British Journal of Anaesthesia 1998; **80**: 342–344

Bispectral index: comparison of two montages

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Summary

We have compared fronto-central and bifrontal montages using a new EEG monitor, the Aspect A-1000. The monitor uses bispectral analysis to derive an index of anaesthetic depth, the bispectral index (BIS). We compared reliability, impedance and BIS for each montage. ECG electrodes placed in a bifrontal montage were more reliable than silver dome electrodes in a fronto-central montage and both types of electrodes had impedances in the clinically useful range. However, BIS values derived from each montage were found to differ in an unpredictable manner. The bifrontal montage is easy to apply and reliable but it is not comparable with a fronto-central montage. We conclude that the BIS may be useful for following trends in anaesthetic depth in individual cases but it is less helpful when making comparison between patients or as a single value. (*Br. J. Anaesth*. 1998; **80**: 342–344)

Keywords: monitoring, electroencephalography; anaesthesia, depth; equipment, EEG monitor

A non-invasive, simple to use measurement of anaesthetic depth would be of great value. The measurement should preferably be based on changes at the anaesthetic site of action, ideally would be independent of anaesthetic type, and be able to predict awareness and recovery from anaesthesia. Many attempts have been made to use electroencephalograph (EEG) derivatives such as spectral edge frequency (SEF) and power spectral analysis (PSA) to measure changes in depth of anaesthesia. A limitation of these methods is that they do not use all of the information available within the EEG signal. For example, PSA can only quantify power distribution as a function of frequency, ignoring phase information.[1] SEF and PSA are not universally successful measures of anaesthetic depth and neither are used routinely in the clinical setting.

More recently, the Aspect A-1000, a four-channel EEG monitor, has been introduced into clinical practice in an attempt to fulfil this role. It generates a single number, termed the bispectral index (BIS), which is a guide to the level of consciousness. Initial studies used a fronto-parietal[2] or fronto-central[3] montage (lead arrangements) which requires electrodes to be sited within the hairline. Such montages may be difficult to use in routine clinical practice and the supposedly more convenient bifrontal montage, with electrodes positioned on the skin of the forehead, has also been used.[4] We have compared the BIS generated from two montages to determine if it is montage-dependent. We have also compared the reliability and impedance of ECG electrodes (which may be used conveniently for the bifrontal montage) with silver dome electrodes which are needed for the fronto-central montage.

Patients and methods

After obtaining approval from the local Research Ethics Committee, we studied 15 patients undergoing routine anaesthesia and surgery. Electrodes were placed at Fp1, Fpz, Fp2, C3, C4 and mastoid. The bifrontal and mastoid electrode sites were degreased with isopropanol, abraded with Nuprep (DO Weaver and Co., USA) and paediatric silver–silver chloride self-adhesive ECG electrodes (NiKo Medical Products) applied. The scalp was abraded with Nuprep at C3 and C4 and silver dome electrodes applied using Ten 20 (DO Weaver) adhesive paste. BIS was computed by an Aspect A-1000 (software v2.51 Aspect Medical Systems, Framingham, MA, USA) from the Fp1–Fpz and Fp2–Fpz pairs and from Fp1–C3 and Fp2–C4 pairs simultaneously, using the mastoid as ground.

Data were collected by computer every 15 s from 15 patients undergoing a variety of surgical procedures. Anaesthesia was not standardized and was controlled without regard to the results produced by the EEG. Electrode impedances were recorded whenever an impedance check was requested during the case, commonly when resiting an electrode. The last impedance value only from such an episode was used in the analysis. The security of lead placement was investigated by comparing the number of cases in which the frontal ECG leads were secure throughout, to the number of cases in which the central silver dome leads were secure throughout, using Fisher's exact test. The impedances of the two electrode types were compared using the Mann–Whitney test. BIS values from the bifrontal montage and fronto-central montage were compared using scatter plots for each individual. Data from all patients were pooled and the two montages correlated. Data were processed using Excel v7.0 and Arcus Biomedical v6.8.

Results

A total of 30 h of data were collected. At least one frontal electrode needed resiting during four cases, and at least one central electrode needed resiting

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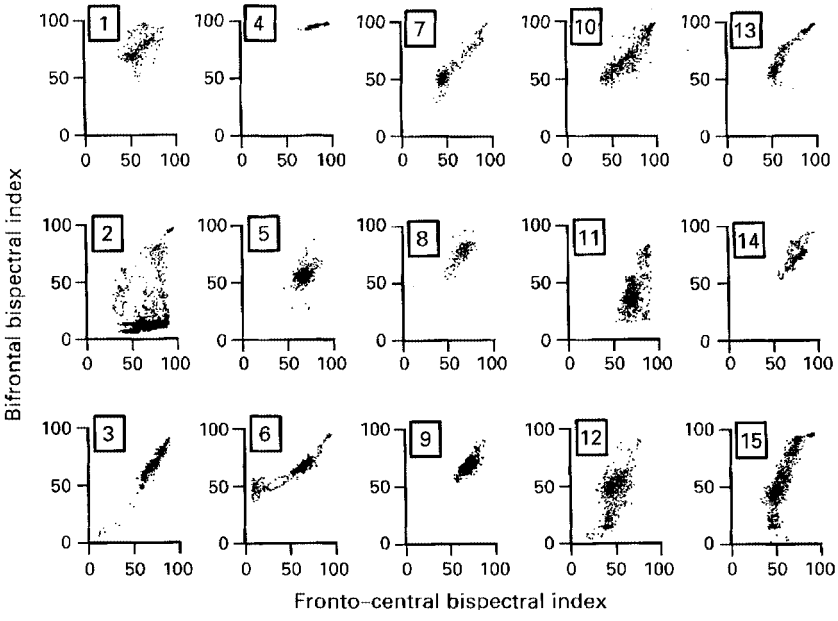

Figure 1 Fronto-central bispectral index plotted against bifrontal bispectral index for 15 patients during routine anaesthesia. Drugs administered included: methohexital (patient Nos 1, 3, 4, 5, 8, 9, 10, 12, 13 and 15), midazolam (patient Nos 2, 11, 12 and 15), fentanyl (patient Nos 2, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14 and 15), morphine (patient Nos 3, 4, 6 and 8), pethidine (patient No. 1), halothane (patient Nos 2, 5 and 13), isoflurane (patient Nos 3, 4, 8, 9, 10 and 12), sevoflurane (patient Nos 1, 4 and 7), enflurane (patient Nos 6, 7 and 14), desflurane (patient No. 6) and propofol (patient Nos 1, 6, 11 and 14). The variable relationship between bispectral index derived from the two montages does not seem to be drug related, and in many individuals the difference in simultaneous bispectral index measurements is greater than the separation found between patients who moved in response to surgical stimulation and those who did not.

during 11 cases ($P<0.02$). Median impedances were 2425 Ω (ECG electrodes) and 2700 Ω (dome electrodes). There was no difference in their distributions and values were within the clinically useful range.

Inspection of individual scatter plots of BIS from the two montages did not support the hypothesis that they were equivalent (see fig. 1). The agreement could not be improved by excluding BIS data pairs recorded during periods of poor signal quality or low total power. The pooled data revealed that the bifrontal BIS was, on average, 13 less than the fronto-central BIS and could be estimated as 0.68 (95% confidence intervals 0.65–0.71) of the fronto-central BIS.

Discussion

The EEG is a complex signal that can, through Fourier analysis, be broken down into several component frequencies. The analysis generates information on the frequency, power and phase of the signal and so facilitates interpretation. In order to use as much of the EEG signal as possible, a technique called bispectral analysis has been applied in the Aspect A-1000. This technique was developed in the 1960s by geophysicists to study retrospectively complex seismic waveforms.[5] The bispectrum is a measure of the level of phase coupling between different frequencies of the Fourier spectrum of a signal but it is difficult to interpret. Important information relating to anaesthetic effect may be contained within the phase relationships. Features of the EEG bispectrum which predicted response to surgical stimulus were defined using a stepwise regression.[6] These features were then combined using discriminant analysis into a multivariate index, with values from 0 to 100. This index is being refined and updated continually, although the details are not published, and it is known as the bispectral index (BIS). In summary, BIS is a number derived by the Aspect A-1000 from the bispectrum and other features of the EEG.

BIS has been investigated as an indicator of anaesthetic depth. One study showed that during thiopental–isoflurane anaesthesia with a fronto-parietal montage, BIS was significantly different between movers and non-movers.[6] In another study of isoflurane–alfentanil and propofol–alfentanil anaesthesia, BIS was significantly different between movers and non-movers in each anaesthetic group but could not differentiate between movers in the propofol group and non-movers in the isoflurane group.[7] BIS was also a better predictor of movement than end-expired isoflurane concentration.[7] These results suggest that BIS is dependent on the drug used in addition to depth of anaesthesia.

Regardless of its capability as a monitor of anaesthetic depth, we believe that it must be convenient to use if it is to become accepted clinically. We have not found the manufacturer's recommended electrodes (Zip-Prep, Aspect Medical Systems) to be useful within the hairline and in such positions we have had consistent success only with silver dome electrodes. Frontal electrodes are easier to apply and we have shown that they give a more reliable signal, which probably explains their adoption in more recent studies. It would be convenient if the BIS was independent of the choice of montage, but Kochs and co-workers found that EEG changes were dominant in frontal areas during isoflurane anaesthesia[8] and therefore it might be expected that different montages would give more or less sensitive indices of depth of anaesthesia.

Individual BIS data (fig. 1) showed differences between montages. Although a few cases showed excellent agreement between the two montages, in the

majority the difference between the bifrontal and fronto-central BIS was too great and too unpredictable to enable them to be used interchangeably under clinical conditions. For example, when the fronto-central BIS is in the clinically important range of 60–70, 50 % of bifrontal BIS measurements were outside the range 44–67 and 10 % outside the range 11–77. We conclude that if comparisons between bispectral indices are to be made, it is important that the montages and anaesthetics used are the same. If bifrontal ECG electrodes are used to obtain a BIS value during anaesthesia, it is important not to act on the measured value on the basis of studies using fronto-central montages. The BIS may be useful for trends in individuals, but single values or comparison between patients are of little use.

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