BIS EEG monitoring: what it can and cannot do in regard to unintentional awareness

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THE purpose of this lecture is to review the basic and clinical aspects of bispectral index (BIS)TM electroencephalogram (EEG) monitoring and the implications of this technique in regard to unintentional awareness.

I - BISTM EEG monitoring

What is the BIS monitor?

The BIS monitor has gained considerable popularity in the last five years, particularly in the United States. Recent advertisement (for example see the issue of October 2000 of *Anesthesiology*) indicates that it “provides information to help determine the optimum level of anesthetic for each patient”. The ads also claim that BIS “has been shown to improve patient care through reduced hypnotic drug use, faster wake-ups and monitoring for risk of awareness”. The Web site of the manufacturer (www.aspectms.com) presents the BIS technology as “the measure of excellence in consciousness monitoring”.

The BIS monitor is a device that records and processes the EEG to calculate a single, dimensionless number, called the BIS Index and designed to help the anesthesiologist adjust the dosage of anesthetic drugs. The word BIS was probably chosen because calculation of the Index depends in part on bispectral analysis of the EEG. The current version of BIS Index is the result of a search to identify features of the EEG that would reflect the clinical end-points of sedation and hypnosis.¹ The landmark study was published in 1997.²

The BIS Index is a proprietary combination of three parameters derived from analysis of the EEG: 1- burst suppression ratio; 2- relative β ratio and 3- SynchFastSlow. These parameters describe features belonging to the temporal, frequency and bispectral domain, respectively. The relative β ratio and SynchFastSlow components depend on high (30–47 Hz) EEG frequencies.³ Scalp muscles can produce sig-

nals in this frequency range and thus interfere with recording of the EEG and calculation of BIS.

BIS values and clinical end-points

The recommended BIS ranges are 65–85 for sedation, 40–65 for general anesthesia.¹ Values below 40 reflect burst suppression, a pattern associated with deep anesthesia. There is a low probability of explicit recall for BIS of 75 or less.⁴

Using BIS to reduce drug doses and speed postanesthesia recovery

Using BIS to guide anesthetic administration reduces doses and results in faster recovery. For an anesthetic using propofol, nitrous oxide and alfentanil, adjusting the propofol infusion rate to obtain a BIS of 45–60 during maintenance and 60–75 during the last 15 min reduced the infusion rate of propofol (134 vs 116 $\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; $P < 0.001$) compared with standard practice. It also decreased the time for return of responsiveness to commands (10.5 vs 6.7 min; $P < 0.001$) and eligibility for discharge from the recovery room (38 vs 32 min; $P < 0.05$).⁵ Similar findings were reported with desflurane or sevoflurane anesthesia except that postanesthesia care unit stay was not affected.⁶ With sevoflurane, the delay for return of responsiveness to commands was only marginally reduced, despite the statistical significance. A Finnish group confirmed that using BIS to guide administration of propofol or sevoflurane significantly reduces drug use (by 30–40%) and speeds return of consciousness (significant difference in the propofol group only). Detailed cost analysis revealed that BIS monitoring increased total cost because the price of the EEG electrodes exceeded cost savings on drug use. The break-even case duration was 704 min for propofol and 282 min for sevoflurane.⁷

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Pitfalls and limitations

The applicability of BIS monitoring to “real world” multi-drug anesthetic regimen requires further evaluation. The development of the BIS algorithm was based mainly on single anesthetic agent studies.⁸

There have been well documented reports of isolated cases of preserved consciousness (responsiveness to commands) with BIS values in the 50–65 range which overlaps the range recommended for surgery.^{2,9,10} A case of awareness with explicit recall has occurred with a BIS reading of 47.¹¹

Certain artifacts can falsely increase BIS. The most common is by far electromyographic activity.¹² Other possible sources include cardiac pacemakers, iv fluid and patient warming devices.

There are rare situations where BIS may be falsely reduced. These include the appearance of paradoxical EEG delta rhythm and artifacts from the pulsations of temporal artery or from movements of the eyes or head (source: BIS monitor info cards).

BIS is not affected by nitrous oxide even if there is unconsciousness.^{13,14} The same applies to ketamine.¹⁵

II - Awareness

Definition

“Awareness” refers to the conscious experiencing of an event at the time that it occurs. “Recall of awareness”, on the other hand, refers to the ability to remember the episode of awareness.¹⁶ It is important to distinguish “awareness” from “recall of awareness” because awareness can occur without subsequent recall.

It is possible that stimuli delivered to an unconscious, adequately anesthetized patient may, in some way, be retained in memory.¹⁷ The phenomenon of “unconscious learning and memory during adequate anesthesia” is best considered different from awareness and will not be discussed in this review.

Incidence

The incidence of awareness is unknown, as there are undoubtedly many instances when awareness occurs without subsequent recall. Most recent estimates of the incidence of recall of awareness range from 0.16% to 0.29%.^{18–20}

Mechanism

Parsimonious interpretation suggests that awareness results from the administration of an insufficient amount of general anesthetic drugs leading to return of consciousness and ability to recall the events experienced during the episode of consciousness.¹⁶ The dose insufficiency may be absolute (i.e., iv tubing disconnection) or relative (a normal dose given to a

patient who requires a larger amount). In a review of 4,818 cases of general anesthesia, Ranta *et al.*²¹ identified 19 patients with definite or probable awareness. These cases received smaller doses ($P < 0.03$) of the main anesthetic (propofol, isoflurane) compared with control patients.

Critical role of muscle relaxants

Most reported cases of unintentional awareness during surgery consists of patients who are awake but unable to move because of muscle paralysis.^{16,20,22} Traumatic episodes of awareness are invariably associated with muscle paralysis.²⁰ Awareness can occur in the absence of muscle relaxants but the problem is usually detected quickly because the patient moves. The incidence of undetected awareness when muscle relaxants are not used is very low.²⁰

Awareness frequently occurs without recall

There is ample evidence, based on the isolated forearm technique,²³ that awareness frequently occurs without recall.^{24–26} This may happen even if the patients experience pain during the episode of awareness.²⁴

The consequences of awareness without recall are not known. I think that we should nevertheless try to prevent awareness without recall because:

- a) “It is morally unacceptable to allow a patient to remain in pain or distress, even if there is no memory of the suffering”.²⁷
- b) Most patients expect to be unconscious during their surgical procedure and would not like the idea of being only amnesic.
- c) Prevention of awareness is the most effective method of preventing recall.²⁸

III - BIS and awareness

BIS monitoring and incidence of awareness

There is an apparent contradiction between the claims that BIS monitoring can reduce drug use and speed recovery while at the same time decreasing the incidence of awareness. Titrating doses of general anesthetics according to BIS may increase the doses of muscle relaxants as observed by Song *et al.*⁶ Increased reliance on muscle relaxant combined with low level of anesthetic concentrations certainly increases the chance of awareness.

Based on information provided by Aspect Medical Systems, BIS does not appear to increase the incidence of recall of awareness.¹ Definitive evidence on this issue is lacking and may not be available for years because of the very large sample size required.²⁹

What should I do?

BIS monitoring provides an interesting tool which gives the anesthesiologist feedback on the effects of anesthetics on the brain. I think initial experience with titration of general anesthetics based on BIS should only be attempted when muscle relaxants are not used. This approach works best if opioids are used to provide background antinociception. Modest concentrations of opioids markedly reduce the concentration of general anesthetics required to suppress movements^{30,31} and have a minimal effect on BIS.^{2,32,33} Another advantage of opioids (fentanyl) is that unconsciousness occurs at higher BIS values (BIS of 75 for the propofol and fentanyl group compared with 66 for the propofol only group).³⁴ With a target BIS of 60, the chance of consciousness is therefore probably reduced enough for the difference to be clinically significant. Whether the same phenomenon occurs with inhaled agents and other opioids needs to be determined. After familiarization with this technique, BIS titration may be attempted with cases with muscle relaxation. It is essential to adhere to the following recommendations:

- a) Use neuromuscular blockers only when necessary, and in the smallest amount needed. Maintain at least two twitches on train-of-four monitoring.
- b) Somatic and automatic signs of insufficient anesthesia should be treated with anesthetic agents, not with neuromuscular blockers, beta-adrenergic antagonists and vasodilators. The following report by a health worker³⁵ who experienced awareness is clear: *"I immediately realized that what I had done {move a leg} was to invite more pancuronium{...}"*. *"The nearest comparison would be the pain of a tooth drilled without local anesthetic - when the drill hit a nerve."*
- c) If there is a discrepancy between your clinical assessment and the BIS value, always pay attention to the patient first. If BIS is higher than expected, ensure that the patient is receiving the intended dose of anesthetic by confirming proper functioning of anesthetic delivery systems. If BIS is lower than expected, rule out artifacts and reduce hypnotic dosage only if the overall clinical picture suggests adequate anesthesia.
- d) Although the likelihood of consciousness is very low with a BIS of 40 (assuming it is a true reading not contaminated by artifacts) blind reliance on BIS to rule out awareness should be discouraged.
- e) If there is a discrepancy between BIS and conventional clinical methods of assessing the level of anesthesia, the information from BIS should be given a lower priority, particularly if the conventional methods suggest light anesthesia.

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