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Can anaesthetists be taught to interpret the effects of general anaesthesia on the electroencephalogram? Comparison of performance with the BIS and spectral entropy

J. P. Barnard, C. Bennett, L. J. Voss* and J. W. Sleigh

Department of Anaesthesia, Waikato Hospital, Hamilton, New Zealand
**Corresponding author. E-mail: vossl@waikatodhb.govt.nz*

Background. Unlike the other physiological waveforms monitored in anaesthesia, the EEG lacks a regularly repeating pattern, implying that it would be very difficult for an anaesthetist to obtain any useful information from the raw EEG. There are, however, clear changes in the EEG caused by GABA-ergic anaesthetic agents. The anaesthetized EEG still looks like a random waveform, but clearly a different random waveform from that seen when conscious.

Methods. The aim of this study was to assess how 40 anaesthetists would perform at interpreting intra-operative EEGs compared with two processed EEG (pEEG) monitors, BIS and entropy, after a short educational presentation. Short segments of EEGs were used from the pre-induction phase, the intra-operative phase with adequate surgical anaesthesia, and the transition phase between these two states.

Results. While anaesthetists' performance varied widely, most could reliably differentiate an anaesthetized from a conscious EEG. Further, both humans (41% wrong) and machines (30% wrong) made mistakes. Unlike the anaesthetists, the pEEG monitors did not make a major error (i.e. producing a number in the conscious range (>85) when analysing an anaesthetized EEG or the converse error).

Conclusion. A brief PowerPoint presentation enables anaesthetists to recognize the effects on the EEG of GABA-ergic anaesthetic agents. In the clinical context, it remains likely that the combination of a pEEG monitor that clearly presents the EEG and a clinician who has a good, basic understanding of, and a willingness to look at, the raw EEG will result in more accurate interpretation of the intra-operative EEG.

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The EEG was first described in the early 1900s. The effect of anaesthesia on the EEG was noted soon after the discovery of these drugs.[1] Since the 1950s, anaesthetists have been trying to use the EEG to monitor 'depth of anaesthesia', but the complex and random nature of this physiological waveform has made its interpretation difficult. The development of the processed EEG (pEEG) monitors in the 1990s revolutionized the use of EEG during anaesthesia.[2] They use rapid mathematical analysis of the frontal EEG to generate a 'number' that can be used to titrate anaesthetic delivery.[3–5] pEEG monitors have been correlated with clinical indicators of anaesthesia and measured drug plasma (end-tidal) concentrations.[6–11] A recent, large, randomized, controlled trial showed that the use of BIS monitoring decreased the incidence of intra-operative awareness in high-risk patients.[12] Both BIS and entropy have also been shown to decrease both total anaesthetic administered and time to extubation.[13 14] Clinical indices based on physiological waveforms (e.g., ECG, invasive blood pressure, and pulse oximetry) are routinely checked by validating the processed output against the raw waveform. This should be no different for pEEG monitors. However, there is an assumption that EEG interpretation is beyond all but a select few anaesthetists who spend years

acquiring that skill. While this might be true of the full scope of EEG interpretation, we believe the basic changes seen with the transition from awake to anaesthetized states using GABA-ergic-based general anaesthesia are simple and consistent. Any anaesthetist can learn to recognize them, and this ability will add clinical value, not just academic interest. As long as the raw EEG remains a mysterious wavy line to anaesthetists, the EEG monitors will remain in a time warp of under-utilization and distrust. Anaesthetists cannot do the fast Fourier transformation or the spectral entropy calculations. However, we are quick to recognize patterns, potentially faster than the pEEG monitors.[15] Most importantly, we know the clinical context. The ability of anaesthetists to learn how to interpret the effects of general anaesthesia on the raw EEG has not been studied. This study had two aims as follows:

- To teach anaesthetists about the frontal EEG and how it changes from the awake to the anaesthetized state.
- To see how anaesthetists, after our teaching session, compared with BIS and entropy at grading EEGs in terms of 'depth of anaesthesia'.

Methods

We prepared a 15 min long educational PowerPoint presentation. This focused on the features of an awake EEG and the changes that occur as a patient becomes anaesthetized (see Appendix). The teaching presentation was repetitive, simple, focused on key themes, and had numerous examples.

Segments of EEG recordings from previous studies done at Waikato Hospital (Hamilton, New Zealand) using sevoflurane and propofol anaesthesia were used. The clinical context for each EEG was known, and this was our 'gold standard'. The three clinical contexts were

- awake: alert and responsive to verbal commands, before the administration of any anaesthetic drugs.
- transition/sedated: within 30 s of loss of responsiveness to a verbal command after either an i.v. propofol or an inhalation sevoflurane induction.
- anaesthetized: during the course of a surgical procedure using clinical and pharmacological means (MAC or estimated plasma concentration) to ensure anaesthetic depth.

The EEG educational presentation was presented to the Waikato Hospital anaesthetic department as part of one of our routine monthly educational meetings. There were 30 specialists or trainees at the live presentation, and CD copies of the presentation (fully automated with the same commentary) were sent to the remainder of the department.

Immediately after the teaching presentation, the subjects were tested on their ability to match sample EEGs with behavioural state. Each EEG presented was 5 s long and scaled so that the tracing nearly filled the width of a PowerPoint slide. The test was divided into two parts. The first part involved ranking triplets of EEGs. Ten different triplets required ranking. Each triplet was taken from the EEG of a single patient. It was presented on a single slide and demonstrated a segment of awake EEG, a segment of EEG taken during transition from awake to anaesthetized, and a segment of EEG taken during surgical anaesthesia (Fig. 1). The vertical ordering of the segments on each slide was randomized and the subjects were asked to order the segments as awake, transition/sedated, and anaesthetized. Each ranked triplet was marked either correct (if all three EEGs were ranked appropriately) or incorrect.

The second part of the test involved interpreting 30 randomly chosen EEG segments. This was intentionally made as difficult as possible, as the segments were presented without any context whatsoever. The subjects were blinded to the fact that there were 10 from each of the awake, transition and anaesthetized states. For each EEG, we asked the following question, 'Is this patient awake or asleep (i.e. drug-induced unresponsiveness)?' If the anaesthetist thought the patient was asleep, there was a second part to the question: 'Imagine that surgery is proceeding currently; on the basis of the EEG are you happy for surgery to continue?' On the basis of the answers to these questions, the subjects' interpretation of each EEG was categorized as either (i) awake, (ii) transitional/sedated ('asleep but not happy for surgery to continue'), or (iii) anaesthetized ('asleep and happy for surgery to continue'). Contingency tables were tabulated comparing 'actual' (the clinical context that the EEG was taken from) with subject interpretation. The performance of the 'average anaesthetist' was obtained by pooling the results generated by all the subjects and dividing by the number of subjects.

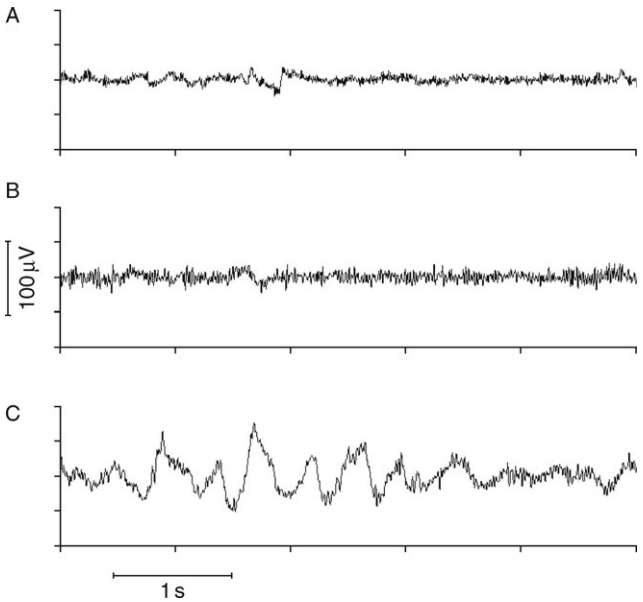

Fig 1 Graph showing an example of one of the EEG triplets used in the first part of the teaching quiz. (A) Awake EEG, (B) transition EEG, and (C) anaesthetized EEG.