttraumatic cervical syndrome; NA, not applicable

*Post-TSB VAS is an evaluation on a day after TSB in each patient

bLost to follow-up