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CLINICAL TRIAL REPORT

The Impact of Anesthetic Management Under Bispectral Index Monitoring on the Early Recovery Quality of Elderly Patients Undergoing Laparoscopic Surgery: A Blinded Randomized Controlled Trial

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Purpose: To comprehensively evaluate the impact of bispectral index (BIS) monitoring-guided anesthesia depth on the early recovery quality in elderly patients undergoing laparoscopic surgery.

Methods: Ninety patients aged ≥60 years scheduled for laparoscopic surgery under general anesthesia were randomized into three groups: Group C (empirically guided anesthesia), Group B1 (BIS-guided, target range 40–60), and Group B2 (BIS-guided, target range 50–60). Blinded researchers evaluated recovery quality (QoR-15), pain (VAS), and sleep (RCSQ) preoperatively and on postoperative days 1, 2, 3, and 7 ($POD_{1,2,3,7}$). Postoperative delirium was assessed with CAM (POD_1–POD_3), and cognitive function (MMSE) was measured preoperatively, POD_3, and POD_7. Intraoperative data included vital signs, BIS values, anesthetic dosage, emergence/extubation times, PACU stay, and adverse events within three days post-surgery. Time to first ambulation and hospital stay were also recorded.

Results: Compared with Group C, Group B1 and B2 had lower propofol consumption, shorter emergence/extubation times, and higher BIS values (T_2-T_5 and overall mean) ($P<0.05$). QoR-15 scores improved on POD_2 in Group B1 and on both POD_1 and POD_2 in Group B2 ($P<0.05$). The RCSQ scores increased on POD_1 and POD_3 in Group B1 ($P<0.05$) and on POD_1, POD_2 and POD_3 in Group B2 ($P<0.05$). In addition, Group B2 had a shorter PACU stay and time to first postoperative ambulation ($P<0.05$). No differences were found in the incidence of postoperative delirium, POCD, or MMSE scores among the three groups. Compared to Group B1, Group B2 exhibited shorter emergence and extubation times, elevated BIS values at T3 and T5, a higher mean BIS value throughout surgery, and enhanced QoR-15 scores on POD_1 and POD_2 ($P<0.05$).

Conclusion: BIS monitoring-guided anesthesia management can enhance early recovery from laparoscopic surgery in elderly patients with BIS values within a safe range, which may be particularly advantageous for this demographic during laparoscopic procedures.

Keywords: bispectral index, BIS, elderly patients, quality of postoperative recovery, cognitive function, sleep quality

Introduction

With the development of surgical treatment techniques, more elderly patients receive operations and the postoperative survival time has been prolonged, thus the quality of postoperative recovery has received increasing attention.[1,2] Because of the decline in organ function and comorbidities, elderly patients have a poor ability to tolerate surgery and anesthesia, which can lead to various postoperative complications, thus anesthesia management appears to have certain particularities and complexities.[3] Large deviations in intraoperative anesthetic management and preoperative physiological

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compensatory function will contribute to a significant increase in the incidence of serious postoperative complications as well as mortality.[4] With the purpose of improving perioperative management and quality of early postoperative recovery among elderly patients; the primary task for anesthesiologists is to optimize anesthesia management to shorten the perioperative non-physiological process and create conditions for the rapid recovery of postoperative organ and system function under the premise of maintaining the preoperative physiological status and compensatory function of elderly patients. One solution is to optimize the anesthesia plan in terms of providing short-acting sedation and analgesic drugs to control the depth of anesthesia and provide an effective anti-stress response, ensuring that elderly patients are fully awake when extubating, facilitating postoperative recovery of physiological state and early out-of-bed mobilization, and avoiding mechanical ventilation support.

Depth control is an important part of general anesthesia management and is closely related to patient safety and postoperative prognosis. Especially for elderly patients, the depth of anesthesia is difficult to control due to their increased sensitivity to general anesthesia drugs and decreased rate of drug clearance.[5] Bispectral index (BIS) monitoring is considered as an accurate, sensitive, real-time and convenient indicator for judging the depth of sedation under anesthesia because of its association with the depth of sedation and with the state of consciousness of patients.[6,7] Intraoperative monitoring of BIS level is helpful to predict the prognosis of patients and reduce the complications related to depth of sedation,[8] thus perioperative use of BIS to monitor the depth of anesthesia may shed light on promoting the quality of postoperative recovery in elderly surgical patients.

Enhanced recovery after surgery (ERAS) provides a new platform and mode for patients undergoing surgical treatment, and a large number of clinical practices based on the ERAS concept have demonstrated that individualized and accurate anesthesia management is essential to improve the quality of postoperative recovery in elderly patients.[9,10] Recent studies have shown that the use of BIS on the depth of anesthesia monitoring can reduce the dosage of intraoperative sedative drugs, shorten emergence time and extubation time, and decrease adverse stress reactions.[11] However, most previous clinical studies only evaluated the quality of early postoperative recovery in terms of emergence time, pain, or other adverse reactions, which have been insufficient to comprehensively reflect the postoperative recovery quality of patients. The QoR-15 scale is a patient-centered, highly reliable and valid questionnaire with good compliance that broadly assesses the quality of postoperative recovery of patients from five dimensions, which are emotional state, physical comfort, psychological support, physical independence, and pain.[12] Currently, no known research has focused on using QoR-15 to assess the effect of BIS monitoring on the quality of postoperative recovery in elderly patients. Moreover, previous studies on elderly patients have focused on a wider range of BIS values (40–60), it remains poorly understood whether slightly higher BIS values (50–60) are beneficial.

Postoperative cognitive function recovery is essential for evaluating the quality of recovery in elderly patients. Postoperative delirium (POD) and postoperative cognitive dysfunction (POCD) are common postoperative complications in elderly surgical patients. Early assessment and active intervention are effective measures to prevent and manage POD and POCD.[13–15] However, the effect of intraoperative depth of anesthesia monitoring through BIS grade on postoperative cognitive function remains controversial. Furthermore, there is a close relationship between sleep quality and cognitive function, and postoperative sleep disturbance is a significant factor affecting postoperative recovery in elderly patients,[16] which deserves further attention.

In summary, by applying the QoR-15, Confusion Assessment Method (CAM), Mini-Mental State Examination (MMSE), and Richards-Campbell Sleep Questionnaire (RCSQ), this study aimed to comprehensively investigate the effect of depth of anesthesia monitoring through the BIS on early recovery quality among elderly patients after laparoscopic surgery to provide a reference for improving the quality of anesthesia and early postoperative recovery among elderly patients and create good conditions for improving postoperative prognosis and outcome.

Materials and Methods

Study Subject

The institutional review board of the Second Affiliated Hospital of Guilin Medical University approved this prospective, randomized, double-blind study, which was registered in the Chinese Clinical Trial Registry (ChiCTR2200055416).

Ninety patients aged ≥60 years who received general anesthesia for laparoscopic surgery were recruited between January and June 2022. All the participants and their families provided written informed consent after a detailed understanding of the study objectives, procedures, and potential risks. This study adhered to the Declaration of Helsinki, ensuring ethical standards in medical research involving human subjects, encompassing informed consent, participant safety, and scientific validity.

The inclusion criteria were as follows: (1) age ≥ 60 years, (2) scheduled for elective laparoscopic surgery, (3) expected anesthesia time of >2 hours, (4) grade I to III according to the American Society of Anesthesiologists (ASA) physical status classification, and (5) signed informed consent. Patients were excluded if they (1) had a history of severe neurological or psychiatric disorders, (2) had alcohol and drug abuse, (3) had severe organ dysfunction, (4) had preoperative sleep disorders, (5) received other test drugs or participated in other clinical trials 3 months before surgery, and (6) had severe hearing and visual impairment that could not cooperate with the examination. The withdrawal criteria were as follows: (1) serious intraoperative or postoperative adverse reactions that affected the quality of surgery or were life-threatening, (2) operation time > 6 h, (3) intraoperative blood loss > 1000 mL, and (4) voluntary withdrawal from the clinical trial.

Grouping

Ninety patients were randomly assigned using a simple randomization method into three groups: Group C (control group with empirically guided anesthesia), Group B1 (BIS-guided anesthesia with a target range of 40–60), and Group B2 (BIS-guided anesthesia with a target range of 50–60). BIS values were monitored in all patients using a bispectral index monitor (Covidien IIc, Mansfield, MA, USA). The patients in Group C received an empirically guided depth of anesthesia. The BIS values were blinded to the attending anesthesiologist throughout the anesthesia procedure, with the instrument screen either backward to the anesthesiologist or covered with a sticker. Patients in Groups B1 and B2 received anesthesia management guided by BIS monitoring, with target BIS values ranging from 40 to 60 and 50 to 60, respectively. The group assignments were blinded to the patients, PACU staff, follow-up staff, and the data recorders. Only the anesthesiologist in charge was blinded, and the participants were managed as assigned.

Anesthetic Procedures and Postoperative Management

All patients underwent routine fasting and liquid fasting before surgery, and were administered preoperative medication according to the actual condition. After admission to the operating room, venous access was established and noninvasive blood pressure, electrocardiogram, and pulse oxygen saturation were monitored. Before induction of anesthesia, all patients were monitored using the BIS, and data were recorded every minute. After the BIS values were stable, anesthesia was induced by intravenous injection of midazolam 0.04~0.1 mg/kg, sufentanil 0.3~0.6 μg/kg, cisatracurium 0.1~0.2 mg/kg, and etomidate 0.15~0.2 mg/kg. Mechanical ventilation was performed after successful tracheal intubation with a tidal volume of 8–10 mL/kg and respiratory rate of 10–14 breaths/min. Pressure of end-tidal CO_2 ($PetCO_2$) was monitored, and the respiratory rate was adjusted as necessary to maintain it within the range of 35–45 mmHg. Anesthesia maintenance was achieved through total intravenous anesthesia, combining propofol (4~12 mg/kg/h) and remifentanil (0.05–0.2 μg/kg/min), supplemented with intermittent doses of cisatracurium (0.03–0.05 mg/kg) for muscle relaxation.

Intraoperative management was performed according to groups following routine clinical anesthesia. Based on the principles of patient safety and stable vital signs, noninvasive blood pressure changes were maintained within 20% of those before induction. In addition to common causes, anesthesia should be appropriately deepened or reduced if abnormal vital signs are related to the depth of anesthesia.

After all anesthetics were withdrawn at the end of surgery, patient-controlled intravenous analgesia (PCIA) was administered. The patients were then admitted to the PACU and the endotracheal tube was removed after adequate recovery of consciousness and spontaneous breathing.

Observation Indicators

Preoperative general indicators included age, sex, height, weight, body mass index (BMI), ASA of Anesthesiologists Classification, and educational level.

Surgery- and anesthesia-related information included operation time, anesthesia time, dosage of anesthetic drugs, blood loss, urine volume, infusion volume, time from the end of surgery to awakening and extubation, and duration of PACU stay. Mean arterial pressure (MAP), heart rate (HR), and BIS values were recorded before anesthesia induction (T_0), 5 min after intubation (T_1), at the beginning of surgery (T_2), 1 h after initiation of surgery (T_3), 2 h after initiation of surgery (T_4), and at the end of surgery (T_5). The BIS data were exported from 5 minutes after the completion of intubation to the end of surgery, and the mean BIS values during this period were calculated. Intraoperative events included bradycardia (HR < 50 bpm), tachycardia (HR > 100 bpm), hypertension (MAP>105 mmHg or MAP increase ≥20% of baseline value), hypotension (MAP<60 mmHg or MAP decrease ≥20% of baseline value), and cardiovascular medication remedies.

Postoperative quality of recovery, intensity of pain, and sleep quality were evaluated using the QoR-15, Visual Analog Score (VAS), and RCSQ at Preop, POD_1, POD_2, POD_3, and POD_7. CAM was used to assess delirium within three days after surgery. The MMSE was conducted to observe the occurrence of POCD preoperatively and on, POD_3 and POD_7. Adverse reactions, as well as surgery- and anesthesia-related complications, were followed up and recorded within 3 days after surgery. The time to first postoperative ambulation and postoperative hospital stay were recorded.

Statistical Analysis

This randomized controlled study used the QoR-15 score on POD1 as the primary outcome, hypothesizing superiority in BIS-guided groups (B1 and B2) over Group C. Pilot data (n=10 per group) estimated scores of 100.6 ± 7.85 (C), 107.7 ± 9.36 (B1), and 109.5 ± 7.72 (B2), consistent with ranges reported by Liu et al.[17] The minimum clinically important difference for QoR-15 was 8.0.[18] Using PASS 15 software (NCSS LLC, Kaysville, Utah, USA) with a mean difference of 9 (B2 vs C), pooled SD of 8.5, α=0.05, and 90% power (two-tailed), we calculated 27 patients per group. Adjusting for a 10% dropout rate, we enrolled 30 patients per group, totaling 90 patients.

Data normality was assessed using the Kolmogorov–Smirnov test. Continuous variables are expressed as mean ± standard deviation or median and interquartile range (IQR) for normally and non-normally distributed variables, respectively. Categorical variables are presented as n (%). Numerical differences between the two groups were assessed using the chi-square test or Fisher's exact test for categorical variables and analysis of variance or the Kruskal–Wallis test for continuous variables. Statistical significance (*P* value) was assessed using a 2-tailed test in all instances, and the threshold for significance was set at $P<0.05$. All statistical analyses were performed using SPSS (version 25.0 (SPSS Inc., Chicago, IL, USA)) and GraphPad Prism software (version 8.0; GraphPad Software, San Diego, California, USA).

Results

Preoperative General Information

A total of 132 patients were screened, and 90 eligible patients were divided into Groups C (n=30), B1 (n=30), and B2 (n=30). Based on the inclusion and exclusion criteria, 83 patients were included and analyzed in this study. Figure 1 shows a detailed flowchart.

As shown in Table 1, there were no significant differences among the three groups in terms of sex, age, height, weight, BMI, ASA classification, or education level at baseline ($P>0.05$).

Intraoperative Information

Surgery and Anesthesia

No significant differences were found among the three groups in terms of specialty distribution, surgical duration, anesthetic duration, intraoperative sufentanil, remifentanil, cisatracurium dosage, infusion volume, blood loss, urine volume, or incidence of intraoperative hemodynamic adverse events ($P>0.05$). Compared with Group C, the dosage of propofol was significantly reduced in Group B1 and Group B2 ($P<0.05$). In addition, emergence and extubation times

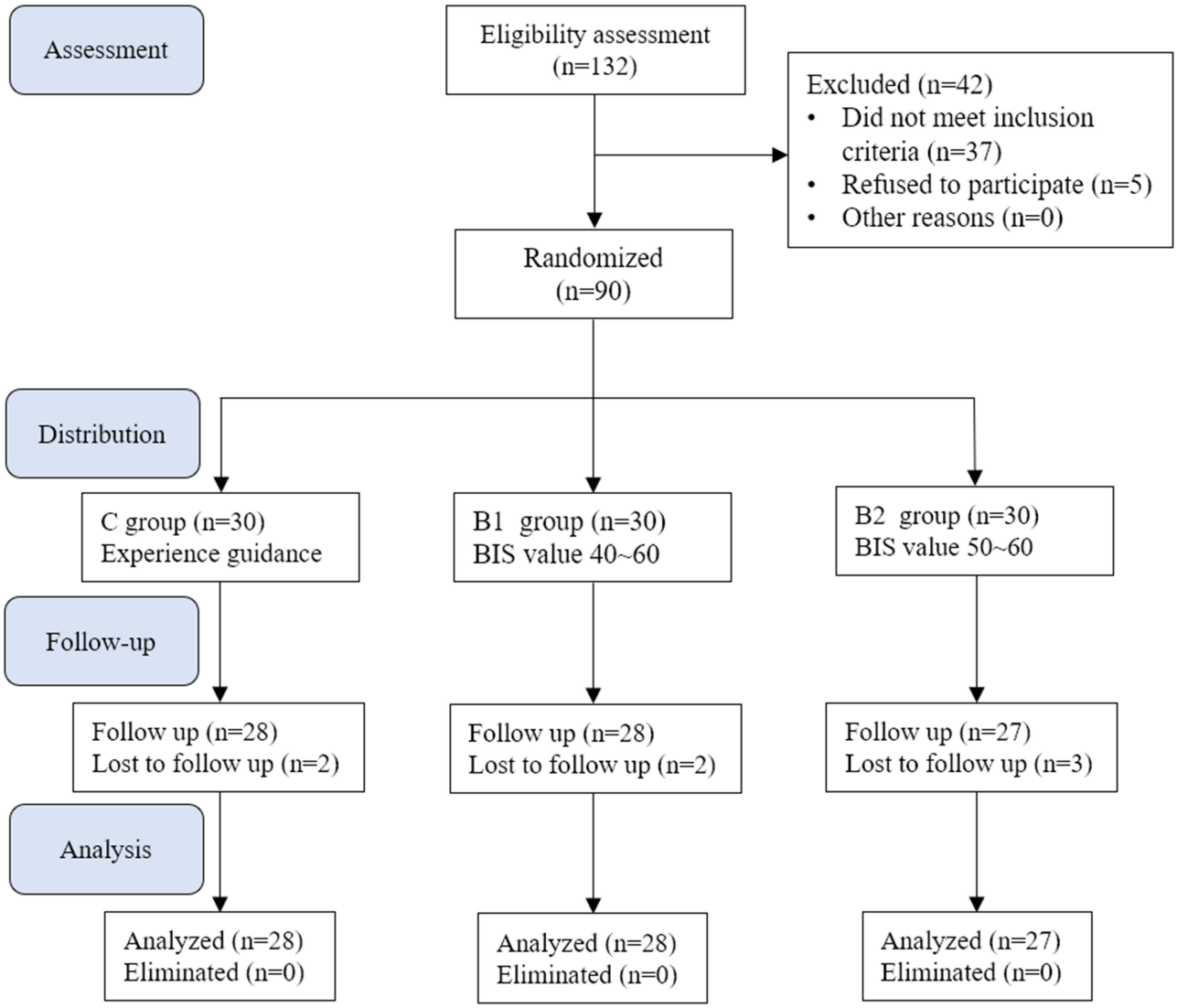

Figure 1 Flowchart of patient recruitment, randomization and analysis.

were significantly shortened in Group B1 and Group B2 ($P<0.05$), and PACU stay was significantly shorter in Group B2 ($P<0.05$). In addition, compared with Group B1, Group B2 had statistically shorter emergence time and extubation time ($P<0.05$). The details are presented in Table 2 and Figure 2.

Table 1 Patients Characteristics

	C (n=28)	B1 (n=28)	B2 (n=27)	χ^2/F	P
Gender (male/female)	11/17	13/15	11/16	0.326	0.849
Age (yr)	67.82±4.73	68.00±5.56	68.52±5.42	0.130	0.878
Height (cm)	162.07±7.78	161.64±6.08	160.00±7.92	0.613	0.544
Weight (kg)	64.76±9.97	61.33±8.93	63.63±10.31	0.905	0.409
BMI (kg/m^2)	24.55±2.64	23.42±2.77	24.79±3.26	1.763	0.178
ASA class I/II/III	6/18/4	5/19/4	4/18/5	0.630	0.960
Education Level (yr)	6 (1.75)	6 (1)	6 (2)	0.188	0.910

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Table 2 Information of Operation and Anesthesia

	C (n=28)	B1 (n=28)	B2 (n=27)	χ^2/F/H	*P*
Distribution of specialties					
Gynaecology	12(42.9%)	11(39.3%)	10(37.0%)	1.552	0.956
Urology	5(17.9%)	7(25%)	8(29.6%)		
Hepatology	5(17.9%)	6(21.4%)	5(18.5%)		
Gastroenterology	6(21.4%)	4(14.35)	4(14.8%)		
Surgical duration (min)	164(49.75)	158.5(60.5)	161(61)	0.042	0.979
Anesthetic duration (min)	190(51.75)	194.5(63)	196(71)	0.399	0.819
Infusion volume (mL)	2217.9±448.1	2314.3±535.6	2351.9±443.0	0.579	0.563
Urine volume (mL)	450(150)	412.5(187.5)	500(150)	0.329	0.849
Bleeding volume (mL)	60(50)	55(70)	80(50)	3.443	0.179
Sufentanil usage (μg)	45(10)	40(10)	40(15)	2.909	0.233
Remifentanil usage (μg)	1565(436)	1497.5(642)	1363(294)	2.628	0.269
Propofol usage (mg)	1034.9±153.1	914.4±212.1*	863.5±171.1*	6.568	0.002
Cis atracurium usage (mg)	19.21±2.71	18.54±3.61	19.07±4.10	0.290	0.749
Emergence time (min)	38(11)	34.5(7.5)*	23(15)*#	24.436	0.000
Extubation time (min)	49.6±9.2	41.4±6.5*	35.7±10.8*#	16.879	0.000
PACU stay duration (min)	80.5(15.5)	75(10)	67(18) *	15.455	0.000
Cardiovascular events	3(10.7%)	2(7.1%)	2(7.4%)	0.286	1.000
Hypertension	0(0)	0(0)	0(0)	/	/
Hypotension	2(7.1%)	1(3.57%)	1(3.7%)	0.498	1.000
Tachycardia	0(0)	0(0)	1(3.7%)	2.099	0.325
Bradycardia	1(3.57%)	1(3.57%)	0(0)	0.988	1.000

Notes: *P<0.05, compared to Group C; #P<0.05, compared to Group B1.

BIS Value

Compared with Group C, Group B1 and Group B2 had notably higher BIS values at the intraoperative T_2, T_3, T_4, and T_5 time points and higher average BIS values over the course of surgery (P<0.05). In addition, compared with Group B1,

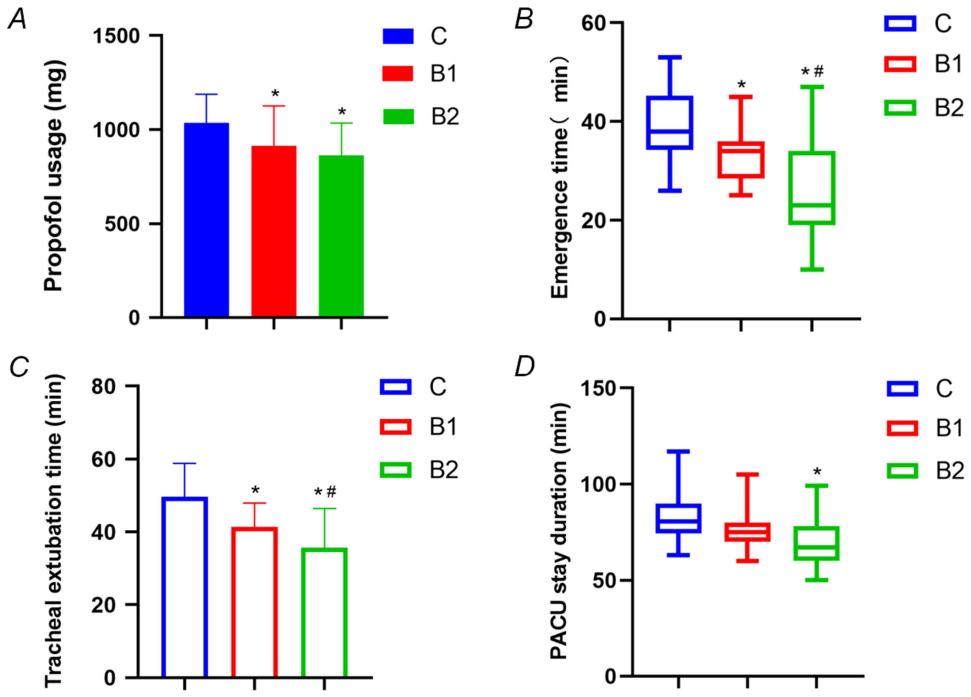

Figure 2 (**A**) Propofol usage. (**B**) Emergence time. (**C**) Tracheal extubation time. (**D**) PACU stay duration.
Notes: *P<0.05, compared with Group C; #P<0.05, compared with Group B1.

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Table 3 BIS Value at Different Time Points and Overall Average Value During Operation

	C (n=28)	B1 (n=28)	B2 (n=27)	H	P
T_0	97(3)	95(5.75)	96(4)	2.033	0.362
T_1	42.5(6)	42(4.75)	43(5)	5.315	0.070
T_2	45(5.75)	47.5(8.5)*	52(7)*	22.298	0.000
T_3	41.5(9.5)	48.5(7.75)*	54(5)*#	42.770	0.000
T_4	42.5(6. 5)	48(6.75)*	53(5)*	51.399	0.000
T_5	45(6.75)	50(10.5)*	56(4)*#	36.380	0.000
Overall average	42(4.75)	47(5.5)*	53(4)*#	54.178	0.000

Notes: *P<0.05, compared to Group C; #P<0.05, compared to Group B1.

Group B2 had significantly higher BIS values at the intraoperative T_3 and T_5 time points (P<0.05). Table 3 and Figure 3 provide details.

MAP and HR

No significant difference in MAP was found among the three groups at any time point (P>0.05). Compared to T_0, the MAP of Group C decreased significantly at all time points from T_1 to T_5 (P<0.05). In Group B1, the MAP decreased from T_1 to T_4 time points (P<0.05), whereas the MAP in Group B2 decreased at T_1, T_2 and T_3 (P<0.05). Further details are provided in Table 4.

There was no significant difference in the HR among the three groups at any time point (P>0.05). Compared with T_0, the HR from T_1 to T_5 time points in Group C and Group B1 decreased significantly (P<0.05). In Group B2, the HR decreased considerably from T_1 to T_4 time points considerably decreased (P<0.05). For more details, please refer to Table 4.

Postoperative Recovery Information

As shown in Table 5, there were no significant differences among the three groups in the VAS scores and postoperative analgesic remedies (defined as VAS>5) (P>0.05).

No significant difference in QoR-15 score was found among the three groups in Preop (P>0.05). Compared with Preop, QoR-15 scores significantly decreased on POD_1, POD_2, POD_3, and POD_7 in Group C (P<0.05) while on POD_1, POD_2, and POD_3 in Group B1 and Group B2 (P<0.05). Compared with Group C, Group B1 had significantly higher

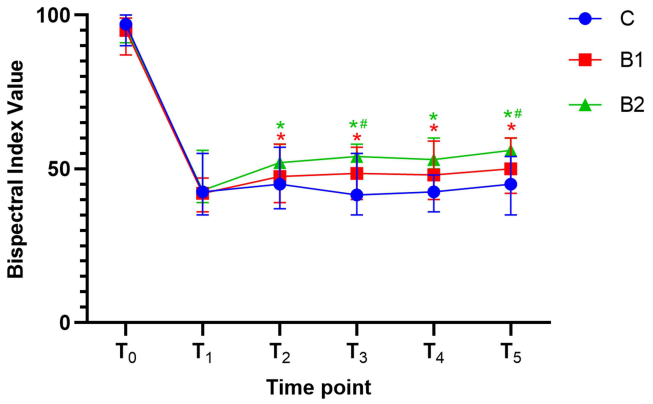

Figure 3 BIS values at different time points.
Notes: *P<0.05, compared with Group C; #P<0.05, compared with Group B1.

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Table 4 MAP and HR of T_0-T_5

	C (n=28)	B1 (n=28)	B2 (n=27)	F	*P*
MAP					
T_0	93.14±8.58	90.25±8.99	91.19±7.91	0.842	0.435
T_1	79.68±9.48$^{\Delta}$	80.46±8.53$^{\Delta}$	81.11±8.81$^{\Delta}$	0.177	0.838
T_2	80.29±9.12$^{\Delta}$	82.36±8.84$^{\Delta}$	83.07±9.84$^{\Delta}$	0.675	0.512
T_3	80.75±9.19$^{\Delta}$	79.39±7.87$^{\Delta}$	82.26±9.44$^{\Delta}$	0.721	0.489
T_4	80.79±9.09$^{\Delta}$	80.25±9.38$^{\Delta}$	84.33±9.80	1.515	0.226
T_5	83.54±8.13$^{\Delta}$	84.07±8.70	85.59±8.58	0.434	0.649
HR					
T_0	78.75±7.06	80.29±6.20	79.11±9.72	0.298	0.743
T_1	65.89±5.04$^{\Delta}$	67.25±5.65$^{\Delta}$	68.74±5.36$^{\Delta}$	1.945	0.150
T_2	70.32±5.45$^{\Delta}$	72.82±5.95$^{\Delta}$	73.30±6.27$^{\Delta}$	2.039	0.137
T_3	69.29±6.00$^{\Delta}$	69.46±5.78$^{\Delta}$	71.86±6.07$^{\Delta}$	1.636	0.201
T_4	71.07±7.90$^{\Delta}$	71.29±6.84$^{\Delta}$	70.85±5.78$^{\Delta}$	0.027	0.973
T_5	72.82±6.57$^{\Delta}$	73.04±6.61$^{\Delta}$	74.59±7.86	0.517	0.598

Note: $^{\Delta}P<0.05$, compared to T_0.

Table 5 VAS Score and Remedial Analgesia

	C (n=28)	B1 (n=28)	B2 (n=27)	χ^2/ H	*P*
Preop	0(0)	0(0)	0(0)	0.003	0.988
POD_1	3.5(1)	4(1)	4(1)	0.116	0.944
POD_2	3(1)	3(1)	3(1)	0.463	0.793
POD_3	2(1)	2(0.75)	2(0)	1.889	0.389
POD_7	1.5(1)	1(1)	1(1)	2.613	0.271
Remedial analgesia	3(10.7%)	4(14.3%)	3(11.1%)	0.202	0.904

QoR-15 scores on POD_2 ($P<0.05$), and Group B2 had significantly higher QoR-15 scores on both POD_1 and POD_2 ($P<0.05$). Moreover, compared with Group B1, Group B2 had significantly higher QoR-15 scores on POD_1 and POD_2 ($P<0.05$). For more information, please refer to Tables 6 and Figure 4.

The RCSQ scores on Preop of the three groups were not significantly different ($P>0.05$). Compared with Preop, the RCSQ scores significantly decreased on POD_1, POD_2 and POD_3 in all three groups ($P<0.05$). Compared to Group C, Group B1 had remarkably higher RCSQ scores on POD_1 and POD_3 ($P<0.05$), and Group B2 had noticeably higher RCSQ scores on both POD_1, POD_2, and POD_3 ($P<0.05$). In addition, no difference in the RCSQ score was found on POD_1, POD_2, POD_3, and POD_7 between Group B1 and Group B2 ($P>0.05$). Further details are provided in Tables 7 and Figure 5, respectively.

Table 6 Perioperative Qor-15 Scores

	C (n=28)	B1 (n=28)	B2 (n=27)	F	*P*
PREOP	134.43±7.26	130.89±8.79	132.78±5.32	1.652	0.198
POD_1	104.54±9.85 $^{\Delta}$	107.82±6.79 $^{\Delta}$	114.15±8.57*$^{\#\Delta}$	9.065	0.000
POD_2	107.50±8.65 $^{\Delta}$	113.82±6.94*$^{\Delta}$	120.37±8.54*$^{\#\Delta}$	17.463	0.000
POD_3	118.61±8.76 $^{\Delta}$	121.04±8.26 $^{\Delta}$	122.85±8.26 $^{\Delta}$	1.757	0.179
POD_7	124.43±7.02 $^{\Delta}$	126.57±9.00	128.44±5.42	2.076	0.132

Notes: *$P<0.05$, compared with Group C; $^{\#}P<0.05$, compared with Group B1; $^{\Delta}P<0.05$, compared with Preop.

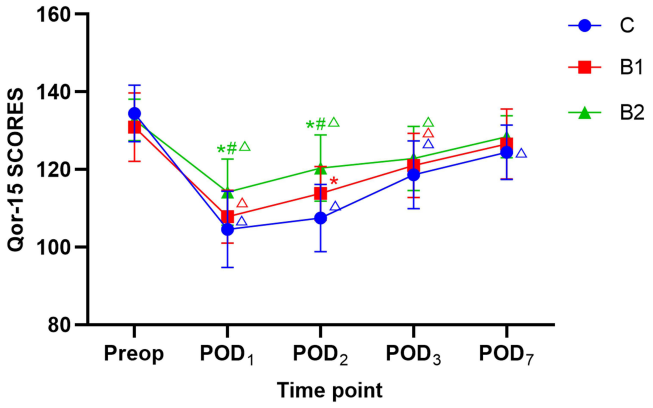

Figure 4 Perioperative Qor-15 scores.
Notes: *P<0.05, compared with Group C; #P<0.05, compared with Group B1; ΔP<0.05, compared with Preop.

The incidence of POD and POCD at any time point, their total incidence (POD or POCD: C, 17.9%; B1, 14.3%; B2, 11.1%), and MMSE scores exhibited no significant differences across the three groups (P>0.05), with no notable trends in incidence rates. Similarly, postoperative complication rates were lower in Groups B1 (3.6%) and B2 (7.4%) compared to Group C (10.7%), though not significantly (P>0.05). No respiratory complications occurred in any group, and the incidence of circulatory system complications also showed no significant differences across groups (P>0.05), with postoperative hospital stay remaining similar (P>0.05). However, the time to first ambulation in Group B2 was significantly shorter than in Group C (P<0.05), suggesting enhanced early mobility, whereas Group B1 showed no significant difference from Group C (P>0.05). Additional details are presented in Tables 8 and 9.

Discussion

This study indicated that the depth of anesthesia monitoring under BIS could promote early recovery after laparoscopic surgery in elderly patients, which has significant implications for the selection of intraoperative anesthetic monitoring as well as the improvement of anesthetic management among elderly patients.

In clinical practice, anesthesiologists generally judge the depth of anesthesia through a series of vital sign changes such as blood pressure, heart rate, pupil size, muscle tone and nerve reflexes.[19] However, such vital signs sometimes do not accurately reflect the depth of anesthesia level because of the differences in stimulation intensity, surgical types and individuals, also, there will use adequate analgesics, muscle relaxants, vasoactive drugs, anticholinergics and other drugs during anesthesia, thus it becomes difficult and unreliable to identify and judge the depth of anesthesia through simple clinical observation. Too light anesthesia can lead to a significant stress response, circulatory system hyperexcitability, supply and demand imbalance of oxygen in various vital organs, endocrine and metabolic disorders, and even intraoperative awareness and more serious adverse consequences, such as post-traumatic stress disorder, causing great

Table 7 Perioperative RCSQ Scores

	C (n=28)	B1 (n=28)	B2 (n=27)	F	P
PREOP	75.46±5.19	74.82±5.11	77.00±3.99	1.488	0.232
POD_1	60.43±4.32 Δ	63.32±5.46*Δ	65.00±6.30*Δ	5.046	0.009
POD_2	65.07±5.93 Δ	67.25±5.57 Δ	69.15±6.18*Δ	3.297	0.042
POD_3	66.86±4.78 Δ	70.39±6.15*Δ	71.89±5.26*Δ	6.264	0.003
POD_7	74.75±5.63	75.86±5.51	74.63±6.03	0.388	0.680

Notes: *P<0.05, compared with Group C; ΔP<0.05, compared with Preop.

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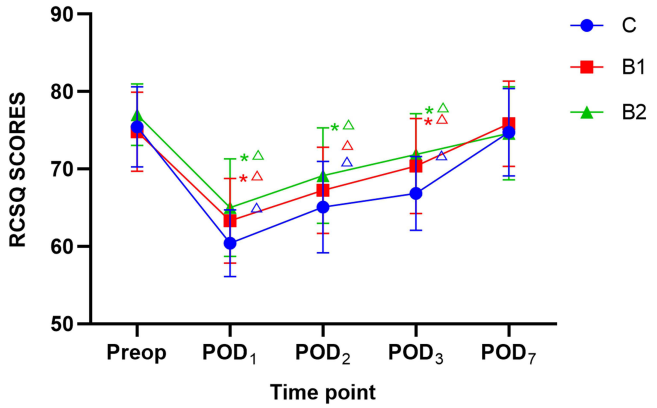

Figure 5 Perioperative RCSQ scores.
Notes: *P<0.05, compared with Group C; #P<0.05, compared with Group B1; ΔP<0.05, compared with Preop.

physical and mental damage to patients. On the other hand, anesthesia that is too deep can trigger adverse events including insufficient stress response, severe respiratory and circulatory function inhibition, delayed awakening, and postoperative neurocognitive dysfunction, and in severe cases, irreversible damage or death.[20] Therefore, the evaluation of depth of anesthesia is of great significance for the safety and postoperative recovery of patients, especially for elderly patients with vulnerable physiological status, and accurate monitoring of the depth of anesthesia has special value.[21]

Table 8 POD Incidence, POCD Incidence, and MMSE Scores

	C (n=28)	B1 (n=28)	B2 (n=27)	χ^2/ F	*P*
Incidence of POD					
POD_1	3(10.7%)	3(10.7%)	2(7.4%)	0.229	0.892
POD_2	2(7.1%)	2(7.1%)	1(3.7%)	0.381	0.827
POD_3	1(3.6%)	0(0)	0(0)	1.988	0.370
Total cases	5(17.9%)	4(14.3%)	3(11.1%)	0.507	0.776
Incidence of POCD					
POD_3	4(14.3%)	4(14.3%)	3(11.1%)	0.160	0.923
POD_7	3(10.7%)	2(7.1%)	1(3.7%)	1.008	0.604
Total cases	5(17.9%)	4(14.3%)	3(11.1%)	0.507	0.776
MMSE scores					
PREOP	24.68±2.16	24.71±1.96	24.93±2.15	0.112	0.894
POD_3	23.14±2.49	23.32±2.83	23.41±2.14	0.080	0.923
POD_7	24.04±2.19	24.93±2.61	24.33±2.02	1.104	0.336

Table 9 Complications, First Postoperative Ambulation, and Postoperative Hospital Stay

	C (n=28)	B1 (n=28)	B2 (n=27)	χ^2/F/H	*P*
Postoperative complications	3(10.7%)	1(3.6%)	2(7.4%)	1.067	0.690
Nausea and vomiting	2(7.1%)	1(3.6%)	1(3.7%)	0.498	1.000
Respiratory complications	0(0)	0(0)	0(0)	/	/
Circulatory complications	1(3.6%)	0(0)	1(3.7%)	1.044	0.770
First postoperative ambulation (h)	24(14.5)	20(6)	18(10)*	8.380	0.015
Postoperative hospital stay (d)	7.57±1.83	7.25±1.90	7.96±1.99	0.962	0.386

Note: *P<0.05, compared with Group C.

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According to previous studies on BIS monitoring among elderly patients, the first concern related to the depth of anesthesia was its influence on the quality of anesthesia recovery. Anesthesia recovery is most strongly linked to anesthetic methods, selection of anesthetic drugs, and management. Anesthetic management is particularly crucial under the established anesthetic and drug regimens. Lewis et al[22] found that using BIS monitoring to guide the depth of anesthesia could reduce intraoperative awareness and dosage of intraoperative sedative drugs, shorten anesthesia emergence and extubation times, and facilitate early postoperative recovery. Yu et al[23] applied intraoperative BIS monitoring to maintain the depth of anesthesia at a specific level in elderly patients, and reported that this method could better inhibit adverse stress responses, reduce anesthesia-related hypotension, and maintain hemodynamic stability. Monitoring the depth of anesthesia to improve the management of intraoperative hypotension in elderly patients might be a convenient intervention with the potential to reduce the incidence of intraoperative anesthesia-related hypotension in this vulnerable group.[24] Similar to previous findings, our results showed that compared with Group C, dosage of intravenous anesthetic propofol, emergence time and extubation time were all less in Groups B1 and B2, suggesting that depth of anesthesia under BIS monitoring could reduce intraoperative anesthetic drug consumption and improve the quality of recovery. In addition, no significant difference was observed in the incidence of intraoperative hemodynamic adverse events among the three groups, whereas the time required for emergence and extubation was shorter and PACU stay was shorter in Group B2 than in Group B1, indicating that slightly higher BIS values were more favorable for anesthesia recovery in elderly patients undergoing laparoscopic surgery under the premise of anesthesia safety.

The recovery of postoperative cognitive function is important for evaluating the quality of recovery in elderly patients, especially POD and POCD, which have a high incidence in elderly surgical patients. Age is the most significant factor of postoperative cognitive function recovery, while surgery and general anesthesia are generally considered as common risk factors for POCD, but the specific mechanism remains unknown.[25,26] Clinical studies have suggested that the depth of anesthesia has a certain correlation with the occurrence and recovery of POCD,[27] while BIS monitoring of depth of anesthesia can promote early postoperative cognitive function recovery and reduce the occurrence of acute POD.[28] However, Wildes et al[29] disagreed with the above results through a randomized controlled study of 1232 elderly patients aged 60 years and above undergoing major surgery, from which they found no superior effect of electroencephalography-guided anesthesia on POD reduction compared with conventional anesthesia. Some investigators therefore believed that current evidence could not support its routine use to prevent POD in elderly patients or any other patients.[30] A meta-analysis also reported no significant correlation between depth of anesthesia and POCD.[31] Studies on the effect of different depth of anesthesia on cognitive function also remain controversial, including the view of targeted light anesthesia could reduce the incidence of POD and the risk of POCD,[32] and avoiding too deep anesthesia through intraoperative monitoring might help improve postoperative cognitive function to benefit patients at high risk of POCD.[33] Quan et al[34] performed deep anesthesia with BIS values at low levels (30~45) and decreased the occurrence of early POCD after abdominal surgery in elderly patients. The diverse conclusions might stem from the heterogeneity of studies, but the development of deep anesthesia could independently predict POD and should be vigilant for explosive suppression during surgery.[35,36] Current evidence suggests that early risk identification, as well as careful adjustment of the depth of anesthesia and treatment of pain guided by processed electroencephalographic monitoring, were the most effective strategies for reducing the risk of POD.[37]

In our study, there were no significant differences in POD, POCD, and MMSE scores among the three groups, which may be because unlike the more invasive surgical types, minimally invasive laparoscopic surgery had no significant effect on postoperative cognitive function in elderly patients. Second, the relatively small sample size limited the statistical power and may not have been sufficient to detect subtle changes. Third, patients included in this study generally had a lower education level and could not complete complex scales such as the Montreal Cognitive Assessment (MoCA); therefore, the MMSE was finally selected. MMSE is the most commonly used cognitive function assessment scale in previous studies, with the disadvantages of being relatively simple, less sensitive, and having learning and capping effects when repeatedly evaluated. Future studies are needed to synthesize more scales and diagnostic tools for systematic cognitive function assessment.

Sleep quality has an indispensable relationship with cognitive function, and sleep problems and disorders may lead to impaired cognition.[38] Epidemiological studies have shown that about 50% of the elderly have sleep problems, but it is

often not fully appreciated in elderly people in clinical practice.[39] The general anesthesia can change postoperative sleep architecture, especially in elderly patients with a high incidence of postoperative sleep disorders; general anesthesia can cause deleterious effects such as increased risk of delirium and cardiovascular events, and poor recovery.[16] It may take a week or more to recover after surgery due to decreased subjective sleep quality and efficiency and increased daytime fatigue.[40] Song et al[41] proved that compared with subarachnoid anesthesia, general anesthesia is associated with greater impairment of melatonin rhythm and sleep patterns, as well as a higher incidence of POD in elderly patients. This might be due to the effect of propofol on sleep rhythm, and the use of propofol at the recommended sedation level in critically among patients with assisted ventilation mode would inhibit rapid eye movement sleep and further deteriorate their sleep quality, but very few reports focused on the effect of propofol on the postoperative sleep quality of elderly patients during routine surgical anesthesia application.[42] As one of the instruments used to evaluate sleep quality, the RCSQ scale contains five items, with higher scores representing better sleep quality.[43] Compared with the more commonly used Pittsburgh Sleep Quality Index, the RCSQ is more concise and easier to understand and capture, and its items are relevant to sleep quality and have shown good reliability and validity, providing a comprehensive sleep assessment over a short length of hospital stay.[44] In this study, RCSQ scores in all three groups returned to the preoperative baseline on POD_7. Group B1 had higher RCSQ scores on POD_1 and POD_3 than Group C, whereas Group B2 had higher RCSQ scores from POD_1 to POD_3 than Group C. It could be concluded that the postoperative sleep quality was better than that of Group C to some extent when monitoring the depth of anesthesia through BIS. Maintaining an intraoperative BIS value of 50–60 could improve postoperative sleep quality more effectively, which is beneficial for postoperative recovery.

Anesthesia recovery and cognitive function recovery are part of the postoperative recovery quality, whereas in the evaluation of perioperative recovery quality, the subjective feelings of patients are often easily ignored. The effectiveness and safety of current anesthesia also place greater emphasis on patient-centered outcome measures.[45] QoR-15 is a widely used and validated patient-reported outcome measure for quality of recovery after surgery developed by Stark et al from QoR-40,[12] which has equivalent psychometric properties but is more feasible to use and meets the requirements of validity, reliability, interpretability, acceptability, and feasibility.[18,46] Items of QoR-15 include five dimensions, which are emotional state, physical comfort, psychological support, physical independence, and pain, and the anesthesiologist is able to assess the patient ‘s recovery from multiple dimensions reported by the patient after surgery and further evaluate the quality of anesthesia.[47] On the basis of Consensus-based Standards for the selection of health Measurement Instruments (COSMIN), a recent systematic review suggested the use of QoR-15 as a standard outcome measure for quality of recovery in surgical and anesthetic clinical trials since the primary aim of surgical and anesthetic interventions was to improve patient outcomes.[48] Whereas in previous studies on the influence of depth of anesthesia on postoperative recovery, the results were generally physician-centered evaluations that focused only on some morbidity parameters, and the effect remained unknown if taking the patient ‘s physical and psychological status into account. Our results indicate that monitoring and regulation of the depth of anesthesia could impact patients’ perception and evaluation of recovery quality. Compared to Group C, Group B1 had significantly higher QoR-15 scores on POD_2, and Group B2 had significantly higher QoR-15 scores on both POD_1 and POD_2. In addition, compared with Group B1, Group B2 had significantly higher QoR-15 scores on POD_1 and POD_2. It could be inferred that lighter anesthesia resulted in a better evaluation of early postoperative recovery quality in elderly patients undergoing laparoscopic surgery.

Pain is an essential factor that affects the postoperative status. Significant postoperative pain can reduce patients’ postoperative comfort and satisfaction, and also lead to complications such as sympathetic hyperexcitability, increased stress response, cognitive impairment, sleep disorders, postoperative activity limitation, increased risk of thromboembolism, and prolonged hospital stay, all of which slow patients’ postoperative recovery.[17] In our study, the same postoperative analgesia method was used in the three groups, and no significant differences were found in VAS score and analgesic remedy at each time point. However, Group B2 had a significantly shorter time to first postoperative ambulation than Group C, indicating that the QoR-15 score could better reflect the overall level of recovery of the patients. The mean QoR-15 scores did not return to the preoperative baseline on POD_7 in all of the three groups, which might be because after minimally invasive laparoscopic surgery, the body could not adapt and effectively compensate for the negative effects within a short period of time, such as pain, disruption of dietary patterns, energy metabolism and endocrine dysfunction, sleep disorders, and reduced physical activity. Some scholars believed that this might be a long-

term and slow repair process,[35] at the same time, whether baseline data could truly reflect the preoperative status of patients also required further verification.[48]

Through this trial, we also found that compared with Groups B1 and B2, more anesthetic drugs were used in Group C, and the BIS values at each time point and the mean BIS values during surgery in Group C were lower, indicating that the depth of anesthesia guided by experience might generally be deeper and that deep anesthesia lasts for a longer period than expected in elderly patients, which could be a potential risk for elderly patients. Therefore, it is necessary to monitor and adjust the depth of anesthesia within a certain range during the perioperative period to avoid long-term deep anesthesia in elderly patients with poor health. Through this trial, we also found that compared with Groups B1 and B2, more anesthetic drugs were used in Group C, and the BIS values at each time point and the mean BIS values during surgery in Group C were lower, indicating that the depth of anesthesia guided by experience might generally be deeper and that deep anesthesia lasts for a longer period than expected in elderly patients, which could be a potential risk for elderly patients. Therefore, it is necessary to monitor and adjust the depth of anesthesia within a certain range during the perioperative period to avoid long-term deep anesthesia in elderly patients with poor health. Our results demonstrate that BIS-guided anesthesia significantly enhanced immediate postoperative recovery, notably earlier ambulation in Group B2 compared to Group C [18(10) vs 24(14.5) hours; P=0.015], but did not significantly reduce other complications (eg, total incidence: B1 3.6%, B2 7.4%, C 10.7%; P=0.690; nausea/vomiting lower in B1 and B2). This is consistent with Chiang et al[11] and Gruenewald et al[19] who found BIS-guided techniques primarily improve short-term outcomes like mobility without broadly affecting complication rates unless optimized for high-risk patients. This suggests that anesthesia depth's primary benefit lies in immediate recovery, supporting its targeted application in clinical practice.

In light of these results, an intriguing question arises regarding the potential role of total intravenous anesthesia (TIVA) in this context. TIVA, which allows for precise titration of anesthetic agents such as propofol, may offer an alternative or complementary approach to controlling anesthesia depth more effectively than inhaled agents alone. Studies such as those by Li et al[49] suggest that TIVA, when paired with depth-of-anesthesia monitoring, could provide finer control over sedation levels, potentially enhancing outcomes like mobility while minimizing oversedation-related risks. This precision is particularly advantageous in procedures requiring tight control, such as in elderly or hemodynamically unstable patients.[50] Whether TIVA could outperform BIS-guided volatile anesthesia in our study population—particularly in terms of refining immediate postoperative recovery—remains an open question worthy of further investigation. To fully elucidate these possibilities, future research should compare BIS-guided volatile anesthesia with TIVA in similar cohorts, focusing not only on mobility but also on other short-term recovery parameters, such as cognitive function and patient-reported outcomes. Additionally, while our findings suggest that anesthesia depth management has a limited scope in reducing overall complications, its role in specific patient subgroups (eg, the elderly or those with comorbidities) warrants further exploration. In conclusion, our study highlights the nuanced impact of anesthesia depth on postoperative recovery and opens the door to considering alternative strategies, such as TIVA, to optimize patient outcomes in the immediate postoperative phase.

This study has some limitations. First, all included participants were elderly patients with lower educational levels who underwent elective laparoscopic surgery, thus, our results may not be generalizable to more educated, healthier, and younger patients and other surgical modalities. Second, we only performed follow-up within 7 days after surgery because of limited resources, while recovery after anesthesia and operation might take weeks or even years, and the impairment and recovery of cognitive function are also slow processes. In addition, these assessments are not realistic for emergency surgery because of the need to obtain baseline data. Finally, the ability of TIVA to maintain a stable pharmacokinetic profile might theoretically improve depth control, but its practical superiority would depend on factors such as patient-specific responses, surgical type, and resource availability, which were not directly assessed in our study. Nevertheless, our results still indicate that using the BIS to monitor the depth of anesthesia and maintain a higher BIS value within a safe range in laparoscopic surgery in elderly patients could help improve the quality of anesthesia recovery and promote sleep quality recovery and early autonomous activity in a short period of time after surgery, which might be one of the important means of enhancing the quality of early postoperative recovery in elderly patients. These results remain of great value for the evaluation and prediction of long-term health status of elderly patients after surgery.

Conclusion

In summary, this study demonstrated the guiding significance of BIS in monitoring the depth of anesthesia after laparoscopic surgery among elderly patients in terms of reducing the amount of general anesthesia, shortening emergence time and extubation time, and decreasing the length of PACU stay. Furthermore, it improved the postoperative sleep quality to a certain extent, thereby promoting early postoperative recovery from the patient ‘s perspective. Experience-guided anesthesia in elderly patients has the potential to result in deep anesthesia or even prolonged deep anesthesia, whereas lighter anesthesia may be more beneficial in elderly patients undergoing laparoscopic surgery. These findings have important implications for the selection of intraoperative monitoring tools and optimization of anesthetic management.

Abbreviations

QoR, quality of recovery; VAS, visual analog scale; CAM, confusion assessment method; MMSE, Mini-Mental State Examination; RCSQ, Richards-Campbell sleep questionnaire; BIS, bispectral index; POD, postoperative delirium; POCD, postoperative cognitive dysfunction; PACU, post-anesthesia care unit; MAP, mean arterial pressure; HR, heart rate.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

There are no conflicts of interest reported by the authors. An unauthorized version of the Chinese MMSE was used by the study team without permission, however this has now been rectified with PAR. The MMSE is a copyrighted instrument and may not be used or reproduced in whole or in part, in any form or language, or by any means without written permission of PAR (www.parinc.com).

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