The BIS monitor should be standard in all cardiac operations.

PRO

Avery Tung, M.D.
Associate Professor,
Department of Anesthesia
and Critical Care
University of Chicago
Medical Center

Relative to other types of surgery, patients undergoing cardiac surgery are at higher risk for awareness[1]. The reasons underlying an increased risk of awareness in cardiac surgery patients are many. The wide scope of surgical stimulation requires that anesthetics be titrated to a wide range of stimuli including sternal division and skin closure. Hemodynamic instability limits the administration of volatile anesthetics, and cardiopulmonary bypass unpredictably alters drug levels. Increased case complexity diverts attention away from anesthetic titration, raising the risk of inadequate anesthesia. Finally, uncertainty about the return of mental status in patients at risk for neurologic injury may make physicians reluctant to administer intravenous agents such as midazolam. In light of these issues, the high incidence of awareness documented in the literature during cardiac surgery is predictable.

In principle, a monitor to detect intraoperative awareness should be extremely useful. By warning of inadequate anesthetic levels during a complex case, a monitor of anesthetic depth may redirect attention and help anesthesiologists avoid inadvertent anesthetic underadministration. By reassuring the caregiver about the adequacy of anesthetic depth, a depth monitor may help avoid anesthetic overdose (on induction, for example), and subsequent cardiovascular instability. By measuring anesthetic depth in the brain, a depth monitor allows a more nuanced assessment of changes in blood pressure or heart rate. Finally, identifying the occasional patient who is resistant or excessively susceptible to anesthetic agent may allow more rapid recognition of inadequate anesthetic administration.

Despite more than 15 years of experience and national society guidelines[2], however, widespread acceptance of brain function monitors (BFMs) has not yet occurred. Considerable controversy currently exists among anesthesiologists with regard to the utility of such monitoring. Arguments against use of the monitor have included cost (routine use of BFMs is too expensive)[3], lack of proven efficacy (results of clinical trials[4, 5] are flawed or mixed[6], an unacceptably high error rate (occasional reports of awareness with BFM use exist)[7, 8] and disagreement as to the real rate of awareness after anesthesia (for review see 9). Even as intraoperative awareness has become a JCAHO sentinel event[10], disagreement among anesthesiologists persists.

All of the above arguments are reasonable, and are well documented. But they are not unique to BFMs, and nearly all have been made at one time or another about practically every monitor currently in routine use by anesthesiologists.

It is unclear from clinical trial data, for example, whether brain function monitoring reduces the incidence of awareness. While one retrospective[4] and one large multicenter trial[5] found benefit, another[6] was equivocal. Based on these data, an argument that BFMs are not useful seems reasonable. But no currently used monitor, whether used by anesthesiologists or otherwise, has ever demonstrated unquestioned benefit in prospective, randomized, controlled trials. Rather, some monitors have clinical trial data unequivocally demonstrating no outcome effect (PAC[11], pulse oximetry[12]), whereas others (arterial pressure monitoring, EKG, end-tidal gas monitoring, or neuromuscular block monitors) have not been tested in a prospective, randomized fashion. This historical inability to show benefit to even basic monitoring is nearly universal in medicine (neither fetal heart rate[13] nor fetal pulse oximetry[14] change outcome in obstetrics), and suggests that adequate metrics to evaluate the cognitive and decision-making benefits of monitoring have not yet been developed.

Perhaps the closest analogy to brain function monitoring might be intraoperative transesophageal echocardiography (TEE). TEE is clearly superior to EKG or PAC for detecting perioperative myocardial ischemia[15]. Similarly, brain function monitoring is well correlated to anesthetic dose and the likelihood of awareness (for review see[16]). Both affect decision-making[17, 18]. But the effect of TEE on revascularization outcomes is less clear, as is the effect of brain function monitoring on awareness incidences. If clear evidence of efficacy in prospective, randomized clinical trials is the litmus test for choosing intraoperative monitors, then both the PAC and pulse oximeter should disappear from today's operating room.

This lack of solid outcome data involving monitors also applies to arguments involving cost. Clearly, if BFMs fail to reduce awareness, they cannot be cost effective. But again, the same argument could be applied to PAC monitoring (at a far greater cost), pulse oximetry, or TEE. None (like BFMs) are cost effective, because none (like BFMs) have clear, documented effects on outcomes.

On absolute terms, reports of brain function monitors failing to detect awareness[7, 8], or producing measurements with difficult-to-explain variability[19] are troublesome. Variable or erroneous measurements, however, are not limited to BFMs. Arterial lines, PACs, EKGs, and pulse oximeters also have well-described modes where they fail to produce accurate measurements, or are corrupted by external influences such as electrocautery, cardiopulmonary bypass, or inadequate perfusion. Although not systematically studied, a finding that BFMs may depend on laterality[19] is, in principle, no different from observations that an arterial line in one wrist may disagree with an arterial line on the other side. In this case, unfamiliarity with typical BFM failure modes may generate an increased aversion to these failures than to more familiar ones. Human aversion to uncertainty is well-established[20], and likely plays a role in this behavior. As with nearly all monitors, it is likely that increased experience with BFMs will reduce uncertainty, and improve acceptance.

Finally, some have observed that the low incidence of awareness renders BFMs unnecessary. This argument implicitly assumes that monitors should be preferentially targeted towards high

frequency events. But this argument, although rational, fails to explain daily clinical behavior, which targets not necessarily high frequency events, but those with the greatest perceived impact on patient outcomes. Literature estimates of the frequency of epidural hematoma (after epidural placement) in cardiac surgery range from 1 in 1700 to 1 in 12000[21]. Moreover, only a fraction of these lead to actual neurologic injury. These incidences are well below consensus estimates of awareness during cardiac surgery (1 in 500 to 1 in 100)[9]. Yet the risk of epidural hematoma is so much more cognitively prominent than the risk of awareness that physicians frequently shun epidural analgesia to avoid the risk of neurologic injury, but do not monitor for postoperative awareness that can be equally as life-altering[22]. Such behaviors indicate that decisions regarding which complications to prioritize are (rightly) not made solely on the basis of statistical probability, but also on the joint preferences of patients who ultimately take the risk and the physicians who deliver the care.

The actual utility of brain function monitoring remains undetermined, may differ among practitioners, and will likely change as technology improves. As described above, metrics to assess the value of specific monitors should not only evaluate outcomes, but also cognitive effects on caregivers and patients, patient preferences regarding which complications to prioritize, and familiarity with failure modes. Many current arguments against brain function monitoring, however, compare it to an ideal monitoring standard where performance is perfect, failure is impossible, outcomes are changed, and cost is minimal. Against this standard, BFMs fall short. But so does every other monitor currently used in cardiac surgery. If the patient prioritizes awareness as a highly undesired outcome, and the technology is available, then perhaps a better question than "why use BFMs" should be "why NOT use BFMs"?

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