CASE REPORT

Intraoperative Raw EEG Monitoring for Anesthetic Depth Assessment in Scoliosis Correction Surgery: A Case Report

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ABSTRACT

Background: Conventional intraoperative monitoring does not directly reflect brain function. Electroencephalography (EEG) may provide better assessment of anesthetic depth. The aim of this case to describe the role of raw EEG monitoring during scoliosis correction surgery. This case demonstrates the use of intraoperative raw EEG as a primary guide for anesthetic titration, without reliance on processed indices such as the Bispectral Index, during scoliosis surgery.

Case: We report a 17-year-old female with adolescent idiopathic scoliosis (Lenke 1AN, Risser stage 5) who underwent spinal deformity correction under intraoperative monitoring. General anesthesia (GA) was maintained with propofol and remifentanil. Raw EEG monitoring using dual channels (CP3–Fpz and CP4–Fpz) was applied throughout the procedure. During induction, incision, spinal rotation/translation, and closure, EEG consistently demonstrated symmetric, dominant frontal alpha activity, corresponding with stable anesthetic depth. Anesthetic titration was guided by EEG patterns without reliance on processed EEG indices. The surgery was completed, and the patient recovered without neurological complications.

Discussion: EEG waveforms change in a dose-dependent manner with anesthetic agents. Dominant frontal alpha activity (alpha anteriorization) is associated with adequate hypnotic depth under propofol, whereas excessive slowing or burst suppression may indicate overly deep anesthesia. Raw EEG monitoring provides direct neurophysiological information and may be more sensitive than processed indices such as the bispectral index, particularly in surgeries requiring intraoperative neurophysiological monitoring.

Conclusion: Intraoperative raw EEG monitoring is a valuable adjunct for assessing anesthetic depth and may optimize anesthetic titration.

Keywords: anesthetic depth; electroencephalography; general anesthesia; intraoperative monitoring; scoliosis; alpha anteriorization

INTRODUCTION

General anesthesia aims to achieve an adequate state of unconsciousness during surgery by ensuring hypnosis, analgesia, amnesia, and muscle relaxation as required by the procedure. In daily clinical practice, intraoperative anesthesia monitoring generally still focuses on hemodynamic parameters such as blood pressure, heart rate, and oxygen saturation. However, these parameters do not directly reflect the condition of the primary target organ of GA, namely the brain. As a result, assessment of anesthetic depth that relies solely on cardiovascular parameters carries the risk of anesthesia being too light or too deep, each of which may increase the risk of intraoperative awareness, hemodynamic instability, and postoperative neurocognitive disorders.[1]

Corrective surgery for spinal deformity in patients with adolescent idiopathic scoliosis is a major surgical procedure with a long duration, prolonged anesthetic requirements, and the potential for significant nociceptive stimulation.[2] The use of intraoperative monitoring, such as electromyography (EMG), electroencephalography (EEG), and other neurophysiological modalities is recommended in patients undergoing spinal deformity correction surgery to prevent overdosing and to reduce emergence time after surgery.[3]

Electroencephalography (EEG) is a noninvasive method that records the electrical activity of the cerebral cortex and has evolved as a tool to monitor brain responses to anesthetic agents.[4] Changes in EEG wave patterns during anesthesia are dose-dependent and reflect the level of cortical depression. The predominance of slow waves such as delta and theta, the emergence of frontal alpha activity (alpha anteriorization), and burst suppression patterns in very deep anesthesia have been reported as physiological markers associated with anesthetic depth. Therefore, intraoperative EEG interpretation can provide information regarding the patient's neurophysiological state during surgery.[1]

In the context of scoliosis surgery with long duration and the need for intraoperative monitoring, intraoperative EEG has the potential to be a valuable adjunct for assessing anesthetic depth in real time, preventing excessive anesthesia, and maintaining neurological stability.[5] In addition, raw EEG waveform is more sensitive for anesthetic monitoring during surgery compared with processed EEG outputs such as the bispectral index; however, raw EEG is less commonly used than bispectral index monitoring.[6,7]

This case report aims to describe the role and interpretation of intraoperative EEG in a patient with adolescent idiopathic scoliosis undergoing spinal deformity correction surgery, and to discuss the correlation between EEG wave patterns and anesthetic depth during different stages of surgery. Currently, evidence on the application of raw EEG to use as a monitor in scoliosis surgery remains limited, especially in the context of intraoperative neurophysiological monitoring.

CASE

A 17-year-old female patient with a diagnosis of Adolescent Idiopathic Scoliosis Lenke 1AN Risser Stage 5 was scheduled for deformity correction under intraoperative monitoring. The surgery was performed on September 17, 2025, at Prof. dr. I.G.N.G. Ngoerah General Hospital.

From the medical history, the patient reported a curved spinal deformity that had been present for the past five years. Currently, the patient only complained of mild back discomfort that occurred when feeling fatigued. There were no complaints of tingling, numbness, or pain in the extremities. A history of food or drug allergies was denied. A history of hypertension, diabetes mellitus, asthma, heart disease, and other systemic diseases was denied. A history of previous surgery was denied. Smoking and alcohol consumption were denied. The patient was a high school student who, prior to illness, was able to perform moderate physical activity without dyspnea or chest pain.

Physical examination revealed the patient to be in good general condition with a body weight of 43 kg, height of 154 cm, body mass index (BMI) 18.13 kg/m², axillary temperature 36.8°C, NRS at rest 0/10, NRS on movement 0/10, and APFEL score ¾. The patient was classified as American Society of Anesthesiologists (ASA) physical status II with moderate restrictive respiratory problems without obstruction secondary to Adolescent Idiopathic Scoliosis Lenke 1AN Risser Stage 5, and musculoskeletal problems related to the same condition. The scoliosis program (04/09/2025) showed a single curve scoliosis involving the thoracic curve Th4–L1 (main structural curve) with right convexity, consistent with Lenke 1A Hyper classification; apical vertebral rotation grade +++ at Th9 according to Nash-Moe; skeletal maturity Risser 4; thoracic curve apex at Th9; Cobb angle 64°; right bending angle 49°, left bending angle 68°; right flexibility 15°, left −4°; coronal balance +1.5 cm (normal <2 cm); sagittal balance +1.3 cm (normal <1.7 cm); thoracic sagittal modifier 37° (+/Hyper); lumbar modifier type A; fulcrum bending right 32°, left not valid; apical pedicle rotation grade +++ at Th9 according to Nash-Moe. MRI contrast whole spine (15/07/2025) showed thoracic scoliosis Th4–L1 with right convexity (Lenke 1) without spinal canal or neural foraminal narrowing; no partial cerebrospinal fluid obstruction. Multislice Computed Tomography (MSCT) whole spine (02/08/2025) showed a single thoracic curve Th4–Th12 with right convexity (Lenke 1AN), apical vertebral rotation grade +++ at Th8 according to Nash-Moe, and skeletal maturity Risser 4.

Premedication of dexamethasone 10 mg IV and diphenhydramine 10 mg IV was given, followed by arterial line placement. At 08:25 am, induction was performed with a propofol infusion at 75 mcg/kg/min via syringe pump and remifentanil using TCI Minto mode with a target of 5 ng/mL. The patient was intubated with a non-kinking endotracheal tube, and a right jugular CVC was placed. The patient was then positioned prone. After prone positioning, EMG and EEG electrodes were applied to monitor electrical activity during surgery. EEG monitoring was performed using dual channels, CP3–Fpz and CP4–Fpz.

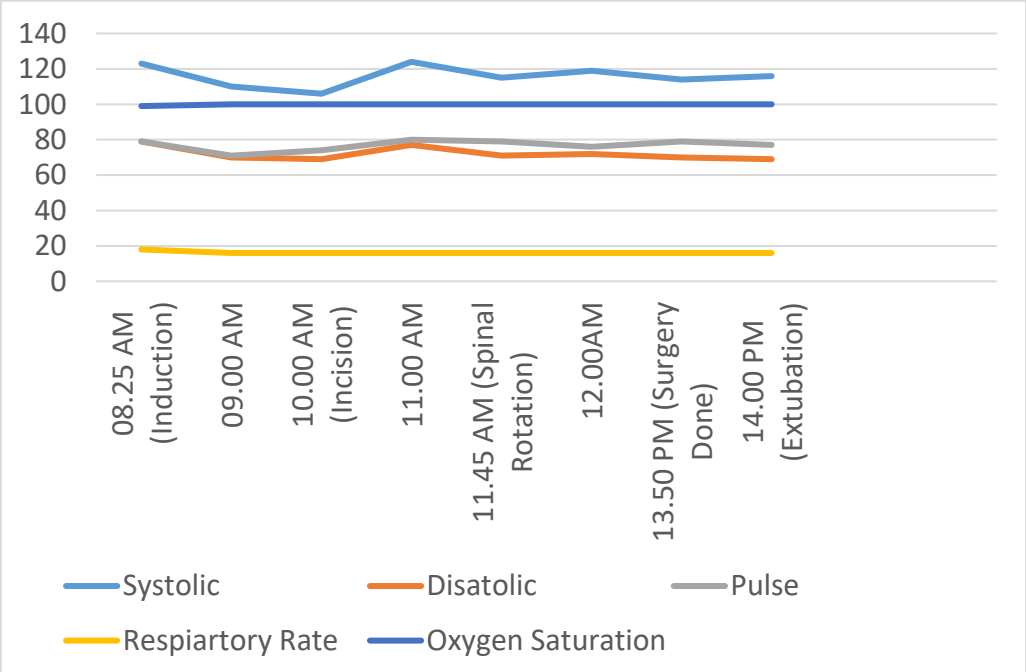
After induction, EEG showed symmetric CP3–Fpz and CP4–Fpz activity with dominant alpha waves. During skin incision at 10:00 am, propofol was titrated to 100 mcg/kg/min and remifentanil to a target of 6 ng/mL, with EEG still showing symmetric dominant alpha waves. At 11:45 am, spinal rotation/translation was performed, followed by an increase in remifentanil target to 8 ng/mL while maintaining propofol at 100 mcg/kg/min; EEG continued to show alpha wave

dominance. After completion of spinal rotation until the end of surgery, remifentanil was reduced to 6 ng/mL while propofol infusion remained unchanged, and EEG continued to show dominant alpha waves until the end of the procedure, and there is no burst suppression or epileptiform activity were seen, indicating that the anesthetic depth was adequate but not excessive. The surgery done at 13.50 PM

Total intraoperative blood loss was 1200 mL, urine output was 800 mL, crystalloid infusion totaled 1500 mL, and colloid infusion totaled 1000 mL. Autologous blood transfusion was 216 mL, and Packed Red Cell (PRC) transfusion totaled 465 mL. The patient was extubated at 02.00 pm and transferred to the ICU.



Figure 1. Scoliosis Program



Graph 1. Timeline and Hemodynamic durante-op

DISCUSSION

General anesthesia aims to prevent pain (analgesia), prevent memory formation during surgery (amnesia), maintain hypnosis, and sometimes requires muscle relaxation by inhibiting muscle reflexes.[8] Monitoring during anesthesia aims to control hemodynamic conditions and anesthetic effects by assessing physiological variables such as blood pressure, heart rate, and respiratory rate. However, these variables fail to provide information about anesthetic depth and to prevent adverse effects such as delirium or cognitive dysfunction.[1,9]

The brain is the primary target organ of GA, and EEG monitoring is an alternative method for monitoring brain responses to anesthetic agents.[9] Monitoring anesthetic depth at the brain level is essential, and EEG plays an important role in this process. EEG records brain electrical activity using scalp electrodes to monitor neuronal activity during anesthesia. There are generally five EEG wave types: delta (δ) 0.5–4 Hz, theta (θ) 4–8 Hz, alpha (α) 8–13 Hz, beta (β) 13–30 Hz, and gamma (γ) 30–90 Hz.[1,10,11]

There are major differences in theta wave activity between anesthesia using volatile agents (isoflurane or sevoflurane) and propofol. Propofol produces low theta activity independent of drug concentration, whereas volatile agents increase theta activity.[6] Increasing propofol concentration leads to gradual sedation and eventual loss of responsiveness; as target organ concentration increases, EEG frequency slows and amplitude increases, with alpha waves becoming dominant. Waxing and waning spindle wave patterns may appear transiently during sleep, but during propofol or volatile, spindle activity may be continuous. With further increases in propofol concentration, alpha waves diminish while theta and delta waves dominate, potentially leading to burst suppression patterns.[1,12]

Alpha oscillations around 10 Hz are typically seen in awake, relaxed individuals with eyes closed, primarily originating from the occipital region. During anesthesia or natural sleep, alpha rhythms predominantly originate from the frontal region, a shift known as alpha anteriorization.[10,13] Because alpha activity commonly appears during surgical anesthetic concentrations, changes in alpha waves are speculated to be key indicators of anesthetic effectiveness. The presence of spindle activity within alpha waves during anesthesia, similar to slow-wave sleep, also reflects anesthetic effectiveness.[6,14]

EEG recordings are highly susceptible to artifacts caused by external factors that interfere with signal acquisition.[15] These artifacts can be categorized into physiological and extra-physiological artifacts. Physiological artifacts originate from non-cerebral sources such as EMG, movement or sweating, and electrocardiography (ECG). Extra-physiological artifacts originate from external sources, including environmental factors such as mobile phones and in vivo devices such as pacemakers.[9,16]

Unlike processed EEG such as bispectral index, the raw EEG provides actual level of anesthesia in real time and analyzing the raw EEG waves could provides the depth of anesthesia, especially in pediatric patient, in which the monitor often provides the misleading values.[17] By using the EEG to monitoring a depth

of anesthesia, the clinican could reduce the anesthetic agent consumption and improve the post operative recovery, such as POCD.[7] This case indicates that sustained frontal alpha dominance may function as a practical real-time target for anesthetic titration during prolonged spine surgery.

CONCLUSION

Raw EEG monitoring appears to be a practical and sensitive tool for real-time assessment and titration of anesthetic depth, particularly in prolonged surgeries.

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