BJA

British Journal of Anaesthesia, 131 (6): e175–e202 (2023)

CORRESPONDENCE

Utility of raw electroencephalography monitoring for estimating level of sedation in the perioperative setting

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Keywords: bispectral index; electroencephalography; non-operating room anaesthesia; processed EEG; raw EEG

Editor—Non-operating room anaesthesia (NORA) involves administering sedation and anaesthesia outside the traditional operating room setting for diagnostic and therapeutic procedures, with the goal of enhancing patient comfort during these interventions. However, deeper levels of sedation carry an increased risk of complications, such as airway obstruction or respiratory arrest. This risk is particularly heightened when using drugs such as propofol that have a narrow therapeutic index.[1,2] Complications induced by deep anaesthesia are frequently accompanied by a burst suppression pattern on electroencephalography (EEG) (i.e. a period of spindle-like or rapid spiking activity [bursts]), followed by a flat line phase of isoelectric suppression. Burst suppression is detectable exclusively by using EEG and is correlated with an increased risk of postoperative cognitive impairment, particularly in older patients.[3–5] Monitoring brain activity during anaesthesia is critical for detecting burst suppression, and processed EEG tools, such as the bispectral index (BIS),[6] are commonly used. Nonetheless, processed EEG might lead to imprecise assessments of anaesthesia depth, especially in sedation scenarios where susceptibility to interference from movement artifacts is heightened.

The aim of this study was to assess the interpretative capability of both NORA and operating room staff using raw EEG traces obtained from a single dry-electrode device for sedation monitoring during NORA. The device utilised is the NeuroSky MindWave Mobile-2 (San Jose, CA, USA)[7] which uses a single dry electrode positioned on the forehead above the eye (Fp1) to transmit EEG data wirelessly via Bluetooth to a compatible tablet or computer. The Brain Raw Visualizer app[8] was used to visualise the raw EEG waveform.

The study was conducted at the Endoscopy Unit of Santa Maria Maddalena Hospital (Volterra, Pisa, Italy) between October 2022 and January 2023 (Clinical Trial Registration: NCT05584904). It included all members of the NORA and operating room staffs, 18 nurses (15 female, three male) and eight anaesthesiologists (five women, three men). None of the participants possessed prior familiarity with EEG interpretation, and all fulfilled the study requirements.

EEG experts conducted a training course involving all study participants with the goal to familiarise them with the primary EEG patterns observed during awake and anaesthetised states. BIS and Neurosky EEG data were collected concurrently for the training course and the evaluation test from 10 consecutive patients undergoing colonoscopy under sedation. None of the training course EEGs were used for the evaluation test. EEG traces that were stable for 4 s and consistent with clinical conditions were selected. Using the Observer's Assessment of Alertness/Sedation (OAA/S) scale[9] to assess clinical status and the accompanying EEG BIS values, each EEG segment was classified into three real rank values as follows: level 1, OAA/S 1, deep sedation, BIS <65; level 2, OAA/S 2–4, intermediate state, BIS from 66 to 85; and level 3, OAA/S 5, light sedation, BIS >86.[10,11]

Twelve traces acquired from Neurosky systems, four for each real rank value (Fig. 1), were individually and randomly presented to participants for the final evaluation test. None of these were utilised during the course. Participants were instructed to indicate the number corresponding to the

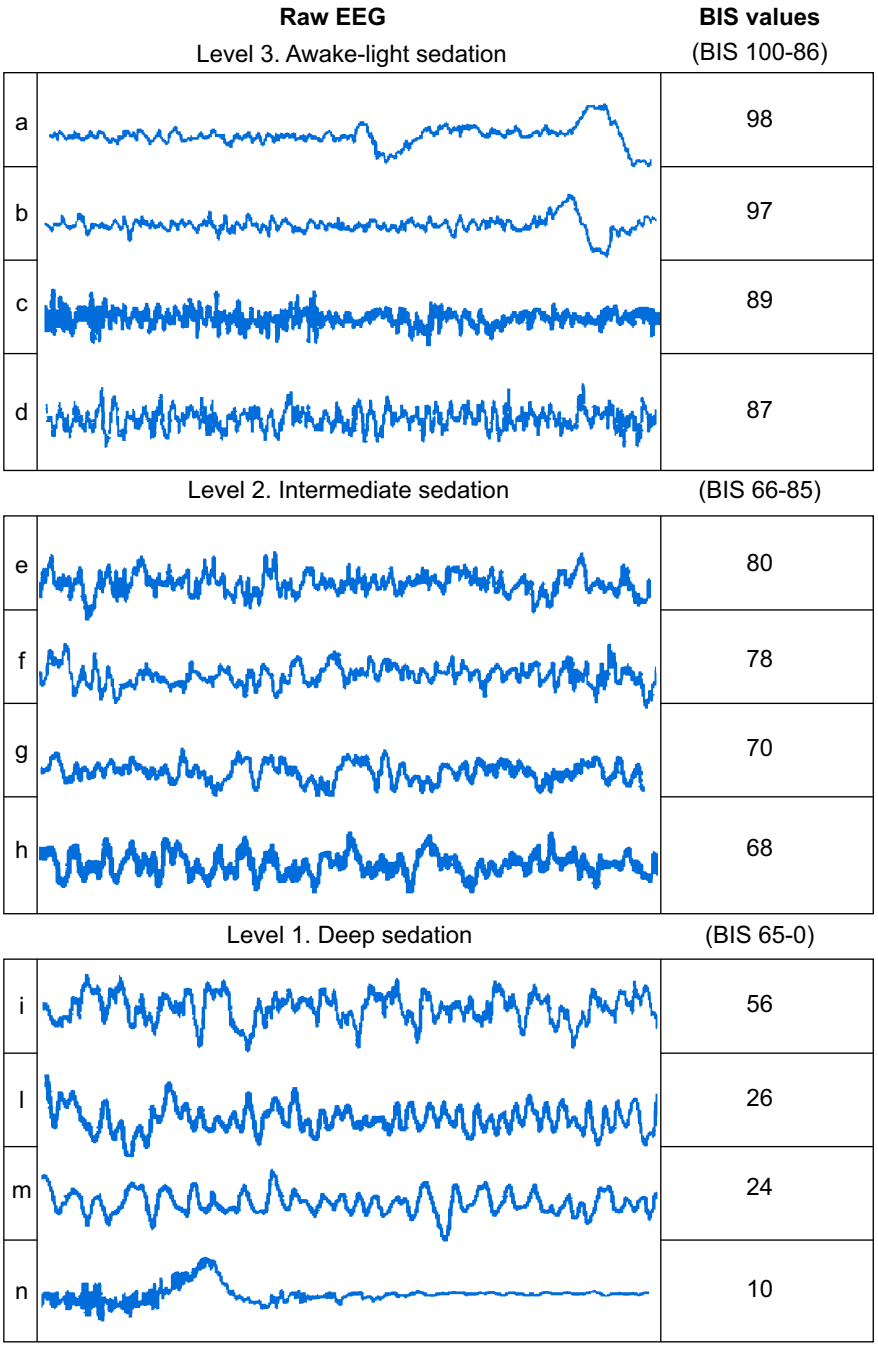

Fig 1. Sedation levels and EEG changes. The central column displays the 12 raw EEG traces utilised for the test, whereas the right column showcases the corresponding digital BIS values. BIS, bispectral index.

sedation level (1, 2, or 3) for the presented raw EEG trace. The data obtained from participants' responses were analysed using R Studio version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria). Because of the non-normal distribution of data, a non-parametric Kruskal–Wallis test was utilised to compare participants' scoring to real rank values. A significance of $P<0.05$ was applied, followed by *post hoc* Dwass-Steel-Critchlow-Fligner pairwise comparisons. A confusion matrix was used to visualise the classification made by participants' scoring regarding the true class real rank values. This matrix illustrates the number of accurately and inaccurately classified observations for each sedation level (1, 2, 3). The data analysis indicates that the majority of participants accurately interpreted raw EEG tracings for light sedation (80.8%) and deep sedation (89.4%), with no significant difference between them ($P>0.05$). However, accuracy was lower when interpreting intermediate sedation stages compared with both light and deep sedation ($P<0.001$ for light *vs*

intermediate; $P<0.003$ for deep *vs* intermediate). The confusion matrix results (see Supplementary Table S1) showed misclassifications primarily between levels 2 and 3, with 6.4% of level 3 answers misclassified as level 2, and 15.7% of level 2 answers misclassified as level 3.

These findings indicate that a majority of participants accurately interpreted levels of light and deep sedation. However, interpreting intermediate sedation was more challenging. The study achieved an overall accuracy rate of 74.4% for classifying the three sedation levels. These findings align with previous studies underscoring the significance of structured training in enhancing interpretation of raw EEG traces.[12–14]

Our study underscores the effectiveness of a single dry-electrode device in accurately assessing depth of sedation during NORA. It offers valuable insights into the interpretative ability of non-expert staff using raw EEG traces, emphasising the need for training to improve accuracy, particularly in distinguishing between intermediate sedation and the awake state. Despite certain device limitations, such as constraints related to patient positioning and absence of shielding in the presence of electrosurgical units, our study supports direct EEG interpretation by anaesthesiologists, and should encourage development of user-friendly and affordable instruments tailored for personal use beyond the operating room. The reliability of raw EEG interpretation, particularly in deeper stages of sedation preceding burst suppression and total suppression, is crucial for ensuring the safety of vulnerable patients and special populations, such as older patients who may be more susceptible to the harmful effects of excessive sedation. Further research with larger and more diverse populations is recommended to explore device effectiveness in various clinical settings and populations.

Authors' contributions

Conceived and designed the experiments: AT
Performed the experiments: ST, FL, AT
Performed the course: FL, AT
Edited the data: GM, AL
Analysed the data: GT
Supervised the work and contributed to the design of the experiments: FT
Wrote, revised, and approved the article: all authors

Acknowledgements

We thank Michael Petrides for his comments on the manuscript revision.

Declaration of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2023.08.036.

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doi: 10.1016/j.bja.2023.08.036
Advance Access Publication Date: 25 September 2023