Bispectral index (BIS) monitoring is new to critical care. The following case presentation and narrative describe our experience with this technology. Although this article highlights the potential benefits of using this technology in the critical care setting, our intention is to stimulate research and discussion that will increase understanding of the benefits and limitations of using BIS monitors in critical care units.

Background

Recent emphasis on promoting comfort for critically ill patients includes optimizing the assessment and management of sedation and analgesia. The Society of Critical Care Medicine and the American Society of Health-System Pharmacists collaborated to issue guidelines that recommend the establishment of a sedation goal or end point and regular redefinition of this end point for each patient. Until recently, sedation has been assessed indirectly, primarily by using vital signs and less commonly by using subjective sedation scales. Because of the limitations of these subjective assessment tools, over- and undersedation remain major challenges to critical care nurses. The BIS, an objective measure of sedation traditionally used in general anesthesia, is now being used in critical care. Our case study illustrates the effects of using BIS monitoring as a tool for adjusting the amount of hypnotic drug a patient receives during periods of chemical sedation in the neurointensive care unit.

BIS monitors provide information clinically relevant to the adjustment of dosages of sedating medications. Use of a BIS monitor may affect overall costs of sedation in critically ill patients. BIS monitors are noninvasive devices that reflect a signal-processed electroencephalogram (EEG). They provide an index of the degree of sedation in patients receiving mechanical ventilation and sedative agents after surgery, trauma, or medical illness. BIS monitoring was first developed as an adjunctive method of monitoring anesthesia states during surgery. After 11 years of validation and utility testing of EEG waveform analysis algorithms, BIS monitors were developed by examining certain EEG features derived from power spectral and bispectral analysis, noting various end points for consciousness, and incorporating features that correlate best with the changes in the hypnotic state.
A BIS monitor provides a continuous display of the current BIS and several parameters important to BIS monitoring (Figure 1). The BIS is displayed in the upper left corner of the monitor. This score ranges from 0 to 100 and is a measure of cerebral electrical activity. A score of 90 to 100 correlates with an awake state, scores in the 70s to 80s with conscious sedation, scores in the 60s to 70s with deep sedation, and scores from the 40s to 60s with general anesthesia (Figure 2). A single-channel raw EEG tracing can be continuously displayed. The signal-quality-index (SQI) bar indicates the reliability of the signal; the higher the SQI, the more reliable is the BIS displayed. The electromyographic (EMG) bar indicates EMG activity, which reflects muscle stimulation and can be caused by anything that increases muscle tone or results in muscle movement. Some of the major causes of increased EMG on a BIS monitor are motor activity, pain, seizure activity, eye movement, and poor electrode contact. The higher the EMG activity, the lower is the reliability of the BIS. The suppression ratio indicates the percentage of isoelectric EEG tracing. The trend part of the screen displays the history of various parameters.

Our neurocritical care unit (NCCU) was first introduced to BIS monitoring several years ago when a physician colleague asked for assistance in data collection for a clinical research study. The physician had hypothesized a direct relationship between BIS values and comatose states. The NCCU had been given a BIS monitor (A-1050, Aspect Medical Systems, Newton, Mass) to help collect data on BIS values and scores on the Glasgow Coma Scale and the Ramsay Sedation Scale. Within a short period, the nurses who worked with the study patients began to see relationships between BIS readings and patients’ sedation levels. The nurses hypothesized that sedation could be optimized by incorporating BIS monitoring into the care of patients in the intensive care unit (ICU).

**Case Study**

Mr B., a 57-year-old man with Guillain-Barré syndrome, had been treated with mechanical ventilation and subsequent tracheostomy. His condition was severe and had progressed to the extent that he could move only his head and neck. He could generate only minimal tidal volumes when he attempted to breathe on his own. The ICU team, including registered nurses, nurse practitioners, pharmacists, respiratory therapists, and the attending physician, had been finding it increasingly difficult to help him breathe effectively. One night, Mr B. had a dramatic decrease in PaO₂ and a marked increase in PaCO₂ related to ventilator asynchrony. Because Mr B. was receiving about 10 µg/kg per minute of propofol, a dosage that had previously reduced the amount of asynchronous ventilation, the choice

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**Figure 1** Bispectral index monitor with key components.

**Figure 2** Level of consciousness in relation to bispectral index.
was made to increase sedation levels to help him achieve adequate ventilation. In less than 2 hours, the propofol dosage was increased to more than 50 µg/kg per minute, and Mr B. experienced sustained tachypnea and asynchrony, rapidly deteriorating values on blood gas analysis, and increasing hemodynamic instability.

The medical team decided to chemically paralyze Mr B. while continuing sedation with propofol in an effort to control his ventilation. The nursing team received orders to prepare a continuous infusion of cisatracurium for chemical paralysis and to maintain a continuous infusion of propofol for sedation. Additionally, a phenylephrine infusion was ordered to treat hypotension that might have been caused by the propofol administration and poor ventilation. BIS monitoring was started before the cisatracurium was administered.

The initial BIS readings were confounding. Despite large doses of propofol, the BIS was between 85 and 98. The staff evaluated the validity of the readings and noted that the SQI bar was 100% and the EMG bar was slightly greater than 50%. These values signified a reliable BIS, but indicated that Mr B. had increased muscle tone. Although Mr B. had existing orders for analgesics, he had indicated that he had no pain or discomfort, and therefore he had not received any pain medication. Our nurses had previously noted that patients who are in pain often have high EMG levels because of increased facial muscle tone. A test dose of 2 mg of morphine was given intravenously, and Mr B.’s BIS decreased to less than 40 within 3 minutes of administration. The SQI bar remained at 100%, and the EMG bar decreased to zero. Asynchronous ventilation ceased, and pulse oximetry indicated improvement in the end-tidal carbon dioxide level and oxygen saturation. On the basis of his reaction to the test dose of morphine, Mr B. was given a continuous infusion of the drug. Subsequent blood gas analysis confirmed improved ventilation and oxygenation. The staff ordered adjustment of the propofol dosage to maintain a BIS between 60 and 70. During the next 12 hours, the propofol infusion was rapidly decreased, and eventually stopped, while the morphine infusion, which had been started at 5 mg/h was decreased to 1.5 mg/h. Use of a continuous infusion of a vasopressor and a paralytic agent and placement of a central venous catheter were avoided.

In this example, the nursing team was able to take the lead in promoting optimal care by encouraging the use of BIS monitoring combined with nurses’ judgment. The medical team was able to avoid the multiple complications that can accompany simultaneous administration of paralytics, sedatives, and vasopressors. Mr B. appeared to benefit from BIS monitoring, as indicated by his improved comfort, improved results on blood gas analysis, and the words of thanks he mouthed to the nurses.

Discussion

In a large, multicenter study, more than 80% of critical care nurses reported using sedative agents as part of their practice in the management of critically ill patients. Because of the severity of their medical condition, or to facilitate therapy such as mechanical ventilation or medical procedures, it is often desirable that critically ill patients not be agitated, nervous, or experiencing pain. However, no objective tool is widely used in critical care to measure the depth of sedation. This lack of an objective tool could lead to undersedation or oversedation, additional medical complications, having nurses function outside their scope of practice (ie, administering anesthetic doses of sedative agents), and a waste of financial resources. Additionally, anxiety and pain are often coupled in critically ill patients, and failure to treat both may result in the use of inappropriate doses of either sedative or narcotic agents.

Sedatives and hypnotics are a mainstay in the delivery of care to critically ill patients. In NCCUs, patients are likely to behave in ways that increase the risk for injury and thus necessitate chemical sedation. Patients with brain injury are often confused, agitated, and combative. Appropriate levels of sedation may prevent patients from injuring themselves or others. Patients at risk for secondary brain injury from cerebral edema and intracranial hypertension may benefit from sedation. Patients who are confused or experience anxiety while receiving mechanical ventilation may benefit from sedation to facilitate adequate oxygenation and cerebral perfusion. Sedation is also a main consideration for any patient undergoing an invasive procedure in the ICU, such as placement of a pulmonary artery catheter, endotracheal intubation, or placement of an intraventricular monitor. Adjusting the dosage of propofol according to the BIS may be useful for relieving discomfort during invasive procedures.

Critical care patients undergo many diagnostic and therapeutic procedures that produce pain. This pain can lead to both physical and psycho-
logical stress. Although patients are often given analgesics or sedatives for such procedures as placement of a central venous catheter, such medication is less likely to be administered for nursing care activities such as turning or endotracheal suctioning. Evidence is increasing that patients experience pain as a result of both turning and suctioning.17 Intubation and sedation interfere with the ability of critically ill patients to report pain.18 Monitoring the BIS in patients who are unable to report pain may provide practitioners and nursing staff additional cues to patients’ needs.

Although the use of sedation is well established in critical care units and some guidelines have been developed for having nurses administer sedatives and analgesic agents,19 the actual amount of sedatives a patient receives is determined on a much less scientific basis.20 Many ICUs lack protocols for sedation and analgesia.21 In a recent study on use of sedation, Weinert et al21 found that nurses are influenced not only by professional factors such as nursing knowledge about balancing sedation and comfort needs during critical illness, but also by personal factors such as individual beliefs and attitudes about sedation needs, and social factors such as the influence of patients’ families on the administration of sedatives. In 2 recent studies22,23 on critical care nurses’ assessment of anxiety, the cues that nurses used to assess anxiety were inadequate. In a study focusing on the impact of sedation assessment in critically ill adults, Devlin et al24 concluded that assessment of sedation in the critical care unit could improve patients’ care.

Brook et al25 found significant reductions in duration of sedation and time receiving mechanical ventilation when a sedation protocol was used. Implementation of a sedation protocol at University Medical Center in Las Vegas, Nevada resulted in significant decreases in length of stay and overall costs.24,25 Along with the development of tools to measure anxiety better, an objective measure of the adequacy of sedation, such as the BIS, could be key to sedation and analgesia protocols.

Conflicting Goals

Determining a patient’s best level of response is a crucial component of a comprehensive neurological assessment, and having this examination marred by the effects of sedation is undesirable. Although at least one study26 supports the use of scheduled once-a-day interruptions in sedation for any critical care patient, a unique aspect of NCCUs is the need to allow patients to awaken from sedation at frequent intervals. This practice complicates care and may make resedation difficult because NCCU patients often have marked underlying problems with agitation, pain, and delirium.26 Propofol is often the sedative of choice in our ICU because it has a relatively short half-life when compared with other sedatives traditionally used in critical care.27,28 Propofol’s short half-life and quick onset of action allow the rapid awakening and resedation preferred for neurological examinations. One common practice in the NCCU is to stop the propofol infusion until the nurse considers the patient sufficiently wide awake for assessment of neuro-

Critical care patients undergo many diagnostic and therapeutic procedures that produce pain.

The need for making this assessment is often balanced against the need for avoiding excessive loss of sedation. Patients who become too wide awake may have an increase in the risk for injury through 3 primary means: interference with adequate ventilation through asynchrony, increased intracranial pressure with the risk of secondary brain injury, and self-injury through self-extubation or removal of arterial or venous catheters.

Our nurses found that use of the BIS monitor in chemically sedated patients facilitated the conflicting goals of maintaining sedation and safely interrupting sedation to perform a neurological examination. The BIS monitor provided a safe means of assessing patients’ level of sedation while avoiding oversedation.29 With BIS monitoring, nurses have an objective measure of a patient’s level of consciousness even when sedation is interrupted. This practice enables them to monitor the patient for an objective determination of when the sedative effects have waned sufficiently. Consequently, fewer patients experience adverse physiological effects related to inadequate sedation.
Purchasing Decision

Use of a BIS monitor reduces cost and decreases the frequency of oversedation in the ICU. Additionally, clinicians are using the monitor in areas beyond ICUs and operating rooms, such as during palliative care and transport of patients. Our decision to integrate BIS monitors into the NCCU was based on 3 primary goals: enhancing patients’ care, decreasing nurses’ workload, and reducing the cost of sedation. We found that these 3 goals were integrally related. An independent audit of our current practice revealed that our patients were oversedated and received insufficient amounts of analgesics. Patients’ care could be enhanced by giving the right amount of sedatives, avoiding oversedation, and increasing awareness of the need for concurrent administration of analgesic agents to sedated patients.

Sedating a combative or confused patient is important for the safety of both the patient and staff. Propofol is an effective means of sedation. However, oversedation because of inadequate assessment of the need for sedation and unclear end points of sedation may result in adverse outcomes for patients. Oversedation not only compromises patients’ conditions but increases nurses’ workloads. A chemically sedated patient is likely to experience longer periods of dependence on mechanical ventilation and periods of hemodynamic instability, thus requiring significant medical interventions. This situation translates directly into increased nursing time, as well as increased costs for direct care. Nursing workload may be decreased because staff nurses can efficiently delegate time and resources to maintain an objective goal rather than having to depend on subjective clinical indicators that are unreliable. Our unit has now developed a sedation protocol in which the order can be written to adjust dosages of sedatives to maintain a prescribed BIS. Because anxiety and pain often coexist, the protocol also includes the concomitant use of narcotic analgesics.

Pilot Study

The cost associated with sedating critically ill patients is estimated to exceed $1 billion per year. It may be possible to decrease the cost markedly by using smaller amounts of sedatives per patient per day. As nurses adjusted dosages of sedatives to achieve a specific BIS goal (usually 60-70), they administered significantly less propofol than had been used before they began using BIS technology.

As our nurses gained confidence with BIS monitoring, it became evident that interest was strong in purchasing the BIS monitoring system to use for patients’ care. A pilot study of 4 patients was undertaken to evaluate cost-effectiveness and budget implications for the coming fiscal year. We retrospectively reviewed records of 4 patients who had been admitted to the NCCU. All 4 patients had been treated with continuous infusions of propofol for at least 24 hours before BIS monitoring was started. Propofol doses (measured in milliliters) during the 24-hour period immediately before BIS monitoring were compared with propofol doses during the 24-hour period after BIS monitoring was initiated (Figure 3).

Data on the number of milliliters of propofol used were compiled for each patient for the 24-hour period immediately preceding BIS monitoring and for the first 24 hours after BIS monitoring was implemented. Each 24-hour period was further broken down into three 8-hour segments to examine trends in drug use. A cost per

Figure 3 Amount of propofol used with and without bispectral index monitoring.
milliliter was determined from the costs for the 20- and 100-mL vials available at this institution, and this value was multiplied by the total number of milliliters of drug used in each 24-hour period. A combined total of 2742 mL of propofol was given to the 4 patients before BIS monitoring. This amount was nearly twice the total volume (1395 mL) of propofol administered to the same 4 patients during the first 24 hours of BIS monitoring. The mean cost per day for a patient requiring propofol for sedation without BIS monitoring was $377.03. This value was considerably higher than the $191.81 mean cost per day for a patient receiving propofol with continuous BIS monitoring.

We determined that our mean cost savings per patient was $185.22. According to the results of previous performance improvement projects, in our NCCU a mean of more than 2 patients per day receives propofol as a primary sedation agent. By extrapolating these numbers to account for a 1-year period, we determined a potential cost savings of $135,210.60 per year if results of BIS monitoring were used to adjust dosages of sedatives.

Hurdles Yet to Overcome

Change often comes slowly. Many nurses who learned to adjust dosages of sedatives without use of BIS monitoring have developed a set of skills upon which they rely. Furthermore, they may be reluctant to try newer technologies. Weinert et al,21 in a study of influences on nurses’ use of sedatives, reported that experienced nurses may prefer very liberal sedation orders. These orders leave the nurses free to adjust dosages of medication rapidly when the situation calls for it. The nurses also rely greatly on their previous experiences with sedation for their population of patients.21 This reliance is coupled with an awareness of a lack of scientific evidence supporting a particular sedative practice. Slomka et al35 explored the difficulties encountered when attempting to implement clinical protocols and found that problems involved reluctance of both physicians and nurses to change. Newer studies12,21,36 indicate that the cues most used by critical care nurses to judge sedation are inadequate, and reports of such results may help encourage a change in practice.

Strategies for encouraging change should take into account the experience of the nurses. Newer staff members, who do not have firmly established ideas about what cues indicate anxiety and pain or adequacy of sedation and analgesia, can be encouraged to use the BIS monitor to develop their own best practice. More experienced and expert staff members can be encouraged in the use of the BIS monitor through familiarization with supporting literature and personal experience to refine their best practice. Ensuring that the nurse practitioners and medical residents who staff the NCCU are early proponents of the technology is also a key factor, because they are often responsible for generating the initial sedation and analgesia orders in collaboration with the attending physician.

Conclusion

Clinically, use of a BIS monitor may help standardize clinical practice and improve patients’ care.4 Physicians may then be able to order sedatives to achieve a BIS of 60 to 70, and nurses can objectively and readily adjust the dosage of sedative as needed throughout a patient’s stay in the critical care unit. Such an arrangement would help alleviate the occurrence of undersedation and its associated stress-evoking memories and/or oversedation, often associated with the provisional need for ventilatory and cardiovascular support. Having an objective BIS as a guide for adjusting the dosage of sedating agents could also minimize medical complications such as pancreatic, liver, and renal injury; depressed cardiac contractility; and blunting of protective reflexes (ie, corneal, cough, gag) associated with excessive use of sedatives and their metabolism. Use of a BIS monitor can also provide financial benefits by limiting excessive use of costly sedatives and decreasing the time to extubation. Further studies are required to determine the potential benefits.9

Although a BIS monitor can be a helpful adjunct to sedation in the critical care unit, nurses are still expected to use critical thinking skills when using this tool. Published reports are inconclusive. In a study of 19 patients consecutively admitted to a surgical ICU, Frenzel et al,27 found that BIS monitoring correlated with level of sedation in some patients but could not be validated as a tool suitable for monitoring sedation in a heterogeneous group of surgical ICU patients. The body of evidence that supports the use of BIS monitoring is growing. Yet by no means is it a perfect tool. One concern is whether a low BIS could reflect a neurological deterioration and not just a deeper level of sedation, which in turn would mandate a different plan of action. In light of the present body of evidence...
regarding the BIS monitor, we think BIS monitoring is a helpful, safe, and cost-effective technology to aid in monitoring depth of sedation in critical care units.

References