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ORIGINAL RESEARCH

A Perioperative Care Strategy for Prevention of Postoperative Delirium in Elderly Patients with Gastrointestinal Tumors: A Clinical Observational Study

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Background: To evaluate the association of a comprehensive perioperative care strategy on postoperative delirium (POD) incidence and perioperative recovery in elderly patients undergoing surgery for gastrointestinal tumors. This institutional pathway extended routine ERAS care by incorporating a nurse-led, protocolized multicomponent bundle specifically targeting modifiable delirium precipitants across the perioperative period.

Methods: This retrospective study included 260 elderly patients scheduled for elective radical resection for gastric or colorectal cancer between January 2023 and December 2024. Patients were categorized into a conventional care group (control, n = 130) and an enhanced perioperative care group (enhanced care, n = 130). POD incidence and severity within 7 days after surgery were assessed using the Delirium Rating Scale-Revised-98 (DRS-R-98). Secondary outcomes included sleep quality (Pittsburgh Sleep Quality Index, PSQI), melatonin levels, cognitive function (Mini-Cog), activities of daily living (Barthel index), inflammatory and stress biomarkers (CRP, IL-6, cortisol), and recovery parameters [time to first ambulation, first flatus, hospital stay, and Quality of Recovery-15 (QoR-15) scores].

Results: Compared with the control group, the enhanced care group showed significantly lower POD incidence and severity ($P < 0.05$). Patients managed under the enhanced care protocol also had lower PSQI scores, fewer nocturnal awakenings, higher melatonin levels, better Mini-Cog performance, and higher Barthel index scores ($P < 0.001$). Postoperative CRP, IL-6, and cortisol levels were also lower in this group ($P < 0.05$). In addition, time to first ambulation, first flatus, and hospital stay were significantly shorter, whereas QoR-15 scores were significantly higher ($P < 0.001$).

Conclusion: In this retrospective cohort, comprehensive perioperative care was associated with lower POD incidence and severity, better sleep, cognitive and functional recovery, and reduced stress and inflammatory markers. Due to the study's retrospective design, findings may be influenced by unmeasured confounders; prospective studies are needed to confirm these results.

Keywords: elderly patients, gastrointestinal tumors, perioperative care, postoperative delirium, cognitive function, sleep quality

Introduction

Elderly patients with gastrointestinal tumors face multiple challenges during the perioperative period, including surgical trauma, anesthetic and analgesic exposure, inflammatory and metabolic stress, nutritional vulnerability and sarcopenia, multimorbidity, and environmental changes associated with hospitalization.[1–3] Among these, postoperative delirium (POD) is one of the most common complications in older surgical patients and is associated with a range of adverse short- and long-term outcomes.[4] Characterized by acute, fluctuating disturbances in attention and orientation, POD can lead to self-extubation, falls, prolonged hospitalization, increased costs, and long-term cognitive impairment.[5–7] The pathogenesis of delirium is considered multifactorial, involving interactions among pathways such as peripheral

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inflammation triggering neuroinflammation, neurotransmitter imbalances, impaired synaptic and network plasticity, and fragmentation of circadian rhythms and sleep.[8,9] In the elderly population, preventable precipitating factors are particularly crucial, including hypoxia, uncontrolled pain, infection, electrolyte imbalances, constipation and urinary retention, high burden of opioid and benzodiazepine use, nocturnal noise and bright light, frequent non-indicated awakenings, sensory deprivation, and absence of family members.[10–12]

Both international and national consensus guidelines advocate multicomponent, largely non-pharmacological, protocol-driven, and reproducible care as a cornerstone of delirium prevention in older surgical patients.[13,14] This includes preoperative risk screening and expectation management, anxiety reduction, and sleep hygiene education;[15] intraoperative optimization of body temperature and hemodynamics, implementation of multimodal analgesia, and avoidance of deep anesthesia and excessive sedation;[16] and postoperative interventions such as environmental and sleep management (noise and light reduction at night, minimizing disruptions, daytime reorientation and light exposure), systematic assessment and management of reversible causes, promotion of early ambulation and functional rehabilitation, encouragement of family involvement, and daily screening with standardized tools for severity grading.[17] Compared with single-component measures, care pathway-based multicomponent ("bundled") interventions may provide broader and potentially synergistic benefits across interconnected domains such as sleep-circadian regulation, stress-inflammation, and functional recovery, thereby improving perioperative outcomes.[18] However, real-world evidence on the impact of such protocolized, enhanced care—implemented as part of in-hospital quality-improvement initiatives—on delirium and multidimensional recovery outcomes in elderly patients undergoing gastrointestinal tumor surgery remains limited across institutions.[19,20]

To address this gap, we conducted a single-center study comparing the effects of an enhanced perioperative care protocol, characterized by process optimization and standardized execution, versus conventional care in elderly patients undergoing gastrointestinal tumor surgery. We assessed its impact on POD and a spectrum of outcomes including sleep, inflammation, function, and quality of recovery.

Methods

Study Design

The study enrolled 260 elderly patients with gastrointestinal tumors who underwent elective surgery at the Third Xiangya Hospital, Central South University between January 2023 and December 2024. Group assignment was based on the sequential rollout of the care pathway across different wards/time periods or actual clinical practice, not researcher randomization. Specifically, patients were assigned to either the conventional care group or the enhanced perioperative care group based on the period of their hospitalization. However, given the non-randomized retrospective design, potential selection bias and unmeasured confounding cannot be fully ruled out, even though allocation was driven by routine clinical practice rather than deliberate clinical selection or investigator intervention. The study protocol was approved by the Third Xiangya Hospital, Central South University's Ethics Committee, which waived the requirement for individual patient informed consent due to the observational nature of the study. The study adhered to the principles of the *Declaration of Helsinki* and was designed and reported following the STROBE statement.[21]

Study Population

Inclusion criteria were: 1) age $\geq$ 65 years; 2) radiological or pathological confirmation of gastric or colorectal malignancy; 3) scheduled for elective radical resection; 4) American Society of Anesthesiologists (ASA) physical status I–III; 5) no documented pre-existing cognitive impairment or history of delirium, no severe psychiatric disorders, and complete medical records. Exclusion criteria included: 1) previous diagnosis of dementia, Alzheimer´s disease, mild cognitive impairment (MCI), or other severe mental illnesses; 2) concomitant severe cardiac, hepatic, or renal dysfunction; 3) emergency or second-look surgery; 4) incomplete data or in-hospital mortality postoperatively. Accordingly, the "high-risk" designation used in the nursing intervention refers to patients without documented pre-existing cognitive impairment/delirium history but with other recognized POD risk factors.

A total of 260 eligible patients were included and divided into the conventional care group (control) and the enhanced perioperative care group (intervention) based on the care model received. This study compared the effects of an optimized care pathway already implemented in the hospital versus historical/concurrent conventional care, constituting a minimal-risk, quality improvement observational study. Data were sourced from routine information in medical and nursing records, without additional interventions, sampling, or collection of identifiable information. Group assignment was based on the sequential rollout of the care pathway across different wards/time periods or actual clinical practice, not researcher randomization.

Nursing Interventions

All assessment instruments used in this study (eg., HADS, CAM, DRS-R-98, VAS, PSQI, Mini-Cog, Barthel Index, and QoR-15) were internationally recognized and widely validated tools, and the corresponding citations are provided to document their original development and established clinical use.

The control group received conventional perioperative care, including routine preoperative education and guidance, intraoperative monitoring, postoperative pain management, and wound/drain care. Importantly, conventional care did not include a protocolized delirium-prevention bundle. Routine HADS screening was not systematically implemented in the control group, and patients with HADS scores ≥ 8 did not receive a standardized, threshold-triggered psychological intervention; psychological support was provided only when requested or considered necessary by routine clinical judgement. In addition, sleep/environmental interventions (night-time noise/light reduction and minimizing nonessential nocturnal awakenings), structured reorientation sessions, and scheduled delirium surveillance were not standardized as part of routine care. Postoperative mobilization and nutrition followed routine medical orders; early mobilization within 24 hours and prioritization of early enteral nutrition were not implemented via a dedicated protocol in the control group. Intraoperative care in the control group followed routine anesthesia practice, including standard temperature management and anesthesia depth monitoring (eg., BIS when clinically indicated), with anesthetic and fluid management at the discretion of the attending anesthesiologist. In both groups, delirium screening using CAM and severity rating using DRS-R-98 (for CAM-positive cases) were conducted according to the same postoperative assessment protocol and were independent of the care model received.

The intervention group received an enhanced perioperative care strategy in addition to conventional care, comprising the following key components: All components were delivered according to a standardized ward-level protocol (quality-improvement pathway) with predefined triggers (eg., HADS ≥ 8) and structured checklists to ensure consistent implementation.

Preoperative Management

Led by specialized nurses, this phase involved using multimedia and face-to-face communication to explain the surgical process, anesthesia considerations, and postoperative recovery points to patients and families, aiming to reduce anxiety from uncertainty. Psychological status was assessed using the Hospital Anxiety and Depression Scale (HADS), a widely used and validated screening instrument for anxiety and depression in clinical settings.[22] Patients with scores ≥ 8 received individualized psychological support from responsible nurses, including relaxation techniques, empathetic listening, positive reinforcement, and music relaxation therapy based on patient preference.[23] Furthermore, patients were guided on maintaining regular sleep patterns and nutritional intake the day before surgery, avoiding prolonged preoperative fasting that could lead to hypoglycemia or dehydration. For patients identified as being at higher risk of POD based on perioperative risk profiling (eg., advanced age, multiple comorbidities, higher ASA class, elevated HADS scores, or poor baseline sleep quality), nurses provided intensified risk education and implemented prominent nursing alerts. Patients with documented pre-existing cognitive impairment or a history of delirium were excluded from the cohort.[23]

Intraoperative Management

In both groups, intraoperative temperature management and anesthesia depth monitoring were part of routine anesthesia care. In the intervention group, these measures were implemented in a protocolized manner with predefined targets and standardized documentation/communication (eg., maintaining core temperature at 36–37°C using forced-air warming and warmed fluids, and BIS-guided depth targets of 40–60 where applicable), and the care team emphasized minimizing

potentially deliriogenic agents (eg., benzodiazepines and anticholinergics) when clinically feasible.[24] Anesthesiologists adjusted anesthetic agents and fluid infusion rates based on real-time hemodynamic monitoring. Nurses maintained dynamic communication with the anesthesiologist and surgical team to ensure hemodynamic stability and adequate oxygenation throughout the procedure.

Postoperative Management

Multimodal analgesia was initiated immediately post-surgery, combining non-opioid analgesics (eg., acetaminophen, non-steroidal anti-inflammatory drugs) with low-dose opioids to control pain. Pain was assessed using the Visual Analog Scale (VAS) at 6, 24, and 48 hours postoperatively, ensuring it remained within a tolerable range. Nurses encouraged patients to ambulate with assistance within 24 hours post-surgery to promote bowel motility and pulmonary function. An early enteral nutrition strategy was prioritized, with gradual increases in intake based on tolerance.

Additionally, nurses conducted reorientation exercises twice daily (morning and evening), involving simple cognitive exchanges regarding date, location, and person, to help maintain reality orientation. The ward environment was kept quiet with soft lighting, and unnecessary nocturnal disruptions were minimized to promote regular sleep. Patients identified as high-risk (eg., advanced age, pre-existing cognitive impairment, multimorbidity) received intensified monitoring for changes in consciousness and behavior. Trained nurses assessed patients twice daily (morning and evening) during postoperative days 1–7 using the Confusion Assessment Method (CAM), a standardized and widely validated bedside tool for delirium screening.[25] For patients with mild cognitive disturbances, non-pharmacological interventions such as context reorientation, family companionship, and daytime light therapy were implemented.[26]

Observation Indicators

POD Incidence and Duration

Trained nurses screened patients twice daily (8:00 and 20:00) during postoperative days 1–7 using the CAM.[27] Delirium ascertainment was performed prospectively at the bedside in both the control and intervention groups using the same schedule and the same standardized instrument. Diagnosis required the presence of acute onset and fluctuating course, inattention, plus either disorganized thinking or altered level of consciousness. Electronic medical records and routine nursing notes were reviewed only as supportive information (eg., to corroborate timing, precipitating factors, and medication exposure) and were not used as the sole basis for delirium diagnosis, because core features such as disorientation/inattention require bedside assessment. Delirium duration was defined as the number of days from the first positive assessment to the first of two consecutive negative assessments. Delirium severity was assessed using the Delirium Rating Scale-Revised-98 (DRS-R-98)[28] for all patients who met CAM criteria for delirium, and categorized as mild (DRS-R-98 total score 20–24), moderate (25–26), or severe (≥27).

Delirium assessments were performed by three nurse assessors who did not participate in the delivery of the enhanced care pathway. All assessors completed standardized training prior to study initiation, including a structured workshop on CAM/DRS-R-98 definitions, case-vignette practice, and supervised bedside scoring, followed by a competency assessment. To ensure inter-rater consistency, two assessors independently rated a random 10% sample of patients during the study period; agreement for CAM (binary outcome) was evaluated using Cohen's kappa, and agreement for DRS-R-98 scores was evaluated using the intraclass correlation coefficient (ICC). Because group assignment was determined by ward/time-period rollout, complete blinding of bedside staff was not feasible; however, outcome extraction and data entry were performed by an independent investigator using de-identified records with group labels masked (coded as Group A/B) to minimize assessment and information bias.

Secondary Observation Indicators

Sleep Quality

Sleep quality was assessed preoperatively and on postoperative day 3 using the Pittsburgh Sleep Quality Index (PSQI).[29] The PSQI comprises seven components (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction), each scored 0–3, yielding a global score range of 0–21 (higher scores indicate poorer sleep quality). PSQI results were retrieved retrospectively from standardized

nursing/ward assessment records in the electronic medical record (EMR) system. When PSQI was not available as a structured field, the documented questionnaire form in the medical record was used.

Inflammatory and Stress Markers

Inflammatory and stress markers were obtained retrospectively from the hospital Laboratory Information System (LIS). C-reactive protein (CRP), interleukin-6 (IL-6), and cortisol measured preoperatively and on the morning of postoperative day 3 were extracted using the unique hospital identifier and verified by LIS timestamps. No additional blood sampling or laboratory testing was performed for the purposes of this retrospective analysis. Results were analyzed using the values recorded in routine clinical care (units as reported by the LIS).

Surgery-Related Parameters and Postoperative Recovery Indicators

Surgery-related parameters (operation time, anesthesia time, intraoperative blood loss, intraoperative fluid volume) and postoperative recovery indicators (time to first ambulation, time to first flatus, postoperative length of stay) were retrospectively extracted from the anesthesia record, operative notes, and nursing documentation in the EMR. Time-to-event indicators (ambulation and flatus) were defined as the first documented occurrence in nursing notes. Overall recovery quality was assessed on postoperative day 3 using the Quality of Recovery-15 (QoR-15) questionnaire.[30] QoR-15 data were retrieved from standardized ward assessment records where available.

Melatonin Level (Circadian-Related Marker)

Melatonin values were retrieved retrospectively from the hospital Laboratory Information System (LIS) for for all included patients. At our institution, melatonin is not a routine perioperative test; therefore, no additional blood sampling was performed for this retrospective analysis. For eligible patients with available measurements, serum melatonin results (pg/mL) obtained at a standardized morning timepoint (08:00) preoperatively and on postoperative day 3 were extracted based on LIS timestamps and linked to each participant using a unique hospital identifier. Between-group comparisons were conducted for preoperative and postoperative day 3 morning melatonin values.

Cognitive and Functional Recovery

Cognitive and functional recovery was assessed prior to discharge by the same researcher using the Mini-Cog[31] scale and the Barthel index.[32] The Mini-Cog includes three-item recall and clock drawing, with a total score of 5, and a score ≥ 4 indicating normal cognitive function. The Barthel index assesses activities of daily living across 10 items, with a total score of 100: ≥ 85 indicates mild dependence, and < 60 indicates severe dependence. Mini-Cog and Barthel index scores were retrieved retrospectively from standardized nursing/rehabilitation assessment records in the EMR prior to discharge.

The scales used to evaluate delirium, sleep, cognition, functional status, and recovery quality were selected because they are established, validated, and widely applied in perioperative and geriatric research.

Statistical Analysis

This single-center retrospective observational study, with the incidence of POD during postoperative days 1–7 as the primary outcome, was designed specifically to compare two independent proportions. Assuming a two-sided α of 0.05, power (1-β) of 0.80, and 1:1 allocation, and referencing an approximate POD incidence of 20% in the control group from a similar population in our center, a "clinically meaningful effect" was defined as an absolute reduction of ≥ 12 percentage points (ie., to approximately 8–9%). Under these assumptions, a total sample size of 260 patients (130 per group) was calculated to achieve the desired power. This sample size was deemed reasonable and feasible, maintaining sufficient power to detect a ≥ 12 percentage point difference even considering minor loss to follow-up/missing data.

Continuous variables were assessed for distributional normality using the Shapiro–Wilk test and visual inspection of histograms/Q-Q plots. Normally distributed variables were summarized as mean ± standard deviation (SD) and compared using the independent-samples *t*-test; non-normally distributed variables were summarized as median (interquartile range, IQR) and compared using the Mann–Whitney *U*-test. Categorical variables were presented as number (percentage) and compared using the Chi-square (χ^2) test or Fisher's exact test, as appropriate. Ordinal variables were compared using the rank-sum test.

To account for potential confounding in this observational study, a multivariable logistic regression model was performed with POD (yes/no) as the dependent variable. Covariates included sex, age, BMI, number of comorbidities, tumor site, and ASA class (and other clinically relevant perioperative factors when available). Results are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs). Multicollinearity among covariates was evaluated using tolerance and variance inflation factor (VIF), with no evidence of problematic multicollinearity observed (tolerance 0.966–0.994; VIF 1.006–1.035). All tests were two-sided, and $P < 0.05$ was considered statistically significant. Analyses were performed using SPSS version 26.0 (IBM Corp., USA).

Results

Baseline Characteristics

A total of 260 elderly patients undergoing gastrointestinal tumor surgery were enrolled, with 130 patients each in the intervention and control groups. There were no significant differences between the two groups in terms of gender, age, body mass index (BMI), number of comorbidities, tumor location, or ASA classification ($P > 0.05$), as seen in Table 1.

Delirium Incidence

During postoperative days 1–7, 25 patients in the control group developed POD (incidence 19.23%), compared to only 9 patients in the intervention group (incidence 6.92%). Regarding severity distribution, the intervention group consisted predominantly of mild cases (7 patients) with no severe cases, whereas the control group had 8 mild, 15 moderate, and 2 severe cases. ($P < 0.05$) (Table 2).

After adjustment, the association remained significant. In multivariable logistic regression adjusting for sex (female=0, male=1), age, BMI, number of comorbidities (0=0, 1–3=1, >3=2), tumor site (gastric=0, colorectal=1), and ASA (II=0, III=1) class, the enhanced perioperative care (Intervention=1) was independently associated with a lower odds of POD (adjusted OR = 0.33, 95% CI 0.15–0.76, P = 0.009). Number of comorbidities was significant overall (P = 0.045); compared with patients with >3 comorbidities, those with no comorbidity had lower odds of POD (OR = 0.33, 95% CI 0.13–0.82, P = 0.017), while

Table 1 Analysis of Baseline Characteristics of the Two Patient Groups

Item	Control Group (n = 130)	Intervention Group (n = 130)	$t/\chi^2/z$	*P*
Gender (male/female)	71/59	78/52	0.770	0.380
Age (years)	72.83 ± 5.13	72.65 ± 4.99	0.282	0.778
BMI (kg/m^2)	23.46 ± 3.11	23.72 ± 3.06	−0.678	0.498
Number of comorbidities			3.119	0.210
0	25	15		
1~3	88	94		
> 3	17	21		
Tumor location (gastric/colorectal)	49/81	45/85	0.267	0.606
ASA classification (II/III)	75/55	80/50	0.399	0.527

Abbreviations: BMI, Body mass index; ASA, American Society of Anesthesiologists.

Table 2 Delirium Incidence

Group	Delirium	Onset Time (d)	Duration (d)	Severity		
				Mild	Moderate	Severe
Control (n = 130)	25	3.00 (3.00, 4.00)	3.00 (2.00, 3.00)	8	15	2
Intervention (n = 130)	9	2.00 (2.50, 4.00)	1.00 (1.00, 2.00)	7	2	0
χ^2/z	8.662	−0.856	−2.959	−2.350		
P	0.003	0.387	0.003	0.019		

the 1–3 comorbidity group did not differ significantly. Multicollinearity was assessed prior to modeling; all covariates showed high tolerance (0.966–0.994) and low VIF values (1.006–1.035) (Table 3).

Surgery-Related Indicators

The two groups were generally comparable in surgery-related indicators. Operation time and anesthesia time were shorter in the intervention group than in the control group (both $P < 0.001$). Intraoperative blood loss did not differ significantly between groups ($P > 0.05$), whereas intraoperative fluid volume was lower in the intervention group ($P = 0.002$) (Table 4).

Early Postoperative Recovery

Postoperative recovery was significantly better in the intervention group. Specifically, the time to first ambulation and time to first flatus occurred earlier in the intervention group. The length of hospital stay was significantly shorter, and the QoR-15 score on postoperative day 3 was higher in the intervention group ($P < 0.001$), while time to first ambulation, time to first flatus, and postoperative length of stay were shorter (all $P < 0.001$) (Table 5).

Inflammatory and Stress Responses

Levels of CRP, IL-6, and cortisol on postoperative day 3 were significantly higher than preoperative levels in both groups (all $P < 0.05$). The postoperative values of these markers were lower in the intervention group than in the control group ($P < 0.05$) (Table 6).

Table 3 Multivariable Logistic Regression Analysis of Factors Associated with POD

Index	B	Wald	Sig	Exp (B)	95% CI	
					Lower	Upper
Intervention technique (1)	−1.1	6.836	0.009	0.333	0.146	0.759
Sex (1)	−0.588	2.273	0.132	0.555	0.258	1.193
Age	−0.045	1.251	0.263	0.956	0.883	1.035
BMI	−0.039	0.355	0.551	0.962	0.847	1.092
Number of comorbidities		6.22	0.045			
Number of comorbidities (1)	−1.11	5.735	0.017	0.329	0.133	0.817
Number of comorbidities (2)	−0.418	0.476	0.49	0.658	0.201	2.16
Tumor site (1)	0.102	0.062	0.803	1.107	0.499	2.458
ASA class (1)	−0.004	0	0.993	0.996	0.459	2.165

Table 4 Comparison of Surgery-Related Indicators Between Groups

Group	Operation Time (h)	Anesthesia Time (h)	Intraoperative Blood Loss (mL)	Intraoperative Fluid (mL)
Control (n = 130)	2.50 (2.40, 2.60)	3.40 (3.30, 3.40)	74.28 ± 8.58	1276.88 ± 166.25
Intervention (n = 130)	2.35 (2.30, 2.40)	3.20 (3.15, 3.35)	75.21 ± 8.19	1209.28 ± 173.31
t/*z*	−7.113	−4.063	−0.895	3.209
p	< 0.001	< 0.001	0.372	0.002

Table 5 Comparison of Early Postoperative Recovery Between Groups

Group	Time to First Ambulation (h)	Time to First Flatus (h)	Hospital Stay (d)	QoR-15 Score
Control (n = 130)	29.00 (28.00, 32.00)	23.00 (22.00, 25.00)	16.00 (16.00, 18.00)	116.25 ± 4.58
Intervention (n = 130)	25.00 (24.00, 26.50)	19.00 (18.00, 21.50)	13.00 (13.00, 14.50)	124.35 ± 3.91
t/*z*	−10.071	−12.722	−9.222	−15.322
p	< 0.001	< 0.001	< 0.001	< 0.001

Abbreviation: QoR-15, Quality of Recovery-15.

Table 6 Comparison of Changes in Inflammatory and Stress Markers Between Groups

Group	CRP (mg/L)		IL-6 (pg/mL)		Cortisol (μg/dL)	
	Preop	Postop Day 3	Preop	Postop Day 3	Preop	Postop Day 3
Control (n = 130)	4.52 ± 0.83	35.47 ± 10.20[a]	5.26 ± 2.14	27.54 ± 9.25 [a]	12.92 ± 4.65	21.22 ± 4.35 [a]
Intervention (n = 130)	4.44 ± 0.69	27.57 ± 9.18 [a]	5.05 ± 1.83	24.52 ± 5.36 [a]	12.10 ± 3.91	16.24 ± 3.32 [a]
t	0.832	6.566	0.842	3.225	0.363	10.369
p	0.406	< 0.001	0.400	0.001	0.717	< 0.001

Note: [a]*P* < 0.05 compared to preoperative value within the same group.
Abbreviations: CRP, C-reactive protein; IL-6, Interleukin-6.

Table 7 Changes in Sleep Quality and Circadian Rhythm Between Groups

Group	PSQI Global Score		Nocturnal Awakenings (Times/Night)		Melatonin (pg/mL)	
	Preop	Postop Day 3	Preop	Postop Day 3	Preop	Postop Day 3
Control (n = 130)	7.00 (6.00, 8.00)	9.00 (8.00, 10.00) [a]	1.00 (1.00, 2.00)	2.00 (2.00, 3.00) [a]	48.52 ± 8.87	37.53 ± 7.65 [a]
Intervention (n = 130)	6.50 (5.50, 8.00)	8.00 (6.50, 9.00) [a]	1.50 (1.00, 2.00)	1.00 (1.00, 2.00)	49.37 ± 8.21	47.22 ± 9.34
t/*z*	−0.142	−9.401	−1.316	−6.795	−0.800	−9.148
p	0.887	< 0.001	0.188	< 0.001	0.424	< 0.001

Notes: [a]*P* < 0.05 compared to preoperative value within the same group.
Abbreviation: PSQI, Pittsburgh Sleep Quality Index.

Table 8 Changes in Cognition and Function Between Groups

Group	Mini-Cog Score		Barthel Index	
	Preop	Postop Day 3	Preop	Postop Day 3
Control (n = 130)	4.00 (4.00, 5.00)	3.00 (3.00, 4.00) [a]	88.00 (84.00, 93.00)	79.00 (75.00, 85.00) [a]
Intervention (n = 130)	5.00 (4.00, 5.00)	3.00 (3.00, 4.00)	87.50 (84.50, 91.50)	90.50 (88.00, 94.00)
z	−1.088	−4.013	−0.208	−7.478
p	0.277	< 0.001	0.835	< 0.001

Notes: [a]*P* < 0.05 compared to preoperative value within the same group.

Sleep Quality and Melatonin Levels

On postoperative day 3, PSQI global scores and nocturnal awakenings were lower in the intervention group than in the control group (both P < 0.001). Melatonin levels decreased postoperatively in the control group, whereas no significant postoperative decrease was observed in the intervention group; postoperative day 3 melatonin levels were higher in the intervention group ($P < 0.001$) (Table 7).

Cognition and Function

On postoperative day 3, Mini-Cog scores were lower in the control group than at baseline, whereas postoperative day 3 Mini-Cog scores were higher in the intervention group than in the control group (P < 0.001). Barthel index scores decreased postoperatively in the control group but were higher in the intervention group on postoperative day 3 ($P < 0.001$) (Table 8).

Discussion

In this retrospective observational cohort, enhanced perioperative care was associated with a significantly lower incidence and severity of POD compared to conventional care in elderly patients undergoing gastrointestinal tumor surgery. The POD incidence during postoperative days 1–7 was 19.23% (25/130) in the control group versus 6.92% (9/130) in the intervention group, a statistically significant difference. Regarding severity distribution, delirium cases in the intervention group were predominantly mild with no severe instances, whereas the control group included moderate and

severe cases. These findings suggest that the enhanced care strategy was associated with both POD occurrence and symptom severity.[33] Given the generally comparable baseline characteristics between groups, the observed improvement in POD outcomes is less likely to be explained solely by measured baseline differences; however, residual confounding from unmeasured delirium-related risk factors cannot be excluded.

Regarding potential mechanisms, this study provides multiple lines of evidence consistent with the pathophysiology of POD, forming a "biological-behavioral-functional" chain. First, concerning sleep and circadian rhythm: the intervention group showed a smaller increase in PSQI score on postoperative day 3, no significant increase in nocturnal awakenings, and higher melatonin levels compared to the control group. Given melatonin's role in circadian regulation and neuroplasticity, the better preservation of postoperative melatonin levels and sleep quality may be linked to lower acute cognitive vulnerability and more stable daytime orientation and attention. This aligns with intervention components such as nocturnal disruption reduction, daytime reorientation, and light management, and corresponds with the clinical phenotype linking nighttime disturbances to daytime delirium.[34,35] Second, the inflammation and stress pathway: both groups exhibited a surgical stress phenotype with elevated CRP, IL-6, and cortisol levels on postoperative day 3, but the increase was smaller in the intervention group. This pattern is consistent with an association between enhanced care and attenuated systemic inflammation and stress responses, potentially mediated through multimodal analgesia, optimized fluid and temperature management, early nutrition, and mobilization.[36,37] These measures may dampen the cascade from neuroinflammation-microglial activation-impaired synaptic function, thereby reducing cognitive fluctuations and psychiatric symptoms.[38] Third, functional and overall recovery: earlier time to first ambulation and flatus, shorter hospital stay, and higher QoR-15 scores in the intervention group were associated with a more favorable recovery trajectory from the operating table to the ward.[39] Functionally, the higher Barthel index postoperatively indicates faster recovery of daily living activities.[40] Together with reduced POD and optimized sleep-inflammation profiles, this constitutes a real-world effect translating into bedside benefits.[41] The observed preservation of postoperative melatonin levels and cognitive function should nevertheless be interpreted cautiously, because although these findings are directionally consistent with improved sleep quality, lower stress and inflammation, and better overall recovery, residual confounding from unmeasured perioperative and patient-level factors cannot be fully ruled out in this retrospective observational study.

It is worth reiterating that the enhanced perioperative care in this study did not introduce novel medical technologies but rather standardized and reinforced the execution of existing in-hospital nursing processes. Components such as preoperative anxiety identification and individualized counseling, intraoperative temperature and anesthesia depth monitoring with communication, postoperative environmental and sleep management, reorientation exercises and family companionship, and standardized delirium screening collectively form a multi-target, low-risk, low-cost care bundle. This characteristic may support scalability: it does not alter medical orders or drug strategies, avoiding iatrogenic risks and ethical hurdles, and relies on training existing staff for replicable implementation, facilitating integration into quality improvement (QI)/continuous quality improvement (CQI) cycles.[20] Metrics like POD incidence, nocturnal awakenings, QoR-15, and length of stay can serve for continuous monitoring and feedback.[19] Unlike previous studies focusing on single components (eg., postoperative sedation or isolated cognitive training), this study observed consistent signals across multidimensional outcomes from biomarkers to clinical function. The significant reduction in delirium incidence and severity corresponds with better postoperative sleep quality and a smaller postoperative reduction in melatonin levels, and attenuated inflammation-stress, ultimately manifesting as improved functional recovery, QoR-15 scores, and shortened hospitalization.[42–44]This longitudinal consistency may support the potential value of such care pathways, suggesting that process and environmental management are significant levers determining postoperative outcomes in elderly patients, alongside pharmacological and surgical techniques.[45,46] For healthcare administrators, embedding this pathway into routine perioperative care and using a dashboard of indicators for departmental performance feedback could potentially achieve multi-endpoint simultaneous optimization without substantial increases in costly equipment or manpower.[47]

This study still has limitations. First, its single-center retrospective observational design is inherently susceptible to selection and confounding biases. Demographic and baseline clinical variables, including sex, age, BMI, comorbidity burden, tumor site, and ASA class, were formally compared between groups and adjusted for in the multivariable logistic regression analysis; however, no subgroup or interaction analyses were performed. Despite comparable baseline characteristics, unmeasured confounders related to the non-randomized design may still have influenced the effect

estimates. In addition, several delirium-specific risk factors, such as frailty status, exposure to potentially deliriogenic medications, and use of physical restraints, were not systematically captured in the available records, and residual confounding therefore cannot be excluded. Second, despite employing a combination of objective and subjective multidimensional indicators, information bias (eg., limitations of subjective sleep scales) remains possible. Although this multidimensional assessment strengthens the internal consistency and plausibility of the findings, it does not overcome the inherent limitations of retrospective observational data, and causal inference remains limited. Third, implementation depended on in-house team training and execution quality; variations in staffing and process maturity across institutions may affect generalizability. Therefore, subsequent research should involve multicenter prospective randomized trials to delineate the marginal contribution of different care bundle elements and identify optimal combinations and triggering thresholds. Incorporating more objective monitoring tools, such as wearable devices for sleep and circadian rhythm assessment, and performing cost-effectiveness analyses may further support future implementation and dissemination of this care pathway.

Conclusion

In summary, this single-center retrospective observational study suggests that a replicable, POD prevention-oriented comprehensive care pathway was associated with lower POD incidence and severity in elderly patients undergoing gastrointestinal tumor surgery. The intervention consisted of a protocolized nursing bundle based mainly on non-pharmacological measures, including standardized psychological screening and support, sleep and environmental management, structured reorientation, scheduled delirium surveillance, and ERAS-aligned early mobilization and enteral nutrition. Compared with conventional care, the enhanced pathway was associated with better postoperative recovery (eg., QoR-15 and length of stay) and more favorable biomarker profiles. However, given the retrospective design and the possibility of institutional implementation bias related to local staffing, training, and process execution, these findings should be interpreted with caution. Multicenter prospective studies are needed to confirm effectiveness and identify the most contributory components.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The study protocol was approved by the Third Xiangya Hospital, Central South University's Ethics Committee, which waived the requirement for individual patient informed consent due to the observational nature of the study. The study adhered to the principles of the *Declaration of Helsinki* and was designed and reported following the STROBE statement.

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.

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Disclosure

The authors declare no competing interests in this work.

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