Development of BDR and BTR on depth of anesthesia using power spectrum density analysis

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Abstract—In this paper, new parameters were developed to estimate the depth of anesthesia during a general anesthesia using EEG. Power spectral density(PSD) analysis was used for these parameters because EEG became slow wave during anesthesia. The new parameters were DTR, ATR, TDR, ADR, BTR and BDR applied to PSD. These parameters were compared with SEF which is conventionally used at clinic and confirmed clinical value.

As the results, DTR, ATR, TDR, ADR among parameters were not useful compared with SEF but BTR and BDR is valuable for clinic.

For 10 patents, at pre-operation BDR the value is 265.36 ± 25.29, at induction the value is 129.23 ± 34.92, at operation the value is 154.99 ± 38.34, at awaked the value is 283.83 ± 39.80 and at post-operation the value is 234.80 ± 23.46. Also at pre-operation BTR value is 183.38 ± 13.59, at induction the value is 104.09 ± 25.11, at operation the value is 115.38 ± 23.42, at awaked the value is 190.33 ± 23.31 and at post-operation the value is 172.38 ± 19.08.

Trend of BDR and BTR is similar to change of SEF, so two parameters are useful to estimate the depth of anesthesia.

Key-Words: -Anesthesia, Depth of anesthesia, EEG

1 Introduction
The anesthesia is composed of unconsciousness, analgesia (pain relief), amnesia (loss of memory) and immobilization. Adequate anesthesia is that become insensitive on outside stimulus and non-memory or unconsciousness and maintains vital signs of steady state[1]. And also that can be applied to appropriate state result from enough relaxation of muscle. For these, it is essential to not only estimation of objective depth of anesthesia but also thermodynamics monitor such as blood pressure, pulse and muscle relaxation. Also, anesthesia is essential to prevent pain or distress in patients[2]. 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 an 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, esophagus contraction, auditory evoked potential(AEP) and spectral edge frequency (SEF) was used for depth of anesthesia. BIS from EEG reflected depth of anesthesia in inhalation and vein anesthesia. However, objective method has not been developed[3-5].

In this paper, we intend to develop the new index using PSD of EEG signal. Because the signal become slow wave according to deeper anesthesia, distribution of PSD is changed.

2 Method of research

2.1 Subjects and Methods
Subjects were included after giving informed written consent. The patients consisted of 10 females ranging in age from 37 to 64 years (mean 47.7 years). All subjects were in ASA class I or II. Exclusion criteria included a known pre-existing or current neurological deficit, pregnancy, use of beta-blockers or psychotropic drugs or allergy to anesthetic drugs.

Patients were premeditated with glycopyrrolate 0.004 mg/kg and midaxolam 0.05 mg/kg roughly 30 minutes preoperatively.

The stage anesthesia is classified into 5 stages in which there are the Pre-operation, Induction, Operation, Awaked and Post-operation stage respectively. Anesthesia during the operation was progressed in accordance with an oral command of attending
anesthetist. Measurement of EEG was acquired and the process of anesthesia was recorded simultaneously. EEG recording of Pre-operation must be acquired immediately after patient’s arriving at the operating room. But it is reasonable to treat the time just after arriving at the operation room as the induction stage of anesthesia which is usually within 5 minutes. Only a few data can be obtained within short period because of an apparent limitation of time.

As a whole, the induction for operation starts immediately after patient is carried to the operating room. It is difficult to acquire the reliable EEG data due to pre-medication. For this reason, Pre-operation data was acquired in the previous day before operation day.

Induction stage is just before intubation, Operation stage is from the end of induction to Awaked stage. Awaked stage is from the end of an input of drugs. For patients at the stage of Post-operation, the data was acquired in the next day after operating because of disturbing factors such as a hand trembling at recovery stage.

To acquiring EEG signal, we used the measurement of bio-signal, that is PhysioLab 400, PhysioLab Co., KOREA. EEG signal was amplified to 100K and used 35Hz low-pass filter, 1Hz high-pass filter and 60Hz notch filter. Sampling rate is 256 Hz and the signal was quantized to 12 bit.

The Ag/AgCl electrode, disposable and stick-on electrode to attach effectively, was used for electrode. According to 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 name 10-20 indicates that the electrodes along the midline are placed at 10, 20, 20, 20, 20 and 10% of the total nasion-inion distance: the other series of electrodes are also placed at similar fractional distances of the corresponding reference distance. The inter-electrode distances are equal along any anterior-posterior or transverse line, and electrode positioning is symmetrical.

2.2 Analysis method
The preprocessing such as base line correction and linear detrend widely used in biomedical signal processing was used for measured brain wave. Base line correction was utilized to eliminate the offset voltage included in the measured signal. On the other hand, linear detrend was used to remove the increasing or decreasing signal values due to the changing resistance resulting from the long term attachment of the electrode and the perspiration. After preprocessing, power spectrum density (PSD) analysis was used to extracting useful parameters. The parameters were SEF, ADR, TDR, ATR, DTR, BDR and BTR. These are compared with each stage and analyzed.

To transform EEG data to frequency domain using the PSD during operation, fast fourier transform (FFT) was performed.

Main frequency band concentrated energy among EEG bands is from 1 to 35Hz. A various component ratio of EEG energy bands was calculated.

Estimation parameter at clinic was 95% SEF appearing the sedation and MF. SEF and MF was calculated as follow equation.

\[ 95\%\; SEF > \frac{TP}{100} \times 95 \]  
\[ MF > \frac{TP}{100} \times 50 \]  

Here, TP(total power) is amplitude of total PSD of EEG, 95% SEF is the frequency below 95% of the total power, MF is the frequency of 50% of the total power.

The raw EEG has usually been described in terms of frequency bands: gamma greater than 30(Hz), beta (13-30Hz), alpha (8-12 Hz), theta (4-8 Hz), and delta(less than 4 Hz). PSD was calculated at each frequency bands. And then we extracted the parameters such as delta ratio, theta ratio, alpha ratio and beta ratio. The equation is as follow.

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

We extracted the new parameters using these parameters. The equation is as follow.

\[ DTR = \frac{\delta \; ratio}{\theta \; ratio} \times 100 \]  
\[ ATR = \frac{\alpha \; ratio}{\theta \; ratio} \times 100 \]
Here, DTR showed the correlation between delta ratio and theta ratio, ATR showed the correlation between alpha ratio and theta ratio, BTR showed the correlation between beta ratio and theta ratio, TDR showed the correlation between theta ratio and delta ratio, ADR showed the correlation between alpha ratio and delta ratio and BDR showed the correlation between beta ratio and delta ratio.

3 Result

Epoch of analysis of EEG data was 10 seconds during operation and 5 seconds data was overlapped. PSD was calculated using EEG of 10 seconds. DTR, ATR, BTR, TDR, ADR, BDR were calculated and then compared with SEF which is used in clinic.

Fig. 1. Trajectory of the SEF variation of patient A.

Fig.1 showed the result of SEF on patient A. This showed SEF value according to time. And also 5 stages of anesthesia were marked on the figure.

Fig. 2. Trajectory of the ADR, TDR, ATR and DTR variation of patient A.

Fig. 2 showed ADR, TDR, ATR, DTR of patient A.

Fig. 3. Trajectory of the BDR and BTR variation of patient A.

Fig. 3 and Fig. 4 showed BDR and BTR of patient A and B.

Fig. 4. Trajectory of the BDR and BTR variation of patient B.

As you know from Fig. 1 to Fig. 4, there is not significance in ADR, TDR, ATR, DTR, but BDR and BTR have.

So BDR and BTR were calculated on 10 patients and compared with SEF.

Fig. 5. The trend of SEF at each anesthesia stages.

SEF appeared in Fig. 5.
4 Discussion

At Fig. 5, SEF value had below 30 at Induction, Operation and Awaked which were affected by anesthetic drugs. Induction and Awaked stage had about half value of Operation stage. Operation stage was complete anesthetic state and Induction and Awaked states were progressed toward anesthetic state. As a result, SEF well reflected anesthetic state, so it was used in clinic. BTR parameter was showed in Fig. 6. At Induction stage BTR had lower value than Operation stage and at Awaked, BTR had higher value than Post-operation stage different from SEF. That result from PSD of beta component, that is, at Induction stage beta component was suddenly decreased and at awaked stage affected the increase of muscle tension and reflection response beta component was dramatically increased. In SEF, the variation is 13% from 30.73 at Pre-operation to 26.91 at induction and is 20% from 24.64 at Operation to 29.59 at Awaked. However, in BTR, the variation is 43% from 183.38 at Pre-operation to 204.09 at induction and is 64% from 115.38 at Operation to 190.33 at Awaked. So we can say that BTR reflected anesthet stage better than SEF. BDR parameter was showed in Fig. 7. At Induction stage BDR had lower value than Operation stage and at Awaked, BTR had higher value than Post-operation stage different from SEF. That is the same reason of BTR. In BTR, the variation is 49% from 256.36 at Pre-operation to 129.23 at induction and is 83% from 154.99 at Operation to 283.84 at Awaked. So we can also say that BDR reflected anesthetic stage better than SEF.

5 Conclusions

In this paper, new parameters were developed to estimate the depth of anesthesia during a general anesthesia using EEG. Power spectral density(PSD) analysis was used for these parameters because EEG became slow wave during anesthesia. The new parameters were DTR, ATR, TDR, ADR, BTR and BDR applied to PSD. These parameters were compared with SEF which is conventionally used at clinic and confirmed clinical value. As the results, DTR, ATR, TDR, ADR among parameters were not useful compared with SEF but BTR and BDR is valuable for clinic. Trend of BDR and BTR is similar to change of SEF and variation of each stage is larger than SEF. So two parameters are useful to estimate the depth of anesthesia.

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References: