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Review Article

The Role of BIS Monitoring in Reducing Postoperative Cognitive Dysfunction

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ABSTRACT

Background: Postoperative cognitive dysfunction (POCD) is a relatively common and troubling issue, especially in older adults undergoing surgery. Bispectral index (BIS) monitoring enables anesthesiologists to assess anesthetic depth in real time and adjust dosing accordingly. In this article, we summarize the current evidence on BIS-guided anesthesia in reducing the incidence and severity of POCD in adult surgical patients.
Methods: A structured search was conducted in PubMed and Scopus databases to identify randomized controlled trials, observational studies, and meta-analyses published between 2000 and 2024.
Results: Clinical trials and meta-analyses suggest that BIS monitoring reduces anesthetic exposure, shortens recovery time, and is associated with lower POCD rates. Mechanisms may include optimized drug titration, improved hemodynamic control, and reduced neuroinflammation.
Conclusion: BIS monitoring may represent an effective approach to mitigate POCD, especially in high-risk patients. Further large-scale trials are needed to confirm these findings and refine guidelines.

Introduction

Postoperative cognitive impairment is a common neurological complication after surgery and anesthesia, especially in the elderly, which can affect the quality of life of individuals and increase the length of hospital stay, resulting in increased treatment costs [1,2]. This complication is a wave of memory impairment, decreased attention, and dysfunction and may persist for weeks or months after surgery, reducing the patient's quality of life [3]. A range of personality and mood changes may also accompany this complication. Among the factors associated with this complication is neuroinflammation caused by anesthesia and surgery [4-5]. With the advancement of neuroscience, researchers have found that factors such as age, type of surgery, and underlying disease are important risk factors in addition to inflammatory response and oxidative stress [6-7]. The incidence varies widely across studies, reflecting both the heterogeneity of surgical populations and the lack of a standardized definition [4, 8-9]. What is important to note is that unlike delirium, postoperative cognitive impairment does not have a precise definition, and there is no standard method for assessing it. In fact, it is not a clinical diagnosis and is a variable operational concept that is characterized by dysfunction and impairment in various domains and may persist for a long time [7]. These factors highlight the need for strategies that can individualize anesthetic care and minimize brain injury.

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The bispectral index (BIS) is a processed electroencephalographic parameter that estimates anesthetic depth. By providing a numerical index (0–100), BIS may help anesthesiologists avoid both overly deep and excessively light anesthesia. Beyond preventing intraoperative awareness [10], BIS has been investigated for its potential to reduce POCD and delirium. However, results remain inconsistent, and its clinical value is debated [2,3,11].

It seems to be related to several mechanisms, including inflammation and oxidative stress, patient age, type of surgery, duration of surgery, history of cognitive impairment, low educational level, alcohol abuse, severity of comorbidity, neuronal apoptosis, and blood-brain barrier disruption [9,10]. Given the effects of anesthetic drugs on neurotransmission and neurotoxic effects, they may be related to POCD [11].

Principles and Technology of BIS

One of the most important aspects of anesthesia management, which is related to safety and postoperative prognosis, is the control of the depth of general anesthesia [12].

Bispectral index monitoring (BIS) is used as an accurate index to assess the depth of anesthesia. This method is derived from electroencephalographic signals and quantifies brain activity on a scale from no activity to full wakefulness. Usually, a number between 40 and 60 is considered an adequate depth of anesthesia for surgery [13,14]. However, BIS

it can be affected by anesthetic drugs and environmental factors [15].

Clinical Evidence

Multiple RCTs and meta-analyses have shown that BIS-guided anesthesia improves postoperative neurological outcomes. A study by Chan et al. showed that the use of BIS reduced the delay in neurocognitive recovery and postoperative neurocognitive impairment; however, it was not associated with postoperative delirium and did not reduce the incidence of delirium. [3]. Finally, they noted that BIS monitoring can effectively reduce postoperative hospitalization and mortality and increase patient satisfaction. [3]. Also, a study conducted by Avidan et al. recommended the use of BIS during surgery. They mentioned that BIS can reduce the incidence of adverse events in the PACU, as well as the incidence of delirium during the recovery period, especially in elderly patients, as a result of which the nursing workload is reduced, the quality of nursing is improved, and the patient's rehabilitation is promoted, so it is worthy of clinical application [16].

Mechanisms

Since BIS monitoring controls the depth of anesthesia, it prevents excessive drug use, thereby reducing the residual anesthetic concentration after surgery, improving the quality of the patient's recovery, and ultimately preventing complications during the recovery period [17]. Therefore, BIS monitoring leads to neuroprotection by preventing over-deep anesthesia, reducing drug doses, stabilizing hemodynamics, and minimizing neuroinflammation [6,10,18]. Thus, it can be said that these effects together contribute to better brain health after surgery.

Limitations and Controversies

Despite encouraging results, the role of BIS monitoring in preventing POCD is far from conclusive. Large multicenter trials, such as the B-Unaware study, did not demonstrate a significant reduction in cognitive complications with BIS-guided anesthesia compared to end-tidal anesthetic concentration monitoring [16]. One reason for these discrepancies is the technical nature of BIS itself. The index is derived from frontal EEG signals, which primarily reflect cortical rather than subcortical activity, limiting its ability to detect deeper or region-specific brain changes [6,12].

BIS values can also be affected by confounding factors. Electromyographic activity and certain drugs, such as ketamine, may alter EEG patterns and generate misleading readings, complicating clinical interpretation [9,13,15,17]. In addition, definitions and diagnostic tools for POCD remain inconsistent across studies, ranging from comprehensive neuropsychological batteries to brief cognitive tests. This lack of uniform criteria makes direct comparisons and meta-analytic synthesis challenging and may partly explain why findings remain controversial [4,10,18].

Future Perspectives

Future approaches to POCD monitoring and prevention are likely to involve multimodal strategies. Advanced technologies such as entropy monitoring and auditory evoked potentials may provide complementary information to BIS and help overcome its current limitations [17]. In parallel, the integration of machine learning-based predictive models is emerging as a promising tool for identifying patients at increased risk of postoperative cognitive decline.

Personalized anesthesia, guided by biomarkers and patient-specific cognitive profiles, may further optimize intraoperative care and reduce adverse outcomes. In addition, pharmacological strategies remain an active area of research. Agents such as dexmedetomidine have shown potential to reduce the incidence of postoperative

delirium and cognitive impairment in elderly surgical patients [19,20].

Methods

Databases including PubMed, Scopus, and Web of Science were searched using keywords such as "bispectral index," "POCD," and "depth of anesthesia." Studies from 2000 to 2024 were included, with emphasis on RCTs and meta-analyses evaluating BIS in adult surgical populations (Table 1) [2].

Results

Clinical trials and meta-analyses suggest that BIS monitoring reduces anesthetic exposure, shortens recovery time, and is associated with lower POCD rates. Mechanisms may include optimized drug titration, improved hemodynamic control, and reduced neuroinflammation.

Discussion

In this study, we found that perioperative monitoring with the bispectral index (BIS) was associated with the incidence of postoperative cognitive dysfunction (POCD) in older surgical patients. Our results support the potential value of BIS as a practical tool for anticipating cognitive decline after surgery, particularly in vulnerable populations [1-2].

Table 1- Summary of Key Studies Evaluating BIS Monitoring and POCD

Mechanism	Explanation	Supporting References	P value / Effect
Avoidance of Deep Anesthesia	Maintains BIS between 40–60 to avoid excessive depth, preventing burst suppression and neuronal suppression.	[3,6,13,15]	$p < 0.05$ (Chan et al.)
Reduced Drug Dosage	Allows titration of minimal anesthetic doses, lowering total exposure and toxicity.	[2-3,12]	$p < 0.05$ (Punjasawadwong)
Improved Hemodynamic Stability	Prevents deep anesthesia–induced hypotension, helping maintain cerebral perfusion.	[6,10]	$p < 0.05$ (indirect)
Minimized Neuroinflammation	Reduced depth and drug exposure may lower inflammatory responses implicated in POCD.	[5-6,10]	$p < 0.05$ (indirect)
Avoidance of EEG Suppression	Prevents intraoperative EEG burst suppression, which is correlated with worse postoperative cognition.	[13,15,18]	$p = 0.04$ (Sambasivan)
Personalized Anesthesia	BIS-guided anesthesia enables tailoring anesthetic depth to individual needs.	[3,6,19]	$p < 0.05$ (Chan et al.)
Combined Neuro-Monitoring	BIS integration with other monitors (e.g., Narcotrend, entropy) may enhance brain protection.	[17,19-20]	Not reported (Chen & Lu)

Several previous investigations have examined the predictive role of BIS in relation to POCD. For instance, Bao et al. reported that lower preoperative BIS values were linked with a higher risk of postoperative delirium and cognitive impairment [1], while other studies suggested a less consistent relationship [3-4]. These discrepancies may be related to differences in patient age, comorbidities, anesthetic techniques, or the cognitive tests applied. Nevertheless, the convergence of findings across multiple cohorts indicates that BIS could reflect underlying neurophysiological vulnerability, making it a clinically relevant marker [6].

The biological mechanisms explaining this association remain incompletely understood. A reduction in BIS values may reflect decreased cortical activity and impaired neuronal connectivity [2], which could predispose the brain to postoperative dysfunction. Furthermore, anesthetic depth and intraoperative hemodynamic instability may interact with these neurophysiological changes, amplifying the risk of POCD [4,7] Although these mechanisms are plausible, further translational research is needed to clarify the causal pathways.

From a clinical perspective, our findings suggest that BIS monitoring may assist anesthesiologists in identifying patients at higher risk of postoperative cognitive decline. For example, in elderly patients undergoing prolonged or complex surgeries, closer perioperative surveillance and tailored anesthetic management might help mitigate adverse cognitive outcomes [3,8]. Incorporating BIS into standard perioperative protocols could therefore have practical implications for patient safety and recovery.

This study has some limitations. The sample size was relatively small, and the data were collected in a single center, which may restrict the generalizability of the results. Moreover, cognitive function was assessed with a limited set of screening tools, and longer-term follow-up was not performed. Despite these constraints, our analysis provides meaningful insights into the predictive potential of BIS and lays the groundwork for larger, multicenter trials [5-6]

In conclusion, perioperative BIS monitoring appears to be a useful indicator for predicting POCD in older patients. Future studies with larger and more diverse populations, standardized assessment methods, and extended follow-up are required to confirm these findings and to further clarify the clinical role of BIS in preventing postoperative cognitive complications [3,5] (Table 2).

Table 2- Mechanisms by Which BIS Monitoring May Reduce POCD

Mechanism	Explanation
Avoidance of Deep Anesthesia	Maintains BIS value between 40–60, preventing excessive anesthetic depth.
Reduced Drug Dosage	Enables precise titration of anesthetics, minimizing exposure.
Improved Hemodynamic Stability	Prevents hypotension which can impair cerebral perfusion.
Minimized Neuroinflammation	Reduced depth of anesthesia is associated with less systemic and neuroinflammation.
Avoidance of EEG Suppression	Helps to prevent burst suppression linked with cognitive decline.

Summary of Clinical Findings

Findings across multiple studies support BIS as a tool for optimizing anesthetic care and reducing cognitive complications. Most benefits are observed in elderly patients undergoing high-risk surgeries [3,6].

Conclusion

Postoperative cognitive dysfunction (POCD) remains a major challenge in perioperative care, particularly for elderly and high-risk patients. Bispectral index (BIS) monitoring offers a practical tool for tailoring anesthetic depth and may reduce the likelihood of POCD through mechanisms such as limiting EEG suppression, stabilizing hemodynamics, and avoiding drug overexposure. Although the evidence is encouraging, it is not yet conclusive. BIS should therefore be considered as one element within a broader multimodal neuroprotective strategy. Larger, well-designed trials are still required to establish its effectiveness and to guide integration into clinical practice [3,6,10].

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