Development of classifier for anesthesia depth index using power spectrum analysis of EEG

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Abstract: Monitoring of depth of anesthesia is an ongoing problem in anesthesia. In this paper, using SEF, BDR, BTR parameters which is calculated by power spectral density. EEG data were obtained from 7 patients (ASA I, II) during general anesthesia with sevoflurane. The anesthetic depth evaluation index algorithm was embodied to obtain a quantified index with the scale of 0 ~ 100. Then quantified index could be obtained from the patients under analysis: the average was 86.05, 36.98, 15.33 and 87.72 for the states of pre-operation, induction of anesthesia, operation and post-operation, respectively.

The results show that when evaluating the depth of anesthesia, more quantified information can be provided for anesthesia doctors, rather than depending solely on their subjective evaluation, achieving the effect of establishing safer environment for surgery.

Key-Words: classifier, anesthesia, depth of anesthesia, BDR, BTR, SEF

1 Introduction
Anesthesia aims to eliminate patients awareness of excruciating pain during surgery. Anesthesia is essential to prevent pain or distress in patients. But some patients are inclined to have uncomfortable experience due to the awakening with or without pain during anesthesia. It is indispensable to evaluate the depth of anesthesia during a surgical operation not to be influenced from it. There have been immense researches in medicine, especially in the field of an anesthesia to seek the safe anesthetic level. EEG and esophagus contraction was used for depth of anesthesia. However, objective method has not been developed. Several depth of anesthesia monitors are available, but there is no ideal monitor that is 100% reliable. Therefore, development of standardized index is necessary for discovered in the early awakening.

In this study, we want to develop the depth of anesthesia index using the SEF, BTR, BDR used each frequency power spectrum phases.

2 Method OF Research

2.1 Data Acquisition
After obtaining approval by the ethics committee and informed written consent, we studied 12 ASA 1 or 2 adult patients. We measured the EEG signal of patients who had a short time operation and in inhalation in Gynecology, Pusan national university hospital. We also were approved by them about this experiment. The average age of the patients was 47.7 ± 9.1 years, the average weight was 70.7 ± 10.5 kg. Fig.1 showed To acquiring EEG signal, we used the measurement of bio-signal, that is PhysioLab 400.

Fig. 2 showed the 10-20 system of electrode placement for EEG recording recommended by the International Federation of Societies for Electroencephalography and Clinical Neurophysiology, actual measuring electrode were attached on 3 spots of the frontal, ground and an earlobe reference electrode. The Ag/AgCl electrode, disposable and stick-on electrode to attach effectively, was used for electrode.
2.2 Development of anesthesia depth index

To transform EEG data to the frequency domain using the PSD during operation, the fast Fourier transform (FFT) was performed. The main frequency band concentrated energy among EEG bands is from 1 to 35 Hz. The raw EEG has usually been described in terms of frequency bands: gamma (greater than 30 Hz), beta (13-30 Hz), alpha (8-12 Hz), theta (4-8 Hz), and delta (less than 4 Hz). PSD was calculated at each frequency band. Then we extracted the parameters such as delta ratio, theta ratio, alpha ratio, and beta ratio. The equation is as follows:

\[
\delta \text{ ratio} = \frac{\delta \text{ Power}}{\alpha \text{ Power} + \beta \text{ Power}}
\]

(1)

\[
\theta \text{ ratio} = \frac{\theta \text{ Power}}{\alpha \text{ Power} + \beta \text{ Power}}
\]

(2)

\[
\alpha \text{ ratio} = \frac{\alpha \text{ Power}}{\delta \text{ Power} + \theta \text{ Power}}
\]

(3)

\[
\beta \text{ ratio} = \frac{\beta \text{ Power}}{\delta \text{ Power} + \theta \text{ Power}}
\]

(4)

A various component ratio of EEG energy bands was calculated. In clinical, the EEG includes the characteristic of various signals. In order to analyze this data for estimation of anesthesia index, we find anesthesia parameters and check the parameter's data and compare. Parameters of this study are SEF, BTR, and BFR. We estimated anesthesia depth parameters using these parameters.

SEF, BTR, and BDR obtain expression is shown below.

\[
BTR = \frac{\beta \text{ ratio}}{\theta \text{ ratio}} \times 100
\]

(5)

TP (total power) is amplitude of total PSD of EEG, 95% SEF is the frequency below 95% of the total power.

\[
95\% \text{ SEF} > \frac{TP}{100} \times 95
\]

(6)

BTR showed the correlation between beta ratio and theta ratio.

\[
BDR = \frac{\beta \text{ ratio}}{\delta \text{ ratio}} \times 100
\]

(7)

BDR showed the correlation between beta ratio and delta ratio.

2.3 Depth of Anesthesia Index Classifier

The structure that estimates anesthesia depth using SEF, BTR, BDR showed fig. 3. At first, set the TH1 and TH_1 of SEF. Next set the TH2 and TH_2 of BTR. Finally set the TH3 and TH_3 of BTR. We obtained index value of A, B, and C applied these three phases. In order to calculate final anesthesia depth index, we multiply 40%, 30%, and 30% of App. Ratio values each index value. The depth of anesthesia index consists of 0-100 step value.

3 Result

An algorithm is used to transform EEG data generated from the analysis into the BIS number. The monitor development team recommends certain values to avoid awareness: values between 40 and 60 are suggested by the manufacturer for surgery under general anesthesia. Fig4. and Fig.5 show the analyzed results that use the EEG data of patients in the anesthesia depth index.
classifier. According to anesthesia, we presented the stage anesthesia though consist of pre-operation, induction, operation, awaked and post-operation. Also, we presented the point of significant surgery such as intubation, extubation and incision. We observed the changing condition of the part of anesthesia depth index. In Fig.4, we presented the analysed result of assessment of anesthesia depth index of patient A. In pre-operation and post-operation, the index presented between 80 and 100. In operation described between 0 and 40. In Fig.5 we presented the analysed result of assessment of anesthesia depth index of patient B. In pre-operation and post-operation, the index presented between 80 and 100. In operation described between 0 and 70. In patients A and B were observed the changing condition of anesthesia depth index of surgical operation points such as incision, intubation and blocking anesthesia drugs. Bispectral index of BIS monitor applies the clinical instruments. BIS usually use to know the anesthesia depth index using EEG signals in operation. BIS index provides a reading between 0 (no brain activity) and 100 (the patient is fully awake).

Results of experiment of EEG data obtained from 7 patients appear in Table 1. In pre-operation, It is between maximum index 98.14 and minimum index 72.71. The average is 86.05. In anesthesia induction, it is widely between maximum index 78.96 and minimum index 17.79. The average is 36.98. We think that this phenomenon is complexed data after perfect anesthesia because the EEG measurement time which is within 5 min is so short. In the anesthesia induction, we think also complexed phenomenon about reflex response and compensatory hyperfunction of an autonomic nervous system through the input of drugs and intubation.

In operation, the other words perfect anesthesia, it is between maximum index 41.99 and minimum index 3.37. The average is 15.33. Therefore, in operation, estimate the depth of anesthesia index change is a little wide. But the index which is under 42 can separate other estimate the depth of anesthesia index of anesthesia steps. In awaked, it is between maximum index 75.53 and minimum index 25.13. The average is 50.88. This result of anesthesia induction and each patients is different. But almost similar distribution. This result is influenced by estimate the depth of anesthesia index because anesthetic drugs block and tension of neural-muscle after extubation and reflex response is increase. Also Beta wave of EEG signals increasing is reason. In post-operation, it is between maximum index 98.20 and minimum index 61.45. The average is 87.72. This patient's change aspect is different. But it is almost similar distribution to pre-operation.

### TABLE 1 Result of index extraction depth of anesthesia

<table>
<thead>
<tr>
<th>Pats.</th>
<th>Pre-Op</th>
<th>Ind.</th>
<th>Oper.</th>
<th>Awaked</th>
<th>Post-Op</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>98.14</td>
<td>78.96</td>
<td>10.37</td>
<td>45.69</td>
<td>87.27</td>
</tr>
<tr>
<td>2</td>
<td>85.41</td>
<td>32.27</td>
<td>41.99</td>
<td>75.53</td>
<td>91.71</td>
</tr>
<tr>
<td>3</td>
<td>72.71</td>
<td>26.66</td>
<td>3.37</td>
<td>38.93</td>
<td>97.75</td>
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<td>4</td>
<td>88.57</td>
<td>25.36</td>
<td>5.52</td>
<td>55.70</td>
<td>84.44</td>
</tr>
<tr>
<td>5</td>
<td>73.12</td>
<td>17.79</td>
<td>13.31</td>
<td>51.19</td>
<td>61.43</td>
</tr>
<tr>
<td>6</td>
<td>87.78</td>
<td>33.43</td>
<td>8.75</td>
<td>63.98</td>
<td>93.24</td>
</tr>
<tr>
<td>7</td>
<td>96.61</td>
<td>44.4</td>
<td>14.18</td>
<td>25.13</td>
<td>98.20</td>
</tr>
<tr>
<td>Avg.</td>
<td>86.05</td>
<td>36.98</td>
<td>15.33</td>
<td>50.88</td>
<td>87.72</td>
</tr>
</tbody>
</table>

### 4 Conclusion

We insert parameters of SEF, BTR, BDR into the estimated depth of anesthesia index and find estimated depth of anesthesia index each anesthesia steps. We implement the analyzer of the estimated depth of anesthesia index using 0-100 steps. For verifying analyzer of the estimated depth of anesthesia index, we found the estimated depth of anesthesia index each steps using EEG signals that obtained by 7 subjects. The result average of...
pre-operation is 86.05. In post-operation, the average is 87.72 and 36.98 in anesthesia induction and 15.33 in operation and 50.88 in the recovery of anesthesia. If index value is over 80 by the estimated depth of anesthesia index analyzer, we can think awakening. In operation index is around 10–20 and around 25–40 in anesthesia induction and around 25–70 in the recovery of anesthesia.

References: