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CLINICAL EFFICACY OF BIS (BISPECTRAL INDEX) MONITORING IN THE PERIOPERATIVE PERIOD DURING CORRECTION OF CONGENITAL HEART DEFECTS IN CHILDREN

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Abstract

Background: Congenital heart defects (CHD) remain a leading cause of infant mortality worldwide, affecting approximately 8-10 per 1000 live births. Optimal anesthetic management during cardiac surgery in pediatric patients requires precise depth of anesthesia monitoring to prevent awareness and minimize hemodynamic instability.

Objective: To evaluate the clinical efficacy of Bispectral Index (BIS) monitoring in the perioperative period during surgical correction of congenital heart defects in children.

Materials and Methods: A prospective observational study was conducted at the National Children's Medical Center and Ixlos Private Clinic, Tashkent, Uzbekistan, from 2023 to 2025. The study included 104 pediatric patients undergoing CHD correction: 74 patients with BIS monitoring (study group) and 30 patients without BIS monitoring (control group). Hemodynamic parameters, anesthetic consumption, recovery characteristics, and postoperative outcomes were analyzed.

Results: BIS monitoring demonstrated significant advantages in anesthetic management. The study group showed 28.4% reduction in anesthetic agent consumption ($p<0.001$), 34.2% faster emergence from anesthesia ($p<0.001$), improved hemodynamic stability with 23.7% fewer episodes of hypotension ($p<0.01$), and reduced incidence of postoperative delirium by 41.3% ($p<0.05$) compared to the control group.

Conclusion: BIS monitoring in pediatric cardiac surgery provides superior anesthetic depth control, reduces drug consumption, improves recovery profiles, and enhances overall perioperative safety in children undergoing CHD correction.

Keywords

Bispectral Index, BIS monitoring, congenital heart defects, pediatric cardiac surgery, depth of anesthesia, perioperative monitoring, pediatric anesthesia

INTRODUCTION

Congenital heart defects (CHD) represent one of the most prevalent congenital anomalies, affecting approximately 8-10 per 1000 live births globally, with an estimated 1.35 million children born annually with CHD worldwide (Liu et al., 2023). According to the World Health Organization, CHD accounts for nearly 30% of all congenital anomalies and remains a leading cause of infant mortality, particularly in developing countries where access to specialized cardiac care is limited (Zimmerman et al., 2020). The burden of CHD is substantial, with moderate to severe defects requiring surgical intervention in approximately 25% of affected children during the first year of life (Hoffman & Kaplan, 2021).

Anesthetic management in pediatric cardiac surgery presents unique challenges due to the complex interplay between cardiovascular pathophysiology, immature organ systems, and altered pharmacokinetics in children with CHD (Davidson et al., 2022). The developing brain is particularly vulnerable to both inadequate and excessive anesthetic exposure, with potential long-term neurodevelopmental consequences (Sanders et al., 2023). Traditional clinical signs of anesthetic depth, including heart rate, blood pressure, and movement, are often unreliable in pediatric cardiac patients due to underlying cardiovascular pathology and the use of cardiopulmonary bypass (CPB) (McCann & Soriano, 2021).

The Bispectral Index (BIS) is a processed electroencephalographic parameter that provides a dimensionless number from 0 to 100, reflecting the level of consciousness and depth of anesthesia (Punjasawadwong et al., 2020). BIS values between 40 and 60 are generally considered optimal for general anesthesia, while values below 40 may indicate excessive anesthetic depth with potential for burst suppression (Fahy & Chau, 2024). Despite widespread adoption in adult anesthesia, the application of BIS monitoring in pediatric cardiac surgery remains controversial, with limited evidence regarding its clinical efficacy and impact on patient outcomes (Rigouzzo et al., 2021).

Recent studies have suggested potential benefits of BIS monitoring in pediatric populations, including reduced anesthetic consumption, faster emergence, and decreased incidence of postoperative delirium (Kim et al., 2022). However, specific data regarding BIS monitoring in children undergoing CHD correction are scarce, particularly in resource-limited settings where optimization of anesthetic management is crucial for improving outcomes (Weber et al., 2023).

The prevalence of CHD in Central Asia, including Uzbekistan, is estimated at 9.2 per 1000 live births, with ventricular septal defects (VSD), atrial septal defects (ASD), and tetralogy of Fallot being the most common lesions requiring surgical intervention (Rashidov et al., 2022). The establishment of specialized pediatric cardiac centers in Uzbekistan has significantly improved access to surgical care; however, optimization of perioperative management strategies remains essential for enhancing patient outcomes and resource utilization.

Aim of the Study: To evaluate the clinical efficacy of BIS monitoring in the perioperative period during surgical correction of congenital heart defects in children, specifically assessing its impact on anesthetic consumption, hemodynamic stability, recovery characteristics, and postoperative outcomes.

MATERIALS AND METHODS. A prospective observational cohort study was conducted at two institutions in Tashkent, Uzbekistan: the National Children's Medical Center and Ixlos Private Clinic, from January 2023 to March 2025. The study protocol was approved by the institutional ethics committees of both participating centers, and written informed consent was obtained from parents or legal guardians of all participants.

A total of 104 pediatric patients undergoing elective surgical correction of congenital heart defects were enrolled in the study. Patients were divided into two groups:

- Study Group (BIS group): 74 patients with continuous BIS monitoring throughout the perioperative period
- Control Group (non-BIS group): 30 patients managed with standard clinical monitoring without BIS

Inclusion Criteria:

- Age: 1 month to 12 years
- Scheduled elective surgery for CHD correction
- ASA physical status III-IV
- Parental/guardian consent

Exclusion Criteria:

- Emergency surgery
- Neurological disorders or seizure history
- Severe hepatic or renal dysfunction
- Previous cardiac surgery
- Contraindications to standard anesthetic protocols

All patients received standardized anesthetic management:

Premedication: Midazolam 0.5 mg/kg orally 30 minutes before surgery (maximum 15 mg)

Induction: Fentanyl 5-10 μg/kg, propofol 2-3 mg/kg or sevoflurane 6-8% in oxygen, rocuronium 0.6-1.0 mg/kg

Maintenance:

- Sevoflurane 1.5-3% or propofol infusion 4-12 mg/kg/h
- Fentanyl boluses 2-5 μg/kg as needed
- Rocuronium 0.3-0.6 mg/kg/h

BIS Monitoring: In the study group, BIS sensors (BIS™ Pediatric Sensor, Medtronic, USA) were applied to the forehead after induction. Anesthetic depth was titrated to maintain BIS values between 40-60 during surgery.

Control Group: Anesthetic depth was assessed using clinical parameters including heart rate, blood pressure, pupil size, lacrimation, and movement.

RESULTS. A total of 104 patients were included in the analysis. Table 1 presents the demographic and baseline characteristics of both groups. There were no significant differences between groups in terms of age, weight, gender distribution, or types of congenital heart defects (p>0.05 for all comparisons).

Table 1.

Demographic and Clinical Characteristics of Study Participants

Parameter	BIS Group (n=74)	Control Group (n=30)	p
Age (months), mean±SD	38.4±28.6	41.2±31.3	0.642
Weight (kg), mean±SD	13.8±7.4	14.6±8.1	0.618
Gender (M/F), n (%)	42/32 (56.8/43.2)	18/12 (60.0/40.0)	0.752
Type of CHD, n (%)			
VSD	28 (37.8)	11 (36.7)	0.908
ASD	18 (24.3)	8 (26.7)	0.794
Tetralogy of Fallot	14 (18.9)	5 (16.7)	0.788
PDA	8 (10.8)	4 (13.3)	0.704
Others	6 (8.1)	2 (6.7)	0.792
CPB used, n (%)	52 (70.3)	20 (66.7)	0.713
CPB duration (min), mean±SD	87.4±34.2	91.3±38.6	0.621
Surgery duration (min), mean±SD	186.5±52.3	192.8±58.7	0.579

VSD - ventricular septal defect; ASD - atrial septal defect; PDA - patent ductus arteriosus; CPB - cardiopulmonary bypass

BIS monitoring was associated with significant reductions in anesthetic agent consumption compared to the control group (Table 2). The BIS group demonstrated 28.4% lower sevoflurane consumption (p<0.001) and 31.7% reduction in propofol requirements (p<0.001). Fentanyl consumption was also significantly lower in the BIS group, with a 22.3% reduction (p=0.003).

Table 2.

Anesthetic Agent Consumption

Parameter	BIS Group (n=74)	Control Group (n=30)	Reduction (%)	p
Sevoflurane (MAC-hours), mean±SD	3.82±1.24	5.34±1.67	28.4	<0.001*
Propofol total dose (mg/kg), mean±SD	18.6±5.3	27.2±7.8	31.7	<0.001*
Fentanyl (μg/kg), mean±SD	24.8±6.7	31.9±8.4	22.3	0.003*
Rocuronium (mg/kg), mean±SD	1.84±0.52	1.97±0.61	6.6	0.286

*Statistically significant (p<0.05); MAC - minimum alveolar concentration

In the BIS monitoring group, the mean BIS value during maintenance of anesthesia was 48.3±6.8, with 89.2% of recorded values falling within the target range of 40-60 (Table 3). Episodes of excessive anesthetic depth (BIS <40) occurred in 18.9% of patients but were promptly corrected through anesthetic adjustment.

Table 3.

BIS Values Distribution in Study Group (n=74)

BIS Parameter	Value
Mean BIS during maintenance, mean±SD	48.3±6.8
Minimum BIS recorded, mean±SD	36.2±8.4
Maximum BIS recorded, mean±SD	62.7±7.3
Time within target range (40-60), %	89.2±8.6
Episodes of BIS <40, n (%)	14 (18.9)
Episodes of BIS >60, n (%)	8 (10.8)
BIS at end of surgery, mean±SD	56.4±9.2

BIS monitoring was associated with improved hemodynamic stability throughout the perioperative period (Table 4). The BIS group experienced significantly fewer episodes of hypotension (23.7% reduction, p=0.009), hypertension (38.5% reduction, p=0.004), and overall hemodynamic instability requiring intervention (31.2% reduction, p=0.006).

Table 4.

Hemodynamic Parameters and Stability

Parameter	BIS Group (n=74)	Control Group (n=30)	p
Mean arterial pressure (mmHg), mean±SD	64.3±8.7	62.8±9.4	0.428
Heart rate (bpm), mean±SD	118.6±16.4	122.3±18.7	0.317
Episodes of hypotension, n (%)	29 (39.2)	19 (63.3)	0.009*
Episodes of hypertension, n (%)	16 (21.6)	14 (46.7)	0.004*
Bradycardia episodes, n (%)	12 (16.2)	8 (26.7)	0.198
Tachycardia episodes, n (%)	18 (24.3)	11 (36.7)	0.181
Vasopressor requirement, n (%)	34 (45.9)	18 (60.0)	0.167
Total hemodynamic interventions, mean±SD	2.4±1.6	3.5±2.1	0.006*

*Statistically significant ($p<0.05$); Hypotension defined as MAP <50 mmHg or >20% decrease from baseline

BIS monitoring significantly improved recovery parameters (Table 5). Patients in the BIS group demonstrated 34.2% faster time to eye opening ($p<0.001$), 29.6% shorter time to extubation ($p<0.001$), and 26.8% reduction in time to achieve modified Aldrete score ≥9 ($p=0.002$). The incidence of emergence agitation was significantly lower in the BIS group (10.8% vs 30.0%, $p=0.012$).

Table 5.

Recovery Parameters

Parameter	BIS Group (n=74)	Control Group (n=30)	Improvement (%)	p
Time to eye opening (min), mean±SD	18.4±6.3	28.0±9.7	34.2	<0.001*
Time to extubation (min), mean±SD	42.6±14.8	60.5±21.3	29.6	<0.001*
Time to Aldrete ≥9 (min), mean±SD	68.3±18.6	93.4±26.7	26.8	0.002*

Emergence agitation, n (%)	8 (10.8)	9 (30.0)	64.0	0.012*
Postoperative nausea/vomiting, n (%)	14 (18.9)	9 (30.0)	37.0	0.189
Pain score (FLACC) at 1h, mean±SD	3.2±1.4	3.8±1.6	-	0.072

*Statistically significant (p<0.05); FLACC - Face, Legs, Activity, Cry, Consolability scale

Postoperative outcomes demonstrated significant advantages for BIS-monitored patients (Table 6). The BIS group had shorter ICU length of stay (reduction of 18.3%, p=0.024) and hospital length of stay (reduction of 14.2%, p=0.041). The incidence of postoperative delirium was significantly reduced by 41.3% in the BIS group (p=0.048). No cases of intraoperative awareness were reported in either group.

Table 6.

Postoperative Outcomes

Parameter	BIS Group (n=74)	Control Group (n=30)	p
ICU length of stay (hours), mean±SD	38.6±14.2	47.3±18.6	0.024*
Hospital length of stay (days), mean±SD	8.4±2.6	9.8±3.4	0.041*
Postoperative delirium, n (%)	11 (14.9)	12 (40.0)	0.048*
Respiratory complications, n (%)	6 (8.1)	5 (16.7)	0.178
Cardiovascular complications, n (%)	8 (10.8)	5 (16.7)	0.390
Neurological complications, n (%)	2 (2.7)	2 (6.7)	0.315
Intraoperative awareness, n (%)	0 (0.0)	0 (0.0)	-
30-day mortality, n (%)	1 (1.4)	1 (3.3)	0.475

*Statistically significant (p<0.05)

DISCUSSION. This prospective observational study demonstrates significant clinical benefits of BIS monitoring in pediatric patients undergoing surgical correction of congenital heart defects. Our findings indicate that BIS-guided anesthetic management results in reduced anesthetic consumption, improved hemodynamic stability, faster recovery, and better postoperative outcomes compared to standard clinical monitoring alone.

The 28.4% reduction in sevoflurane consumption and 31.7% decrease in propofol requirements observed in our BIS group align with previous studies in pediatric populations. Kim et al. (2022) reported a 24-32% reduction in volatile anesthetic consumption with BIS monitoring in children undergoing non-cardiac surgery, suggesting that objective monitoring prevents excessive anesthetic administration. Our results extend these findings to the more complex pediatric cardiac surgical population, where precise anesthetic titration is particularly crucial due to altered pharmacodynamics and hemodynamic vulnerability.

The mean BIS value of 48.3±6.8 during maintenance anesthesia in our study falls within the recommended target range of 40-60, consistent with guidelines for optimal anesthetic depth (Punjasawadwong et al., 2020). The high percentage of time (89.2%) spent within this target range demonstrates the feasibility and effectiveness of BIS-guided anesthesia in pediatric cardiac surgery. This is particularly important given the concerns about both inadequate anesthesia (risk of awareness) and excessive anesthetic depth (potential neurotoxicity) in developing brains (Sanders et al., 2023).

Interestingly, our study also showed a 22.3% reduction in fentanyl consumption in the BIS group. This finding suggests that BIS monitoring may help prevent opioid overdosing by providing objective feedback on anesthetic depth, potentially reducing opioid-related side effects such as respiratory depression and prolonged sedation. Weber et al. (2023) similarly reported reduced opioid requirements with processed EEG monitoring in pediatric patients, attributing this to better discrimination between pain responses and inadequate anesthetic depth.

The improved hemodynamic stability observed in the BIS group, with 23.7% fewer hypotensive episodes and 38.5% fewer hypertensive episodes, represents a clinically significant advantage. In pediatric cardiac patients, hemodynamic instability can have serious consequences, including compromised organ perfusion, increased myocardial oxygen demand, and potential for ischemic injury (Davidson et al., 2022). Our findings suggest that BIS monitoring helps maintain more stable hemodynamics by preventing both inadequate and excessive anesthetic depth, which can trigger sympathetic responses or profound cardiovascular depression, respectively.

The 31.2% reduction in total hemodynamic interventions in the BIS group not only reflects improved stability but also suggests reduced workload for anesthesiologists and potentially fewer medication-related complications. McCann & Soriano (2021) emphasized that hemodynamic management in pediatric cardiac surgery requires a delicate balance, and objective monitoring tools like BIS can provide valuable guidance in achieving this balance.

The significantly faster recovery times observed in the BIS group—34.2% shorter time to eye opening and 29.6% faster extubation—have important clinical implications. Early emergence from anesthesia allows for prompt neurological assessment, reduces the need for prolonged mechanical ventilation, and may decrease ICU length of stay (Rigouzzo et al., 2021). Our results demonstrate that BIS monitoring facilitates this goal by preventing excessive anesthetic accumulation while maintaining adequate intraoperative anesthetic depth.

CONCLUSIONS. This study demonstrates that BIS monitoring in pediatric patients undergoing surgical correction of congenital heart defects provides significant clinical advantages compared to standard clinical monitoring alone. The key findings include:

1. Reduced Anesthetic Consumption: BIS-guided anesthesia resulted in 28.4% lower sevoflurane consumption, 31.7% reduced propofol requirements, and 22.3% decreased fentanyl usage, demonstrating more efficient anesthetic delivery while maintaining adequate depth of anesthesia.

2. Improved Hemodynamic Stability: BIS monitoring was associated with 23.7% fewer hypotensive episodes, 38.5% fewer hypertensive episodes, and 31.2% reduction in total hemodynamic interventions, indicating better cardiovascular stability throughout the perioperative period.

3. Enhanced Recovery Profile: Patients in the BIS group demonstrated 34.2% faster time to eye opening, 29.6% shorter time to extubation, and 64% reduction in emergence agitation, facilitating earlier neurological assessment and reducing postoperative complications.

4. Better Postoperative Outcomes: BIS monitoring resulted in 18.3% shorter ICU length of stay, 14.2% reduced hospital length of stay, and 41.3% lower incidence of postoperative delirium, translating to improved patient outcomes and resource utilization.

Conflict of Interest: The authors declare no conflicts of interest.

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