Case Report

The usefulness of Density Spectral Array during General Anesthesia

Ki Hwa Lee[1*, M.D., Ph.D.]

Abstract

Recently, there has been a growing interest in the use of processed electroencephalography (EEG) and spectrogram in clinical settings. There are several obstacles to overcome when interpreting EEG due to the limitations of processed EEG monitors, such as time delay and interference caused by electrical cauterization. Therefore, it is necessary to look beyond the index produced by the processed EEG monitor. However, it is difficult to understand and apply spectrogram. This case report describes two useful examples of the use of the density spectral array of the SedLine™ monitor during general anesthesia.

Introduction

Monitoring processed electroencephalography (EEG) during general anesthesia is beneficial. Using processed EEG to guide target value during general anesthesia can reduce intraoperative awareness,1 and the amount of anesthetic required,2 and result in fast recovery from general anesthesia.3

The increasing elderly population in recent years has led to increasing interest in anesthesia for elderly patients. The European Society of Anaesthesiology has published that processed EEG can be useful for the avoidance of deep anesthesia and postoperative delirium (POD).4 Several studies have reported that use of processed EEG-guided anesthesia reduces the total amount of anesthetics required and decreases the risk of POD and postoperative cognitive dysfunction (POCD).2,5

However, owing to the limitations of processed EEG monitors, the index produced is not always accurate.6 There are several obstacles to overcome when interpreting EEG signals due to the time delay and interference caused by electrical cauterization. Therefore, the Association of Anaesthetists of Great Britain and Ireland and World Health Organization-World Federation of Societies of Anaesthesiologists indicate that processed EEG is not a standard monitoring modality during anesthesia and recovery.7,8

Recently, several articles have reported that low alpha band power may be related to neurocognitive function.9,10 Although there is growing interest in the use of processed EEG and spectrogram in clinical settings6, it is difficult to understand and apply the spectrogram in reality. Therefore, the aim of

[1]Department Anesthesiology and Pain medicine, Haeundae Paik Hospital, Inje University, Busan, Republic of Korea

***Mailing address of the corresponding author**

Ki Hwa Lee, M.D., Ph.D. Department Anesthesiology and Pain medicine, Haeundae Paik Hospital, Inje University, Busan, Republic of Korea. Mailing address: 875, Haeundae-ro, Haeundae-gu, Busan, Republic of Korea.

Telephone number: +82 1045484249, Email address: tedy333@paik.ac.kr

this report was to describe two useful examples of the use of the density spectral array (DSA) of the SedLine™ monitor during general anesthesia.

Case Report

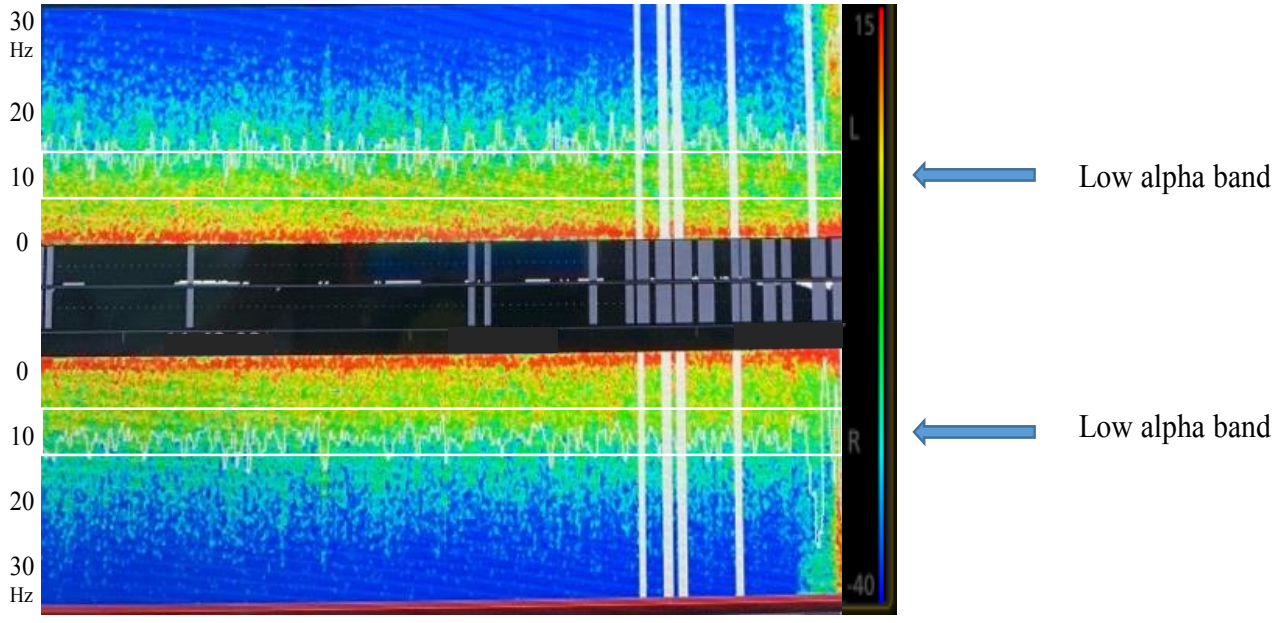
Detection of low alpha power

This case was that of a 57-year-old male patient (169 cm, 71 kg) scheduled to undergo elective spine surgery (posterior lumbar interbody fusion, L5-S1) for low back pain. He had alcoholic liver cirrhosis (Child A score) and a history of smoking (18.5 packs per year). The patient did not receive any premedication. Upon arriving to the operating room, general anesthesia was induced by intravenous administration of 40 mg of 2% lidocaine, 100 mg of propofol, and 50 mg of rocuronium. General anesthesia was maintained with 2-3 vol% sevoflurane using a SedLine™ monitor. The Patient state index (PSI) of the SedLine™ monitor was maintained between 25 and 50 during general anesthesia. The duration of anesthesia and surgery was 205 min and 155 min, respectively.

A total of 2200 ml of crystalloid and 500 ml of colloid were administered to the patient. The estimated blood loss was 470 ml and the urine output was 1400 ml.

After skin closure, the administration of sevoflurane was discontinued. During surgery, the DSA of the SedLine™ monitor showed low alpha band power (Figure 1). After extubation, the occurrence of POD was evaluated using the Nursing Delirium Screening Scale (NU-DESC).11 Delirium was defined as scoring a total of ≥2 points on the NU-DESC. The patient scored a total of 2 points (disorientation, 1; inappropriate communication, 1). Thirty minutes after arriving at the postanesthetic care unit (PACU), the patients scored 0 points on the NU-DESC. The patient was transferred to the general ward

Figure 1. Density spectral array of the SedLine™ monitor.
Power is color-coded (red = high, blue = low) per the displayed scale, and the x-axis represents time..



without any complications. He had no POD symptoms before discharge from the hospital.

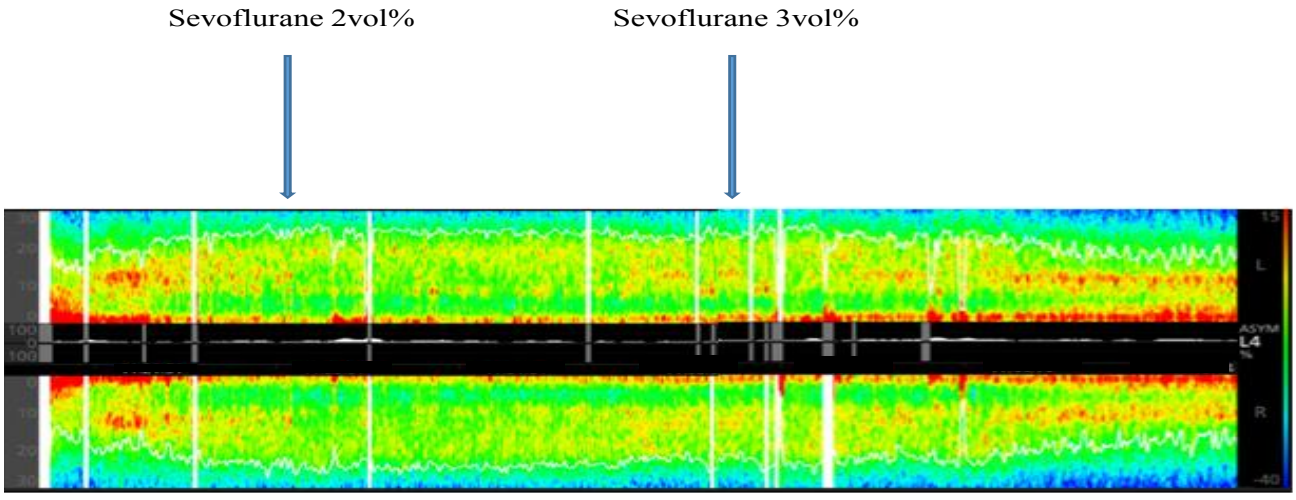
Early detection of low minimum alveolar concentration

This case was that of a 58-year-old female patient (161.4 cm, 52.3 kg) scheduled to undergo elective shoulder surgery (acromioplasty and repair of rotator cuff tear). Her medical history included well-controlled diabetes mellitus. The patient did not receive any premedication. Upon arriving to the operating room, general anesthesia was induced with intravenous injections of 40 mg of 2% lidocaine, 80 mg of propofol, and 40 mg of rocuronium. After endotracheal intubation, 2 vol% sevoflurane was administered. Arterial catheterization was performed using a 20G angio-catheter to monitor blood pressure and cerebral perfusion pressure. The DSA pattern observed before the patient was placed in a sitting position for surgery was different from the usual pattern (Figure 2). At that time, the mean PSI value was 49. When setting up, visible minimum alveolar concentration (MAC), inspired sevoflurane, and end-tidal sevoflurane concentration displayed on the anesthesia monitor (Philips IntelliVue MP70) were 0.4, 1.15, and 0.90, respectively. Administration of sevoflurane was then increased by 3 vol%. Thereafter, the DSA pattern showed a strong alpha power band as expected.

Discussion

This manuscript describes two useful examples of the use of DSA during general anesthesia. The author obtained consents from both patients discussed. Density spectral array is a two-dimensional plot of the spectrogram. Time is displayed along the x-axis and frequency along the y-axis, whereas power is indicated by the color in the spectrogram. The warmer the color, the greater the power.12 The power at a given frequency in the spectrogram is defined in decibels (dB), a logarithmic scale that makes smaller features easier to see. Spectral analysis makes it easier to visualize frequency components and detect subtle changes in frequency structure.13

Figure 2
Changes in the density spectral array pattern after tracheal intubation using sevoflurane.



The spectrogram, a continuous calculation of the spectrum over successive segments of raw EEG data, improves the interpretability of EEG signals and the ability to track EEG oscillations over time 13,14. Kim et al.14 concluded that the depth of general anesthesia could be tracked by monitoring the unprocessed EEG time series and its spectrogram.

In the first patient's case, DSA aided in the detection of low alpha band (8-12 Hz) power during general anesthesia. Several studies have investigated the usefulness of low alpha band power during anesthesia.9,10,15 A prominent feature of EEG under propofol and sevoflurane anesthesia is frontal alpha oscillation, which is known to significantly decrease with age.15 Intraoperative low frontal alpha power may be used as a physiological marker to identify older adults with low cognitive function before surgery, suggesting that it may be used to target patients at risk of this condition to help prevent POD and POCD.9 Analysis of 32-channel EEG recordings of 15 patients showed no correlation between frontal alpha band acitivy and preoperative cognitive function in other EEG frequency bands, such as delta, theta, and beta-bands.9 Shao et al.10 hypothesized that the alpha oscillation could be a potential biomarker for brain vulnerability.

They found that for each decibel decrease in frontal alpha power, the chance of experiencing burst suppression increases by 1.33 times. The absence of frontal alpha power during general anesthesia is closely related to delirium in the PACU.10

Low alpha band power may be an indicator of underlying brain vulnerability with intraoperative burst suppression. The definition of "vulnerable brain" under anesthesia is a hypothesis linking metabolism, brain oscillation, burst suppression, and cognitive decline.

10 Fritz et al.16 found that patients (aged ≥ 18 years and scheduled for admission into the intensive care unit) who had burst suppression at low end-tidal concentrations of volatile anesthetics were more likely to have POD (109/309 [35%]) than other patients (53/309 [17%]).

Although the patient in the first case was 57 years old (< 65 years old), he showed low alpha band power and delirium after extubation. Spine surgery can be a risk factor of POD.17 The etiology of POD is multifactorial, and its prediction and prevention can be difficult.8 PACU delirium is commonly associated with long-term POD and adverse events.19 However, if PACU delirium is also observed in patients who show low alpha power, active treatment can be performed to prevent the occurrence of long-term neurocognitive disorders in vulnerable patients.

In the second patient's case, analysis of the DSA in addition to observation, the index of the processed EEG monitor was helpful. The 5th National Audit Project reported that dynamic phases such as induction of and emergence from general anesthesia are common periods of accidental awareness under general anesthesia.20 Low frequency and high amplitude are typical EEG features that are noted as general anesthesia deepens.21 Observation of the raw EEG beyond the index number is good6; however, it is difficult for an anesthesiologist to interpret the raw EEG while performing various tasks. Although it is important to observe the MAC, intuitively glancing at the DSA enables faster detection. Since the PSI value was within the targeted level for general anesthesia (25-50), it would have been difficult to detect light anesthesia.

The alpha band is a significant indicator of sevoflurane and propofol anesthesia.15 If this typical alpha band power is not displayed on the EEG monitor, it should be considered that something is wrong.

The SedLine™ monitor or BIS monitor can provide the DSA screen. However, understanding the DSA screen requires several challenges to us, and articles about its practical usages are scarce. More information of alpha power band and spectrogram could be more indicative of the general anesthesia status. Therefore, anesthesiologists need to be trained and to get more familiarized with these readings to interpret beyond the number of processed EEG monitors.

Financial disclosures: None.

Conflicts of interest: None.

References

1. P S Myles, K Leslie, J McNeil, A Forbes, M T V Chan. Bispectral index monitoring to prevent awareness during anaesthesia: the B-Aware randomised controlled trial. Lancet 2004;363:1757-63. doi: 10.1016/S0140-6736(04)16300-9.
2. Matthew T V Chan, Benny C P Cheng, Tatia M C Lee, Tony Gin, CODA Trial Group. BIS-guided anesthesia decreases postoperative delirium and cognitive decline. J Neurosurg Anesthesiol 2013;25:33-42. doi: 10.1097/ANA.0b013e3182712ba.
3. Sharon R Lewis, Michael W Pritchard, Lizzy J Fawcett, Yodying Punjasawadwong. Bispectral index for improving intraoperative awareness and early postoperative recovery in adults. Cochrane Database Syst Rev 2019;9(9):CD003843. doi: 10.1002/14651858.CD003843.pub4.
4. César Aldecoa , Gabriella Bettelli, Federico Bilotta, Robert D Sanders, Riccardo Audisio, Anastasia Borozdina, et al. European Society of Anaesthesiology evidence-based and consensus-based guideline on postoperative delirium. Eur J Anaesthesiol 2017;34:192-214. doi: 10.1097/EJA.0000000000000594.
5. F M Radtke, M Franck, J Lendner, S Krüger, K D Wernecke, C D Spies. Monitoring depth of anaesthesia in a randomized trial decreases the rate of postoperative delirium but not postoperative cognitive dysfunction. Br J Anaesth 2013;110:i98-105. doi: 10.1093/bja/aet055.
6. David A Mulvey, Peter Klepsch . Use of Processed Electroencephalography in the Clinical Setting. Curr Anesthesiol Rep. 2020;23:1-8. doi: 10.1007/s40140-020-00424-3.
7. M R Checketts, R Alladi , K Ferguson, L Gemmell, J M Handy, A A Klein, et al. Recommendations for standards of monitoring during anaesthesia and recovery 2015: Association of Anaesthetists of Great Britain and Ireland. Anaesthesia 2016; 71:85-93. doi: 10.1111/anae.13316.
8. Adrian W Gelb, Wayne W Morriss, Walter Johnson, Alan F Merry, Anuja Abayadeera, Natalia Belîi, et al. World Health Organization-World Federation of Societies of Anaesthesiologists (WHO-WFSA) International Standards for a Safe Practice of Anesthesia. Anesth Analg 2018;126:2047-55. doi: 10.1213/ANE.0000000000002927.
9. Charles M Giattino, Jacob E Gardner, Faris M Sbahi, Kenneth C Roberts, Mary Cooter, Eugene Moretti, et al. Intraoperative Frontal Alpha-Band Power Correlates with Preoperative Neurocognitive Function in Older Adults. Front Syst Neurosci 2017;11:24. doi: 10.3389/fnsys.2017.00024. eCollection 2017.
10. Yu Raymond Shao, Pegah Kahali, Timothy T Houle, Hao Deng, Christopher Colvin, Bradford C Dickerson, et al. Low Frontal Alpha Power Is Associated With the Propensity for Burst Suppression: An Electroencephalogram Phenotype for a "Vulnerable Brain". Anesth Analg 2020;131:1529-39. doi: 10.1213/ANE.0000000000004781.
11. A Winter, M P Steurer, Alexander Dullenkopf. Postoperative delirium assessed by post anesthesia care unit staff utilizing the Nursing Delirium Screening Scale: a prospective observational study of 1000 patients in a single Swiss institution. BMC Anesthesiol 2015;15:184. doi: 10.1186/s12871-015-0168-8.
12. Behtash Babadi, Emery N Brown. A review of multitaper spectral analysis. IEEE Trans Biomed Eng 2014;61:1555-64. doi: 10.1109/TBME.2014.2311996.
13. Patrick L Purdon, Aaron Sampson, Kara J Pavone, Emery N Brown. Clinical Electroencephalography for Anesthesiologists: Part I: Background and Basic Signatures. Anesthesiology 2015;123:937-60. doi: 10.1097/ALN.0000000000000841.
14. M Cindy Kim, G L Fricchione, E N Brown, O Akeju. Role of electroencephalogram oscillations and the spectrogram in monitoring anaesthesia. BJA Educ 2020;20:166-72. doi: 10.1016/j.bjae.2020.01.004.
15. P L Purdon, K J Pavone, O Akeju, A C Smith, A L Sampson, J Lee, D W Zhou, et al. The Ageing Brain: Age-dependent changes in the electroencephalogram during propofol and sevoflurane general anaesthesia. Br J Anaesth 2015;115:i46-i57. doi: 10.1093/bja/aev213.

16. B A Fritz, H R Maybrier, M S Avidan. Intraoperative electroencephalogram suppression at lower volatile anaesthetic concentrations predicts postoperative delirium occurring in the intensive care unit. Br J Anaesth 2018;121:241-8. doi: 10.1016/j.bja.2017.10.024.
17. Wonhee Baek, Young Man Kim, Hyangkyu Lee. Risk Factors of Postoperative Delirium in Older Adult Spine Surgery Patients: A Meta-Analysis. AORN J 2020;112:650-61. doi: 10.1002/aorn.13252.
18. Sharon K Inouye, Rudi G J Westendorp, Jane S Saczynski. Delirium in elderly people. Lancet 2014;383:911-22. doi: 10.1016/S0140-6736(13)60688-1.
19. B A Hernandez, H Lindroth, P Rowley, C Boncyk, A Raz, A Gaskell, et al. Post-anaesthesia care unit delirium: incidence, risk factors and associated adverse outcomes. Br J Anaesth 2017;119:288-90. doi: 10.1093/bja/aex197.
20. J J Pandit, J Andrade, D G Bogod, J M Hitchman, W R Jonker, N Lucas, et al. 5th National Audit Project (NAP5) on accidental awareness during general anaesthesia: summary of main findings and risk factors. Br J Anaesth 2014;113:549-9. doi: 10.1093/bja/aeu313.
21. Emery N Brown, Ralph Lydic, Nicholas D Schiff. General anesthesia, sleep, and coma. N Engl J Med 2010;363:2638-50. doi: 10.1056/NEJMra0808281.