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EFFECT OF MONITORING BIOELECTRICITY IN GENERAL ANAESTHESIA

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Abstract

Lately, most doctors have used anesthesia hemodynamic responses (heart rate, blood pressure) or based directly on the patient's movements as sweating, eye movements, and reflecting light to adjust the anesthesia for patients during surgeries. However, they are not good predictors of the likelihood of waking during surgery or post-operative recall. To be more specific, an anesthetic process is defined ideal when the patients lose pains, lie motionlessly, and are unconscious of any happens in the surgeries. Patient's bioelectricity such as EEG, ECG, EMG plays an important role in the judging state changes of patients' bodies in the anesthesia process as well as the impact of external stimuli. Entropy, SPI, and NMT are 3 methods based on the patient's bioelectricity. Entropy is used to measure the state of the brain by data acquisition of EEG (electroencephalograph) and FEMG (frontal electromyography) signals that notice the status of patients in the surgery. SPI is a new method for tracking the hemodynamic response of the patients from a level of pain in surgery, while NMT is a common way to estimate the level of neuromuscular block, also muscle response to a stimulus. Adequacy of Anesthesia (AOA) - the combination of Entropy, SPI, and NMT can help the clinician titrate drugs according to the individual need of patients, especially in low flow anesthesia. This method also helps improve economic efficiency and environmental friendliness.

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Introduction

The role of bioelectric factors in anesthesia has been mentioned since the early 1980s [1]. Accordingly, the electroencephalogram or EEG plays an important role in assessing the cognitive abilities of the patient during anesthesia, as well as the ability to recall the events surgery. BIS (bispectral index) is one of the first recorded measurement values deep anesthesia, the study shows the BIS monitoring reduced the risk contribution awake during surgery and reduce hospitalization costs by promoting patient fast recovery workers and reduce the overuse of narcotics [2]. However in recent years, with the emergence of entropy (Entropy ModuleTM, Datex Ohmeda, Helsinki, Finland), the monitoring of deep anesthesia were more realistic and accurate. Entropy is a kind of parameter of intuition which is presented as an ability to identify a regular signal from an irregular one. Another special feature of Entropy is being unconstrained of absolute scales including the amplitude or the frequency of the signal which is regularly expressed by an elementary sine wave regardless of its speed. In an area of an EEG application, this is supposed to be a crucial property by the virtue of the existence of interindividual variations in the absolute frequencies of the EEG measures. Computed over a frequency range from 0.8Hz to 32Hz, State entropy (SE) contains EEG-dominant part of the spectrum which can tell for the most part of the cortical state of the patient Computed over a frequency range from 0.8 Hz to 47Hz, Response entropy (RE) is made of both components the EEG-dominant and EMG-dominant part of the spectrum. At a lower frequency range of up to nearly 30 Hz, the EEG signal component should be comprised in the biopotentials appearing in the electrodes At higher frequencies, EEG power decreases exponentially while an intermediate existence of EMG signal data announces some responses due to external stimulus of the patient acting as a painful stimulus responding after surgical events. As the result of the higher frequency of EEG signal, not only does it provide an accelerated indication of forthcoming arousal, but more importantly, a considerable amount of the sampling time can probably be reduced in contrast with a much longer time required for the lower frequency EEG signal data. By that way, the overall diagnostic indicator can be able to show a quick indication of changes in the state of the patient through EMG data [3]. Studies on Entropy and effective comparison between the year's Entropy and BIS has also attracted the attention of many researchers. Typically Ellerkmann and colleagues compared the effectiveness of the BIS and Entropy in assessing the effects of intravenous anesthetics propofol, results showed that the BIS seems to predominate Entropy in predicting the effects of Propofol [4]. Meanwhile, when conducting anesthesia with gaseous anesthetics Sevoflurane, more efficient Ellerkmann noticed from using Entropy to evaluate the impact on the patient [5]. With Hocker, when assessing the comparison between the BIS and Entropy in anesthesia by inhalation Desflurane, he showed the two indexes tracked SE and RE will be more effective in BIS Entropy importance to assess the level of received in the form of general anesthesia, in emergency cases, change the perception of the patient will meet with RE and SE faster than the BIS. The cognitive response can observe through increased heart rate HR, but in emergency situations, the assessment through the heart rate will be less significant than [6]. Entropy-depth study on the track through the relationship between the electrical activity of facial muscles, and the difference (RE-SE), Hoffman shows the electrical activity of the facial muscles is a sign that the anesthetic is not effective under the impact of the painful stimulation [7]. Meanwhile, White has conducted comparing the value of the Entropy and BIS during surgery, and the results showed that electrical ablation devices will affect, interfere much with BIS than the entropy [8].

Meet tenderness in surgery is an involuntary reaction in response to the vulnerability of the tissues. This response shows the changes through metabolism, and hormonal autonomy [9]. Under stimulatory effects, the sympathetic nervous cause changes in heart rate, blood pressure, blood circulation and catecholamine level (a hormone secreted by the adrenal gland in response to tension direct physical), which eventually leads to higher degree of tenderness lasting (sustained stress response). This condition can lead to prolonged postoperative period and prolonged patient relative pathological lesions. Thereby, pain pathways are inhibited (antinociception) to reduce the tenderness principles during surgery, which is a matter of interest. However, so far there is yet an approach to evaluating a patient's pain level, whereas previously, common methods were used are an observation in heart rate, blood pressure changes, the movement of patients workers and the muscle tension. While increasing stimulation increases surgical stress, increasing analgesia decreases it. Having the same crucial features, SPI (Surgical Pleth Index) or SSI (Surgical Stress Index) was developed in order that nociception and antinociception could reach the balance. EEG has been revealed to be prone to significant changes in relation to nociceptive stimuli; however; SSI does not use EEG- derived information. SSI was computed as a combination of normalized heartbeat interval (HBI) and plethysmography pulse wave amplitude. SSI increased at skin incision and remained higher after surgery than before surgery. What more has SSI responded to analgesic concentration changes: the lower concentrations of analgesia, the higher it was [10].

Studies on the clinical effectiveness of the monitoring bioelectric factors in anesthesia showed the practical results are forward-looking. Aime and his colleagues have conducted surveillance on the three groups of patients. Group 1 uses routine clinical signs of anesthetic titration. Group 2 was tested using the concentration of sevoflurane anesthesia gas, which is adjusted to maintain BIS between 40 and 60. And group 3 has experimented with sevoflurane concentration that was adjusted to maintain the SE and RE 40-60, rapid injection of sufentanil pain if RE - SE ¿ 10 in 2 minutes. Research shows that the monitoring BIS and Entropy help reduce 29% of the total dosage versus sevoflurane anesthesia routine [11] Meanwhile, Gruenewald conducted his experiment on 72 patients with laparoscopic surgery, who were then divided into 2 groups: "Routine monitoring group" and "Entropy group". In Entropy monitoring group, intravenous anesthetics propofol was adjusted so that 40 $<$ SE $<$60, while analgesics Remifentanil was adjusted to achieve (RE-SE) ¡10. Results showed that the entropy contribution tracking reduces 14.7% of total average propofol. Moreover, the unexpected events after surgery (high blood pressure, high pulse, low blood pressure ...) decreased to 42% [12]. Also, conducted similar surveys have tracked two groups Entropy and routine, Vakkuri shows the average amount of propofol decreased 9% when tracking Entropy. In addition, the monitoring Entropy helps accelerate recovery time with natural breathing, shorten extubation process, reduce the eye-opening time and decrease operating period. All of these specifications are lower comparing to nonconducting anesthesia often regulation [13].

In summary, in the application of BIS monitoring depth of anesthesia, anesthetic Entropy has appeared in many studies. However, the appointment of additional indicators which SPI pain associated with Entropy also appeared in several recent studies. SPI pain index is a new discovery recently but it has shown more prominent advantages than any other previous pain measurement methods. AOA balance anesthesia is a combination simultaneously as Entropy survey, SPI and NMT the muscle relaxant, to assess the need for the right dose of the patient as well as ensuring good postoperative. Sevoflurane inhalation is used in most hospitals with high coverage, so this is a good object to exploit the advantages that research methods bring, as well as scaling advantages to hospitals in which are using this type of anesthesia. Moreover, there is yet any research regarding an application in monitoring bioelectric factors anesthesia simultaneously with gaseous anesthetics Sevoflurane with low traffic. That is why the subject is done. And that is the aim of this project.

2. Experiment

This study was conducted at Department of Anesthesiology in Military hospital 175, Viet Nam. 60 patients, aged 18-70 yr, were randomly allocated to one of two groups: the control group and the AOA group. The patient was scheduled for elective general surgery expected to last at least 2h.

- Control group: The patient was anesthetized in a traditional process by using standard monitor and anesthesia machine. Fresh gas flow (FGF) was taken at least 2 L/min and fixed during surgery. In this group, the anesthesiologist carried out popular anesthesia method. Fresh gas flow (FGF) was taken at least 2 L/min and increased FGF when wake-up signal presented. Meanwhile, the titration of analgesic (Sufentanil) related to age and weight of the patient.

- AOA group: Advance anesthesia machine (GE Datex-Ohmeda Avance CS2) with ecoFLOW was applied. Advance monitor (GE healthcare B650) integrated spectral entropy (E-Entropy module, GE healthcare, Helsinki, Finland), SPI software and NeuroMuscular Transmission (E-NMT module, GE healthcare, Helsinki, Finland), was applied to monitor EEG, blood pressure, SpO2, also predict the possibility of waking during surgery, and estimate nociceptive-antinociceptive balance and level of neuromuscular block. In this group, low flow anesthesia (FGF? 1L/min) was conducted via monitoring ecoFLOW. The anesthesiologist just needs to adjust FGF and FiO2 to keep Fi25 O2 flow is lower than O2 total flow. Entropy value needs to be maintained between 40 and 60, while the titration of analgesia should maintain SPI value between 20 and 50. The right time to do intubation and extubation should base on TOF count and TOF% to enhance patient's comfort, also boost their recovery time.

Entropy value: RE and SE were computed from spectral Entropy formula Vierti-Oja, et al. (2004). RE becomes equal to SE when the EMG power (sum of spectral power between 32 Hz and 47 Hz) is equal to zero, as the RE-SE-difference then serves as an indicator for EMG activation. SE and RE supply more information for the anesthesiologists. State entropy is a stable indicator of the effect of hypnotics on the cortex. The time windows for SE are selected in such a way that transient fluctuations are removed from the data. On the other hand, Response entropy reacts fast to changes. A typical situation in which the different roles of these parameters is demonstrated is during arousal when RE rises first simultaneously with muscle activation and is some seconds later followed by SE Viertiö-Oja, et al. (2004). The SPI is calculated from heart rate (HR) and the pulse-induced volume change (PPG). These values need to be normalized (HBInorm; PPGnorm). We got the SPI formula Huiku, et al. (2007):

$$SPI = 100 - (0.33 \times HBInorm^{+} 0.67 \times PPG) \quad (1)$$

SPI is the dimensionless number, the minimum value is 0 responding to low-stress state, while the higher one dominates at higher values with the maximum value is 100. The SPI is only calculated by finger clip sensor, which simultaneously measures transcutaneous oxygen saturation. The last component is NMT, this is the popular method to estimate the level of neuromuscular block by stimulating a peripheral nerve, usually in the hand. Train-of-four (TOF) is used as a standard stimulation mode. Four supramaximal stimuli are generated at 0.5-second intervals. Each stimulus in the train causes the muscle to contract.

3. Analysis

a. Advantage of monitoring Surgical pleth index (SPI)

Traditionally, anesthesiologist predicted the level of pain through heart rate, blood pressure changes, patient movement and muscle tension to reach adequacy of analgesia. Insuf?cient antinociception may lead to increased morbidity and delayed postoperative recovery. It's important to have a simple numerical index suitable for monitoring surgical stress, that correlates with the level of antinociceptive medication and intensity of nociceptive stimulation during surgery.

Figure 1. Difference between SPI and RE in predicting level of pain.

Huiku realized that PPG and HBI is a good choice for a two-variable model of Total Surgical Stress, while the pulse transit time PTT, systolic blood pressure NIBP and response entropy RE are not appropriate for this model. The surgical pleth index (SSI) uses two continuous cardiovascular parameters, both obtained from photoplethysmographic waveforms of the peripheral oxygen saturation measurement (SpO2): the interval between successive heart beats (HBI) and the pulse photoplethysmographic amplitude (PPGA). The measures are normalized and combined to produce a single SPI value. The better performance of SPI compare to RE was discussed in this study. In Figure 1, we can see the patient had a good hypnotic and unconsciousness (RE =58 and SE=47), however, the patient was feeling pain under nociceptive stimulation during surgery due to high SPI value (71) and heart rate. These values show that SPI gets a faster response than RE-SE value and be a good predictor for adequacy of analgesia than electroencephalography EEG. EEG-based monitors have been shown to reduce anesthetic doses, achieve greater hemodynamic stability, reduce the incidence of intraoperative awareness and shorten recovery time [14]. However, it's not suitable for monitoring analgesia because the anatomic regions in the central nervous system differ for analgesia and hypnosis, and thus these system, which assesses EEG activity in the frontal cortex, are not good for predicting spontaneous movements in response to painful stimuli.

SPI is not constant, this value change depends on painful stimulus and state of anesthesia. We can see SPI's trend recorded during surgery in Figure 2. SPI increased to 62 after intubation and go down quickly to 39 after that. Under painful stimulus: incision, SPI suddenly increases to 75, and after incision, this value drops slightly to 66. This trend looks different to SSI trend of Huiku study. In his research, SSI value continuously goes up after incision. The reason for this difference is a kind of analgesic and anesthetic drug used. Remifentanil - propofol target - controlled anesthesia was applied in his research, while for this study, we used Sufentanil-Sevoflurane component. The average SPI value is approximately 50 in two studies

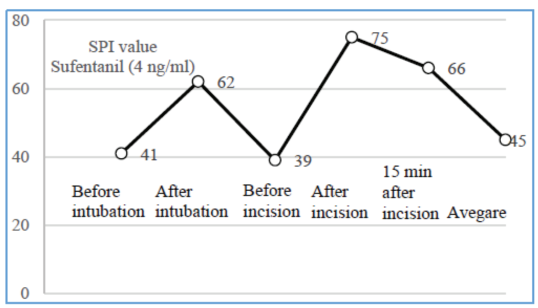

Figure 2. SPI during general anesthesia in all patients.

The advantage of monitoring bioelectric factors was already mentioned in many previous studies [15]. Anesthesia with low flow provides more benefits in terms of economic value and safety for patients as well as environmental friendliness. In particular, the economic value that results from the application of this method is tremendous. The data were analyzed and processed by the software Microsoft Excel 2010. From the data, the consumption of anesthetics and analgesics is significantly reduced when there is the presence of bioelectric factors monitoring: consumption sevoflurane anesthesia falls to 32.56%, while the value for painkillers that sufentanil is 20.75%. Gruenewald observed 2 groups: routine and Entropy, the results displayed that the combination of anesthesia and monitoring reduces the entropy contributed by 14.7% of total intravenous anesthetic propofol [12]. Similar to the result of Propofol, Vakkuri reduced to 9% when the track Entropy in anesthesia [13]. However, these two studies only focused on the effects of intravenous anesthetic Propofol, while research is leading Sevoflurane inhalation has yet to be mentioned. In 2006, Aime has conducted a survey on respiratory Sevoflurane anesthetic and analgesic Sufentanil, he examined the samples of 3 groups: routine anesthesia groups, Entropy groups, and BIS groups. The results obtained show that Entropy and BIS monitoring contribute to reducing 29% of Sevoflurane, while the value in our study was 32.56% [11]. The difference between this study compared with Aime's is the usage of air is mixed. With Aime, the gas mixture is O2 and N2O, however, this gas mixture is rarely used at hospitals in our country, the common mixture is Air and O_2. A worth comparing problem is that the analgesic titration that Aime used is based on the monitoring criteria and operation electromechanical Entropy (RE-SE). The patient will feel painful when RE - SE is ≥ 10 for 2 minutes. While our research is based on the pain index SPI. According to a research by Huiku, the determination of pain index through PPG and HBI (components of SPI) will be the optimal choice, and it is better than RE [10]. Therefore, this is an important point in the combining of the bioelectric factors which other studies have not performed on Sevoflurane anesthetic, especially with low-flow anesthesia. For painkillers, Bergmann and Chen with two different studies of Remifentanil analgesics titration based on the monitoring indicators SPI pain grossed similar results with SPI-based guidelines, which will help Entropy to reduce the amount of Remifentanil pain medication by 25% Bergmann [16] and 22.7% Chen [17] respectively. Meanwhile, research focused on Sufentanil topics, a drug widely used for analgesic in Vietnam, with similar results of the monitoring of anesthesia SPI will reduce 20.75% the total amount of Sufentanil painkiller. The study also showed unexpected events, such as high blood pressure.

	Control group	AOA group	P – value
Consumption of anesthetic drugs			
Sevoflurane (ml kg^{-1} h^{-1})	0.29	0.43	0.007 (< 0.05)
Sufentanil (μg kg^{-1} h^{-1})	0.42	0.53	0.004 (< 0.05)
Recovery time (min)			
Spontaneous (min)	7.27	4.07	0.02 (< 0.05)
Eye open (min)	13.34	11.70	0.36 (> 0.05)
Extubation (min)	30.37	23.30	0.57 (>0.05)
Unwanted events	16	9	

Table 1. Recovery time and Consumption of anesthesia drugs.

"During surgery" date represent the average over the entire duration of the procedure tachycardia, decreased 43.75% when compared to conventional anesthesia. According to research by Gruenewald, this value is 42% when applying entropy method for monitoring the depth of anesthesia patients.

Moreover, the recovery time of patients has shortened anesthesia than normal: 3.2 minutes to reduce the patient's spontaneous breathing, 1.64 minutes for the patient opened their eyes, particularly 6.97 minutes for extubation early.

4. Conclusion

The monitoring bioelectric factor in anesthesia gives the following results: patient safety, economic interests, as well as environmental friendliness. Typically, this monitoring helps reduce 32.56% of Sevoflurane anesthetic respiratory and 20.75% of Sufentanil analgesics compared with routine anesthesia. Moreover, the recovery time of patients has shortened anesthesia than normal: 3.2 minutes to reduce the patient's spontaneous breathing, 1.64 minutes for the patient opened their eyes, particularly 6.97 minutes for extubation early. SPI (Surgical Plex Index) is a new technique recorded patient's pain and very little research articles about this method, the SPI is determined as a function of the degree of pain stimulus and the influence of painkillers. It is based on a modified pulse amplitude and pulse spacing volume. SPI reflects the hemodynamic response of patients with surgical stimulation and the use of analgesics during anesthesia, which other tracking values are not as effective as NIBP, HR, RE, PTT. Especially SPI is more effective than offsets RE-SE which is recorded from the EEG signal. Therefore, the monitoring bioelectric factors in anesthesia should be concerned and replication.

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