

Electromyographic Activity Falsely Elevates the Bispectral Index

THE bispectral index (BIS, Aspect Medical Systems, Framingham, MA) is a complex electroencephalographic (EEG) parameter that integrates several disparate descriptors of the EEG into a single variable and correlates behavioral assessments of sedation and hypnosis.^{1,2}

We report two cases in which the bispectral index failed to measure depth of anesthesia but instead was a measure of electromyographic (EMG) activity. In the first case bispectral index paradoxically increased after increasing propofol concentration, correlating with increasing EMG activity. In the second case the administration of a nondepolarizing muscle relaxant decreased the bispectral index value at constant anesthetic drug concentrations.

Case Report

Case 1

A 35-yr-old healthy male volunteer participated in a study evaluating the pharmacodynamic interaction of remifentanyl and propofol. The

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EEG was recorded continuously with a bipolar montage Fp1-A1, Fp2-A2 (international 10-20 system of electrode placement), using Zippree electrodes (Aspect). Electrode impedance was kept less than 2 k Ω . Electroencephalographic recordings were performed with a A-1000 EEG monitor (Version 3.22, Aspect). The raw EEG signal was filtered with a 30 Hz low-pass filter and a 0.5 Hz high-pass filter. In addition to the processed EEG variables, the raw EEG signal was stored on a computer hard disk for further off-line analysis with a sampling rate of 256 Hz (Datalogger, Aspect). Propofol and remifentanyl concentrations were ramped up- down to predetermined concentrations using a computer controlled infusion pump (STANPUMP). Before changing target concentrations the sedation-anesthetic depth was assessed by applying the following stimuli until the first response: calling his name, shaking the volunteer by the shoulder, painful electrical stimulation, insertion of a laryngeal mask, and direct laryngoscopy.

After having completed the initial assessment of anesthetic depth at a propofol concentration of 1 $\mu\text{g/ml}$ (predicted), remifentanyl was started with an effect compartment concentration of 3 ng/ml. Ten minutes later the volunteer was assessed and responded to soft voice at a BIS of 80. At 9:43 (fig. 1), the propofol effect compartment concentration was increased to 2 $\mu\text{g/ml}$. At 9:57, the volunteer did not respond to loud voice and shaking his shoulder but responded to the insertion of a laryngeal mask at a BIS of 54. At 10:02 the propofol effect compartment concentration was increased to 3 $\mu\text{g/ml}$. The bispectral index paradoxically increased (fig. 1). At 10:12, the patient underwent direct laryngoscopy without a response at a BIS of 84. At 10:17, the infusion pumps with propofol and remifentanyl were stopped and the bispectral index paradoxically decreased.

Case 2

A 36-year-old healthy female volunteer participated in the same study. The EEG montage and the EEG monitor settings were the same as in case 1. After having completed the initial assessment of anesthetic depth at a remifentanyl concentration of 1 ng/ml (predicted), propofol was started with an effect compartment concentration of 1 μ g/ml. At 9:15 (fig. 2) the remifentanyl effect compartment concentration was increased to 2 ng/ml. The bispectral index paradoxically increased. After a first 1 mg vecuronium bolus at 9:05 to minimize opioid-induced muscle rigidity, we gave a second 1 mg vecuronium bolus at 9:25 to prove the hypothesis whether a decrease of the bispectral index value can be noted when a muscle relaxant was given. After administration of vecuronium the BIS decreased to 69 (fig. 2). The conventional EEG parameters spectral edge frequency 95 and median EEG frequency filtered at 30 Hz again decreased appropriately with increasing anesthetic drug concentration.

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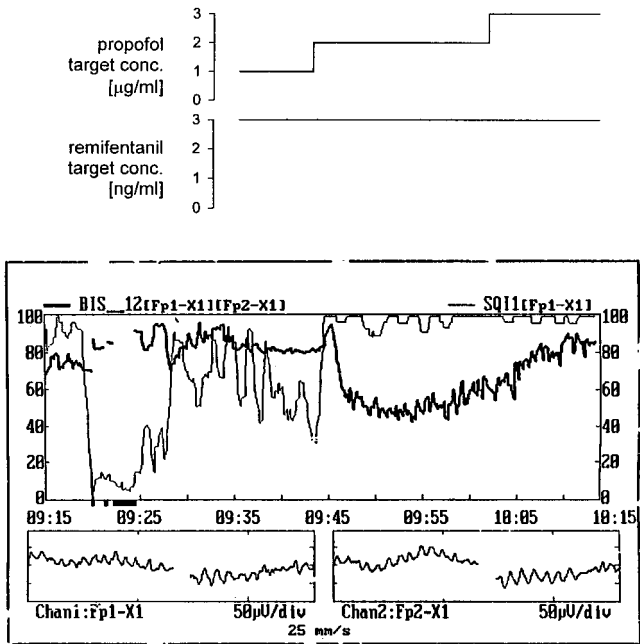


Fig. 1. Bispectral index trend display (bold line) showing bispectral index increase after increasing propofol effect compartment concentration at 10:02. At 10:12 the patient underwent direct laryngoscopy without a response at a BIS of 84 (case 1). The thin line shows the signal quality index trend. The two smaller boxes at the bottom display the raw electroencephalogram (25 mm/s) corresponding to the right end of the trend displays ($\approx 10:15$).

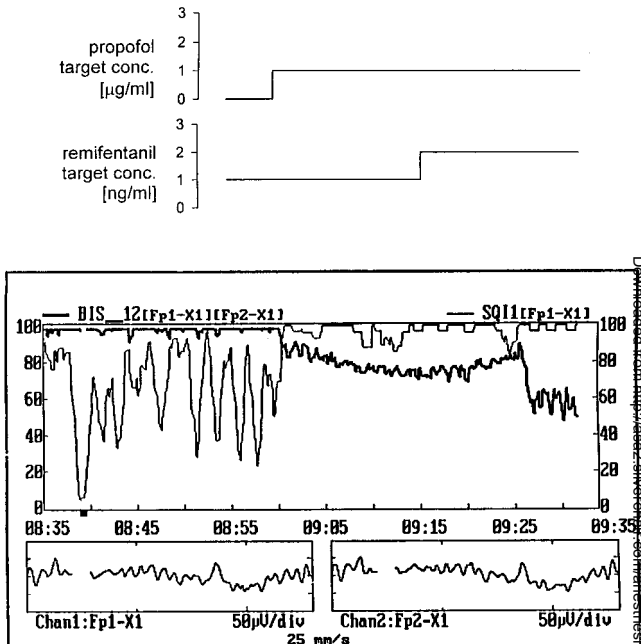


Fig. 2. Bispectral index trend display (bold line) showing slight bispectral index increase after increasing remifentanyl effect compartment concentration at 9:15 and sudden decrease after vecuronium administration at 9:25 (case 2). The thin line shows the signal quality index trend. The two smaller boxes at the bottom display the raw electroencephalogram (25 mm/s) corresponding to the right end of the trend displays ($\approx 9:33$).

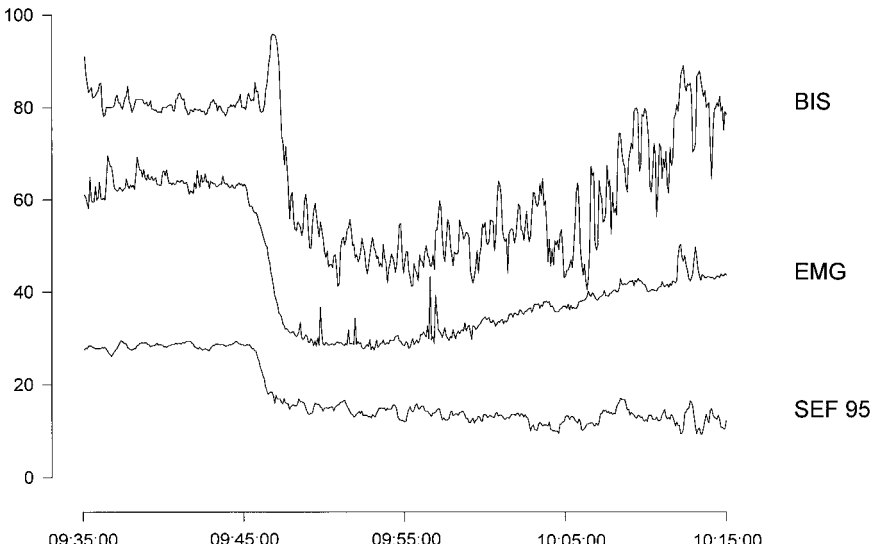
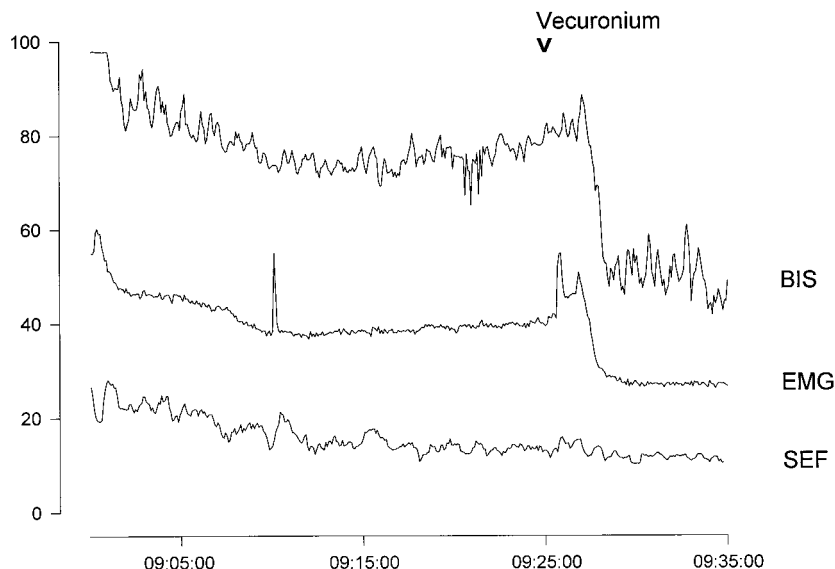


Fig. 3. Electromyographic (EMG) activity correlates with bispectral index (BIS) but not with spectral edge frequency 95% (SEF 95) (case 1). After increasing the propofol target concentration at 9:43 the volunteer was effectively sedated eliminating nearly all the multiple previous movement artifacts which caused an artifactually lowered BIS before 9:46.

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Fig. 4. Electromyographic (EMG) activity correlates with bispectral index (BIS) but not with spectral edge frequency 95% (SEF 95) (case 2).



Discussion

The bispectral index is a multivariate measure, whose weighting coefficients are unpublished and proprietary.^{1,3} Traditionally the EEG is low-pass filtered at 30 to 40 Hz.¹ To calculate the bispectral index requires inclusion of frequencies above 40 Hz, approaching frequencies generated by muscle activity (EMG).

Figures 3 and 4 show the bispectral index, the EMG and spectral edge frequency 95 calculated by the A-1000 monitor for cases 1 and 2 respectively. In each case the anomalous behavior is caused by EMG activity artifactually increasing the bispectral index. The spectral edge frequency 95 was not influenced by the EMG for two reasons. First, differential filtering is used inside the Aspect monitor before calculating the BIS (0–47 Hz) and before calculating spectral edge frequency (0–30 Hz).

Second, the EMG related power in the remaining higher frequencies is quite small in relation to the total power ($\approx 0.5\%$), therefore EMG related changes are not well reflected by spectral edge frequency 95. In contrast the bispectral index includes a feature especially for these higher frequencies: the relative β ratio ($\log(P_{30-47 \text{ Hz}}/P_{11-20 \text{ Hz}})$).¹

Whereas increasing frontalis muscle activity is mostly associated with light anesthesia,⁴ in the described two cases the EMG activity increased after increasing drug concentrations. The appearance of opiate-induced muscle rigidity is a possible explanation.

Interestingly, the high-frequency components caused by the electrical muscle activity could easily be identified

visually in the stored raw EEG, but not in the monitor raw EEG (fig. 1).

It has been suggested that fluctuations of the bispectral index may not be artifacts but rather changes in the clinical state of the subject to which the other EEG measures are not sensitive.⁵ In these two cases the bispectral index misclassified the anesthetic depth. In case 1 the volunteer underwent direct laryngoscopy without a response at a BIS of 84, while he responded before to a stimulus of lower intensity at a BIS of 54. In case 2 the BIS rapidly decreased from 85 to 58 after administration of vecuronium, despite constant target concentrations of propofol and remifentanyl.

We conclude that EMG activity can falsely increase the bispectral index. This is not a problem when the patient are fully paralyzed, but should be considered when the bispectral monitor is used in the absence of muscle relaxants.

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