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BIS – fact or fiction?

By the perioperativeCPD team

Introduction

A Bispectral (BIS) monitor is one of several relatively new technologies used to monitor depth of anaesthesia. The BIS monitor is an electroencephalogram (EEG) device that uses an algorithm to analyse the electrical signal from the frontal cortex of the brain to generate a number between 0 and 100; the 'BIS'. Values between 40 and 60 are said to reflect a level of unconsciousness suitable for surgery.

Since its introduction BIS has proved to be controversial with a large number of studies both for and against it. So how does it work, and does it work?

Why do we need it?

Anaesthesia is an inexact science and getting the depth of anaesthesia right involves balancing the amount of anaesthetic with the varying levels of surgical stimulus and pain. Too little anaesthetic and the patient is aware, too much and the effects of the drugs start to compromise the patient and can slow their recovery.

The incidence of unintended awareness with pain is estimated as high as 1:2,000 general anaesthetics although estimates vary greatly. The recent NAP5 project in U.K. found an overall awareness of 1:19,600 although this varied greatly depending on the setting and whether muscle relaxants were used. Awareness is a real problem and the effects can be devastating for the patient.

There is no definitive way of measuring a patient's depth of anaesthesia. Clinical observations and end-tidal agent monitoring of volatile agents are used but these can be unreliable indices of awareness.
Total intravenous anaesthesia (TIVA) in particular has higher risk of awareness. Target controlled infusion (TCI) pumps do not measure the actual plasma concentration of the intravenous agent in the patient. They give an **estimated** plasma or effect site concentration, and will happily do so even if the infusion line is disconnected and the propofol is being pumped into the drapes or the floor.

BIS monitoring attempted to change this by using the electroencephalography (EEG) to give a number which correlates to a specific depth of anaesthesia or sedation.

Figure 1: Depth of anaesthesia

How does it work?

An EEG is a recording of low voltage electrical deflections caused by brain activity. This can be seen by attaching sensors to the surface of the forehead. The EEG changes that occur with anaesthesia are filtered, analysed and processed using bispectral analysis. The exact algorithm has not been divulged by Aspect Medical who designed the system.

Bispectral analysis uses complex formulas and high end-computer processing to find patterns in a single channel EEG trace and outputs it as an easy to interpret number between 1 and 100. This is known is a dimensionless number as it has no units of measurement.

Bispectral analysis was originally developed by mathematicians as a statistical method of finding patterns in complex multi-dimensional waveforms, specifically ocean waves. Ocean waves are not

only three dimensional; the ocean surface has small waves superimposed on larger waves with an underlying swell, all moving at different speeds and directions. Raw EEG data is similarly complex.

In an awake patient the EEG is characterised by fast low-amplitude activity. As the depth of anaesthesia increases the amplitude increases and the frequency decreases until you get an isoelectric trace (see Figure 2 below).

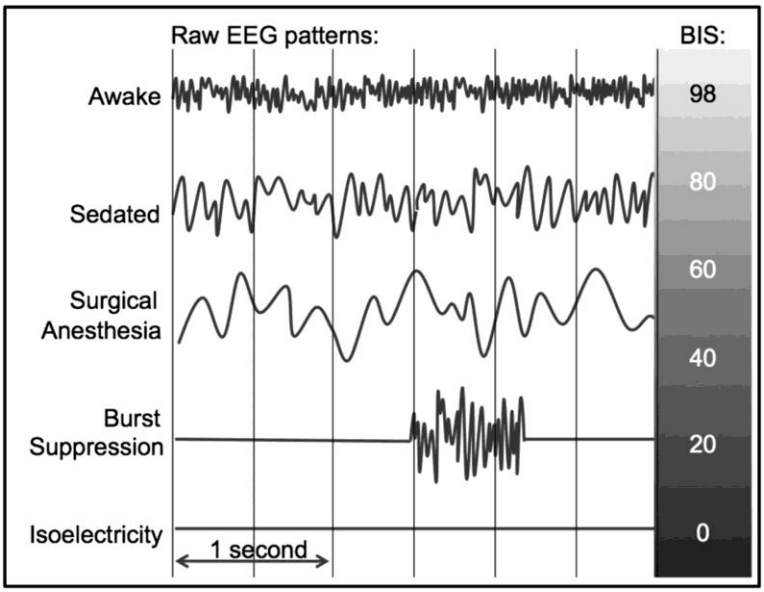

Figure 2: EEG change with deepening anaesthesia levels.

(Redrawn From Kelley SD: Monitoring Level of Consciousness during Anesthesia and Sedation. Natick, MA, Aspect Medical Systems, 2003.)

What is the BIS system?

The BIS system consists of a monitor and a single use electrode strip. These are joined by a patient interface cable which contains the BISx module.

Figure 3: BIS monitoring system

- **A single use adhesive electrode strip** with 4 sensors and a smart chip. Three of the electrodes pick up EEG activity. A fourth electrode is used to measure artefact and electromyographic (EMG) interference. The sensors have a gel pad and small plastic tines to help with contact. These tines can make applying the sensor to an awake patient uncomfortable as they are designed to break the first layer of skin.
  There are separate paediatric sensors (> 1 year), long term sensors and bilateral (dual channel) sensor strips available.

Figure 4: Paediatric BIS sensor.

- **A Monitor**, either stand-alone touch screen unit or as a plug-in module to enable display on an anaesthetic monitor. As well as the BIS index number and a trend graph the monitor can display several other information streams. They include the raw EEG trace, EMG activity, SQI and electrode status.
- **Patient interface cable (incl. BISx),** this joins the electrode strip with the monitor. More recent versions include the BISx module which performs initial filtering and processing of the patient EEG signals. It is located close to the patient's head where the EEG signal is less subject to interference from other medical equipment.

What the numbers mean?

The monitor displays a BIS index number which ranges from 0-100. Each numerical range correlates to a degree of sedation/anaesthesia.

BIS no.	Anaesthetic level	Response Level
90-100	Awake	Responding to normal voice.
70-90	Light Sedation	Responsive to loud commands or mild shaking.
60-70	Deep Sedation	Intense tactile stimulation is needed for a response.
40-60	General Anaesthesia	Unresponsive, Low chance of recall.
<40	Deep Anaesthesia	Increasing burst suppression (EEG pattern characterised by cycles of high-voltage electrical movement alternating with cycles of no activity.)
0	Suppressed EEG	No cortical activity, EEG flatline.

Table 1: BIS values

The BIS number is not displayed in real-time but with delay or smoothing rate. This is because the programme calculates the number as a rolling average of the last 15-30 seconds. This removes excessive fluctuations and artefacts. The raw EEG waveform can be displayed for interpretation by advanced users and this is displayed real time.

Remember: the BIS number tells you what was happening 15-30 seconds ago, not now.

Other Display information:

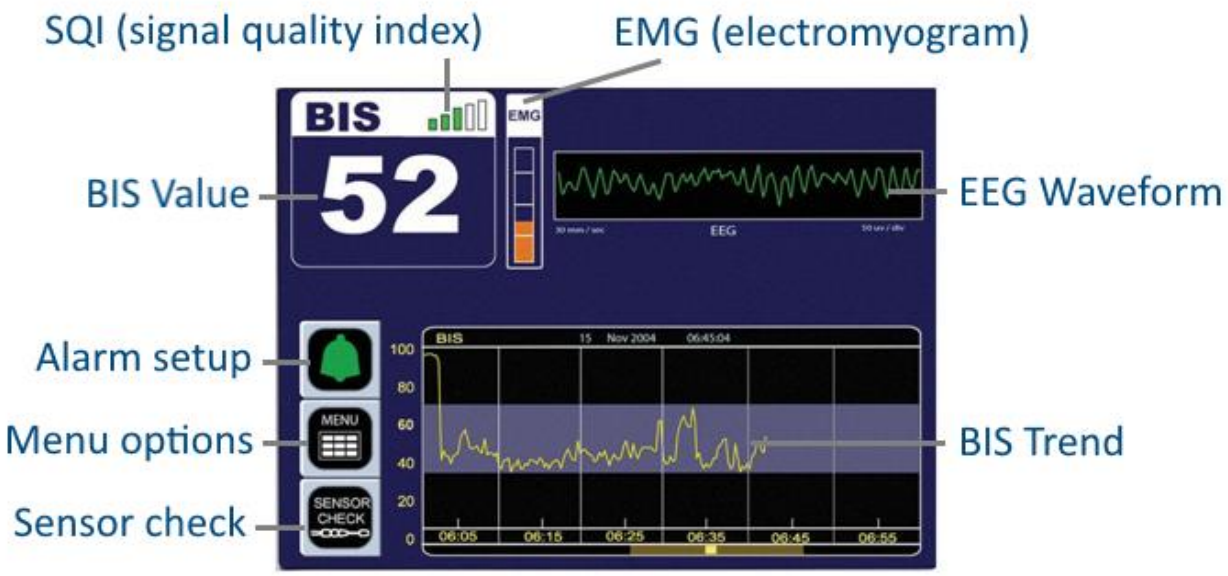

Figure 5: BIS display.

BIS Trend: Displays the BIS values over time.

EEG waveform: Displays the raw EEG waveform in real-time.

EMG (electromyogram): Reflects the electrical power in decibels (dB) generated by facial muscle activity and artefacts. A high level can result in an artificially high BIS reading. BIS monitoring levels are optimal when the bar is empty.

SQI (signal quality index): Shows the quality of the EEG signal and is based on the number of artefacts during the last minute. Ideally all 5 bars should be green. If the SQI is too low and an accurate BIS value cannot be calculated then a BIS value will not be displayed. This is often mistaken as a sensor problem.

SR (Suppression ratio) & Burst count: These optional display parameters are for advanced users.

What are the limitations?

BIs monitoring output can be affected by many factors. These include extremes of age, $PaCO_2$, hyper/hypoglycaemia, electrolyte imbalances, hepatic and renal function. Hypothermia, cerebral ischemia and some neurological states will reduce the BIS value.

Also of importance is knowing the varied response of BIS values to several important anaesthetic related drugs.

Ketamine, etomidate and ephedrine (not phenylephrine) all artificially increase BIS values while beta blockers and alpha2 agonists (clonidine) decrease BIS values.

Nitrous oxide, and opioids which increase the depth of anaesthesia, have almost no effect on the BIS value although the administration of opioids may prevent increases in the BIS level when pain levels increase.

Opioids produce changes in depth of consciousness not discernible by BIS

Neuromuscular blocking drugs (NMBDs) such as suxamethonium and rocuronium may lower BIS values as a result of decreased forehead muscle interference. This is important as these drugs do not provide anaesthesia and can result in awareness if not allowed for.

Applying the sensor.

Although the Quatro, Paediatric and Extend sensors appear easy to apply and clear instructions are included on the packaging, there are several tips that can ensure good contact.

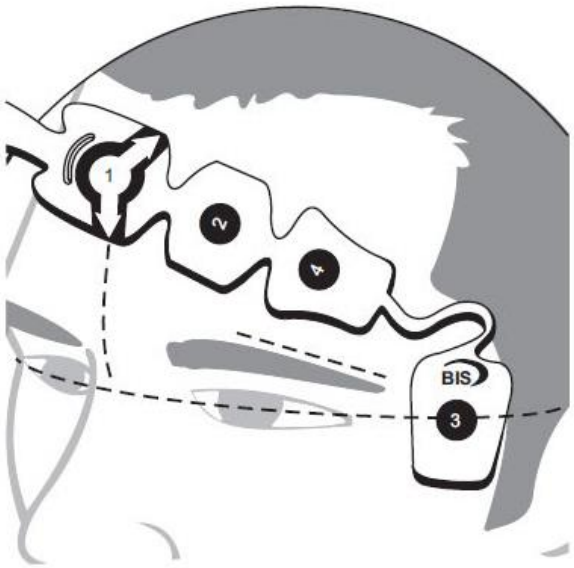

Figure 6: Applying the quatro BIS sensor.

- Check they are within date. Old sensors dry out and do not have enough gel to ensure good contact. Cleaning the forehead with alcohol wipes does make a big difference to the signal quality.
- Follow the instructions and press all around the edge of each of the four sensors before pressing on each centres for 5 seconds. Circling ensures that the tines anchor the sensor.
- Patience is your friend. Often it is not the sensor that is the issue, especially with an awake patient. Sometimes there is too much interference from the forehead muscles to give a reading. This may not resolve until the patient is anaesthetised.

Does it work?

BIS was released 20 years ago as a depth of anaesthesia monitor. It was, and still is, a very controversial piece of technology and it is not uncommon to hear it described as a 'random number generator'.

It has been subject to numerous trials, which have done nothing to clarify the debate. Several large studies showed an increased awareness using BIS as the anaesthetists administered a lighter level of anaesthetic than they would have done without BIS. Case reports show awareness in patients whose BIS level never rose greater than 60 and even one case when the BIS was maintained at 40 intra-op.

Probably the most damaging study to the reputation of BIS was carried out by Australian anaesthetists who administered either suxamethonium or rocuronium to volunteers. No other drugs were given and one arm was isolated using a tourniquet. This allowed the arm muscles to retain function and for the volunteers to communicate by means of hand signals.

With only muscle relaxants on board, no other anaesthetic or sedation drugs, and while answering various questions including mathematical calculations, the volunteers had recorded BIS levels below 50 (general anaesthetic level) for a significant time.

BIS is no longer marketed as a depth of anaesthesia monitor. Coviden (who now owns BIS) sell it as a system that helps clinicians determine and administer the precise amount of drug to meet the needs of each individual patient. Their marketing emphasises that it can reduce costs by saving on drug costs and enables faster wake up times.

This is particularly the case in elderly where BIS monitoring has shown that this group may have been overly anaesthetised.

Other depth of anaesthesia monitoring systems

While BIS is the most popular depth of anaesthesia monitor (if was released first in 1994) there are several other EEG based systems although they all have issues. None can reliably differentiate between a sleeping patient from an unconsciousness and anaesthetised patient.

Narcotrend
Narcotrend uses power spectral analysis and automated pattern recognition algorithms to classify the EEG into stages (A–F) and generate an index of depth of anaesthesia.

M-Entropy
M-Entropy analyses the amount of disorder in the EEG signal ('state' entropy). During anaesthesia, the EEG signal becomes more regular, resulting in decreased entropy.

aepEX
This device generates loud clicks via earphones at 7 Hz and records the EEG response.

Should we use it?

BIS has a role. It has been shown to be of no significant benefit where patients are receiving an inhalational anaesthetic. End-tidal monitoring and an age related MAC are more reliable indicators of the depth of anaesthesia and are not subject to the same level of interference.

Where it is useful is as an additional tool in TIVA cases where NMBDs have been given, especially where the cannula site is not visible. This style of anaesthetic has a higher risk of awareness and many anaesthetic colleges emphasise that brain function monitors should be considered in these cases.

In the case of TIVA it can be considered a tool to ensure that the patient is receiving adequate anaesthesia, the infusion rate is appropriate and to monitor trends, especially in elderly patients.

It cannot replace clinical judgement but is used as a way of confirming it.

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