Case Report

Increases in bispectral index lead to interventions that prevent possible intraoperative awareness

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In this case a woman underwent a cervical laminectomy with a total i.v. anaesthesia technique and during her care two problems occurred with propofol delivery. In both cases, bispectral index increases alerted caregivers to the decreased propofol delivery and allowed them to make corrections in a manner timely enough to prevent the occurrence of awareness during anaesthesia. The case illustrates how intraoperative processed electroencephalographic monitoring may decrease the incidence of recall of awareness following surgery.


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Current estimates are that one to two patients per thousand experience unanticipated recall of awareness (ROA) of intraoperative events following general anaesthesia.¹ A percentage of patients who experience ROA develop post-traumatic stress disorder.²³ Concern for patient well-being has prompted discussion of the potential of electroencephalographic brain activity monitors in decreasing this occurrence. Use of the Bispectral Index Monitor (BIS™, Aspect Medical Systems, Newton, MA) has been associated with an 80% decrease in ROA,⁴⁵ but these studies have not identified how use of the monitor decreases ROA. This case illustrates that the BIS monitor may decrease ROA through identification of issues of vigilance and equipment malfunction.

Case report

A 41-yr-old woman was undergoing an anterior cervical decompression and fusion at the C5–C6 level. She had a past medical history for hypercholesterolaemia, which was treated with atorvastatin 20 mg qd. Her symptoms included a C5–C6 radiculopathy, which presented as sporadic left shoulder pain, numbness and tingling. She had no other significant medical history. On physical exam she had no significant findings. Her height was 163 cm and she weighed 85 kg.

In the operating room, electrocardiography, non-invasive arterial pressure, and pulse oximetry monitors were applied, i.v. access was secured, and midazolam 4 mg was given intravenously for anxiolysis. A BIS XP™ sensor (software version 3.14, 15 s smoothing) was placed on the patient’s forehead according to the manufacturer’s specifications. A Datex M-NMT (Helsinki, Finland) monitor was used to monitor neuromuscular function. The anaesthetic plan was a total i.v. anaesthesia (TIVA) with the following parameters: propofol infusion titrated to maintain a BIS index of 40–60, opiate infusion titrated to maintain heart rate and arterial pressure no greater than 20% above baseline values, and rocuronium infusion titrated to maintain a T4/T1 ratio of 0.1–0.2. Propofol 10 mg cc⁻¹ was placed in a 60 cc syringe and a 1:1 mixture of fentanyl 50 μg cc⁻¹ and remifentanil 50 μg cc⁻¹ was placed in a 20 cc syringe. Each syringe was placed in a syringe pump and attached to a three-way stopcock with a length of extension tubing. The distal end of each extension tubing was attached to another three-way stopcock (Baxter, model 2C6240) and then attached to the distal infusion port of the i.v. line with a grasping connector (LeverLock Cannula, BD).

Following pre-oxygenation, anaesthesia was induced with propofol 1.5 mg kg⁻¹, fentanyl 1 μg kg⁻¹ and remifentanil 1 μg kg⁻¹. Following confirmation of ventilation, neuromuscular monitoring (train-of-four, 20 s) was begun and rocuronium 40 mg was administered. The trachea was intubated easily. The following infusions were started to maintain the anaesthetic goals: propofol at 100 μg kg⁻¹ min⁻¹, remifentanil/fentanyl mixture each at 0.04 μg kg⁻¹ min⁻¹, and rocuronium at 6 μg kg⁻¹ min⁻¹. The patient was positioned with both arms padded and tucked in alongside her torso.

The initial 30 min of surgery was uneventful and the infusions were not altered. Following incision of the periosteum of the cervical vertebrae and over the next 45 min,
the propofol and remifentanil/fentanyl infusions were increased sequentially to 200 μg kg⁻¹ min⁻¹ and 0.06 μg kg⁻¹ min⁻¹, respectively, in order to maintain the anaesthetic indices. The propofol was increased when BIS was increasing above 50. Over this period of time the BIS averaged 47, the maximal BIS value was 65 and the maximal minute-averaged BIS value was 61. At 11.10 am (Fig. 1, arrow A), the BIS rose quickly to a maximum value of 79, the greatest minute-average was 75, and there was no change in vital signs. In assessing the clinical situation, it was discovered that during a recent refill of the propofol syringe the stopcock had not been reopened to the patient, and the propofol was infusing back into the loading syringe. It was then estimated, based on the volume of propofol reinfused into the loading syringe, that the patient had not received propofol for 3–4 min. Following a bolus of propofol 50 mg, the BIS returned to the 50–60 range for the next 7 min. Then the BIS increased again and for 7 min the minute-averaged BIS was over 65 with a maximal BIS value of 80, again with no change in vital signs. The propofol infusion rate was increased to 280 μg kg⁻¹ min⁻¹ and a disconnection of the i.v. line was considered. We were, at that point, unable to fully investigate the tubing because of patient positioning and the contemporaneous delicacy of the ongoing surgery. However, following a bolus of propofol 50 mg, the BIS again decreased to the 50–60 range (Fig. 1, arrow B), making this diagnosis unlikely. For 4 min the BIS was below 60 and then rose once more, this time spending 4 min above 65 with no change in vital signs. The BIS again transiently responded to a bolus of propofol 50 mg (Fig. 1, arrow C). By this time the surgery had progressed to a point where the i.v. line could be investigated, which revealed a hairline fracture of the distal three-way stopcock at the attachment point of the propofol extension tubing (Fig. 2). The stopcock was turned off to the propofol, and desflurane 6% was started. The BIS quickly returned to the 50–60 range (Fig. 1, arrow D). The rest of the case and the emergence and extubation were uneventful.

The patient was questioned about awareness of intraoperative events using the Brice methodology six times: on the day of surgery in the post-anesthesia care unit, on postoperative day 4, and at 3 weeks postoperatively. At no time did she have any recall of intraoperative events.

Discussion

In this case information from the BIS monitor led to the identification of two issues, either of which, if undetected could have led to ROA. One, the incorrectly positioned three-way stopcock, was a failure of vigilance; the other, a cracked stopcock was an equipment malfunction.

While the causes of ROA are multi-factorial, it is clear that some cases result from this type of problem. A number of the ROA cases in the series from the closed claims database reported by Domino can be categorized as lack of vigilance or equipment malfunction. In five of those cases there was an undetected vaporizer leak and in three the vaporizer was not turned on. Inadequate dosing of drugs during difficult intubations (five cases) or during the maintenance phase (eight cases) was also generally judged to be substandard care by the author and related to lack of vigilance. In the 18 cases identified by Sandin, one occurred because the vaporizer was turned off for refilling, then not restarted. In a series of 81 cases of ROA reported by Bergman, 36 were judged because of low inspired volatile agent concentration. Equipment malfunction was causal in 16 of these cases and prolonged attempts at intubation were cited in five. The latter two authors both speculated that a significant percentage of ROA cases might have been prevented by electroencephalographic monitoring of depth of hypnentic state.
Two recent studies of the bispectral index monitor support these suppositions. Compared with 18 patients with ROA in an historical control group of 11 785 patients cared for without BIS monitoring, Ekman reported that only two patients of 4945 demonstrated awareness when cared for with the monitor. The difference in incidence of awareness between the two groups, 0.18 and 0.04%, respectively, achieved statistical significance (\(P<0.038\)). In patients at high risk for ROA investigated in a randomized, prospective clinical trial, Myles reported that the incidence of awareness with BIS monitoring (2 of 1225 patients) was significantly less than that without (11 of 1238 patients, \(P=0.022\)).

In both studies the incidence of awareness was decreased by about 80%.

Neither of these studies clearly explains how monitoring decreases ROA. One could speculate that some of the decrease could be caused by detection of equipment malfunction or lack of vigilance that, if undetected, would lead to ROA. A series of two cases reported that BIS monitoring allowed caregivers to detect equipment malfunctions that exposed the patient to risk of awareness: one vaporizer malfunction and one backed-up i.v. line. In both of these cases, however, the patients did experience ROA.

During the reported case, the patient spent a total of 11 min, during two different periods, with an average BIS value of greater than 65. This is the threshold that is associated with significant risk for ROA. It may seem surprising that this patient did not experience ROA. The threshold of 65, however, was developed from volunteers receiving only a hypnotic agent in a non-surgical setting. The interpretation of BIS values in the surgical setting is more complicated. The addition of opiates shifts the relationship between BIS value and measure of responsiveness to the right, that is, a higher BIS value is associated with a 50% chance of a population responding to a particular stimulus in the setting of hypnotic drugs combined with opiates compared with hypnotic agents alone. It is possible that the combination of propofol with opiates was such that a BIS above 65 was not as predictive of a state of risk for ROA as would have been the case with propofol alone. Also, the midazolam administered before induction may have been protective.

As the ideal BIS value for the prevention of awareness during surgical conditions is unclear, practitioners usually choose to add a ‘margin of safety’ and maintain the index below 65. In this case the goal was to maintain the index between 40 and 60, and in the author’s experience, this is best achieved by titrating the propofol so that the BIS oscillates around 50.

The choice of TIVA for a patient whose arms were not accessible for the duration of the procedure was, in retrospect, not ideal. It is not clear when during the procedure the fracture of the stopcock occurred. It was not evident during induction or during the positioning of the patient. The increased requirements for narcotic and propofol that occurred during the case may have not been due solely to increased surgical stimulation, but perhaps also due to leakage of the i.v. medications. It can be debated whether a TIVA technique exposes a patient to a higher risk of ROA than an inhalation agent technique. Lack of vigilance or equipment malfunction can occur with either technique. A prospective, randomized trial comparing the two techniques is needed before definitive statements can be made.

It is also not clear that ROA would have occurred if BIS monitoring had not been used. It is possible that the changes in the patient’s vital signs eventually would have occurred, which could have prompted intervention before awareness occurred. It should be noted that all of the interventions in patient care were prompted by changes in BIS, not vital signs. As the patient was maintained with only partially neuromuscular block, it is also possible that the patient could have moved in response to either problem, which might have led to intervention in time to prevent ROA.

The practice of combining fentanyl and remifentanil in a single syringe deserves comment. The intent of this mixture was to deliver an opioid that allowed the rapid onset-time of remifentanil with the prolonged postoperative analgesia associated with adequate effect-site concentrations of fentanyl. The practice, however, cannot be recommended for routine care before more information is obtained about the physiochemical properties of such a mixture and the pharmacokinetic/pharmacodynamic consequences of its use.

In this patient two separate events, one as a result of lack of vigilance and one as a result of an equipment malfunction, led to decreased propofol delivery and increases in the BIS index. Investigation of these BIS increases allowed the anaesthesiologist to diagnose the clinical problems and intervene in a manner timely enough to prevent ROA in a patient who might have otherwise experienced it. This case illustrates how brain activity monitoring may have prevented recall of intraoperative events.

References
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