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Perioperative meticulous nursing in patients undergoing general anesthesia: a randomized controlled trial

Running title: Nursing in patients undergoing general anesthesia

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Abstract

Objective: We aimed to observe the effects of perioperative meticulous nursing in patients with digestive system diseases undergoing general anesthesia.

Methods: This randomized controlled trial included 90 patients with digestive system diseases who underwent surgery under general anesthesia in our hospital from August 2024 to October 2024. Using a random number table, patients were allocated to a control group (n = 45) and an observation group (n = 45). Both groups received anesthesia recovery nursing. The control group received routine perioperative nursing, while the observation group received perioperative meticulous nursing. The quality of anesthesia recovery was evaluated by recording the time to recovery of spontaneous breathing, recovery of consciousness, endotracheal extubation, and full awakening. Core body temperature was measured before anesthesia induction (T0), 30 min after anesthesia induction (T1), at the end of surgery (T2), and 30 min after surgery (T3). Stress indicators, including adrenaline (AD), norepinephrine (NE), and cortisol (Cor), were measured before anesthesia induction and at the time of endotracheal extubation. Psychological status was assessed before nursing intervention (1 day preoperatively) and after intervention (within 24 h postoperatively) using the Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS). The incidence of adverse events (nausea and vomiting, hypothermia, shivering, and agitation) and nursing satisfaction were also compared between the two groups.

Results: The observation group showed significantly shorter times to recovery of spontaneous breathing, recovery of consciousness, endotracheal extubation, and full awakening compared with the control group (all $p < 0.05$). Core body temperatures at T1, T2, and T3 were lower than those at T0 in both groups, but were significantly higher in the observation group than in the control group ($p < 0.05$). Serum levels of AD, NE, and Cor at extubation were higher than pre-induction levels in both groups, but were significantly lower in the observation group ($p < 0.05$). After nursing intervention, SAS and SDS scores decreased in both groups, with significantly lower scores in the observation group ($p < 0.05$). The incidence of postoperative nausea and vomiting, hypothermia,

shivering, and agitation was significantly lower in the observation group ($p < 0.05$). Nursing satisfaction was significantly higher in the observation group than in the control group ($p < 0.05$).

Conclusion: Perioperative meticulous nursing combined with anesthesia recovery nursing can significantly improve the quality and safety of anesthesia recovery in patients with digestive system diseases undergoing general anesthesia surgery, and is beneficial for stabilizing core body temperature and reducing stress responses.

Keywords: General anesthesia; Surgery; Perioperative meticulous nursing; Anesthesia recovery nursing; Digestive system diseases; Application effects

Introduction

General anesthesia is a reversible drug-induced state characterized by amnesia, analgesia, unconsciousness, immobility, and relative stability of the autonomic nervous system, respiratory system, cardiovascular system, and thermoregulatory function [1]. Despite its widespread use and continuous advances in anesthetic techniques and pharmacology, general anesthesia is still associated with various perioperative and postoperative complications involving multiple organ systems [2]. These potential adverse effects remain important considerations for anesthesiologists and surgeons when selecting anesthetic strategies and perioperative management plans. Surgery is commonly performed using one or more anesthesia techniques, and from the patient's perspective, satisfaction with anesthesia-related nursing care represents an important indicator of anesthesia quality and overall perioperative experience [3]. To ensure patient safety during anesthesia, objective assessment and monitoring of different anesthesia components at various surgical stages are essential, enabling clinicians to make timely and appropriate decisions to achieve optimal anesthetic depth and physiological stability [4].

With the increasing demand for healthcare services, the growing complexity of surgical procedures, and constraints on healthcare workforce resources, the role of anesthesia nursing has become increasingly important in ensuring safe and efficient perioperative care [5]. Advances in surgery, anesthesia, medical technology, and pharmacology have led to an increase in both the number and complexity of surgical procedures. Effective perioperative nursing interventions can facilitate patient recovery, improve hemodynamic and respiratory stability, and contribute to better control of postoperative pain, nausea, and vomiting, thereby reducing hospital stay, infection risk, and overall healthcare burden [6]. In this context, perioperative nursing requires not only specialized knowledge of anesthesia-related guidelines, surgical procedures, infection control, equipment management, and patient safety, but also strong communication skills, leadership, and humanistic care competencies [7]. The role of perioperative nursing has gradually evolved from task-oriented technical support to patient-centered professional care. Nursing concepts and

theoretical frameworks play an important role in guiding perioperative nursing practice and shaping nursing behaviors toward surgical patients [8].

Meticulous nursing is a patient-centered nursing model that emphasizes individualized care, attention to detail, and refinement of each nursing measure based on patients' specific needs. This approach has been reported to improve quality of life, reduce psychological stress responses, enhance treatment compliance, and increase nursing satisfaction, demonstrating definite clinical benefits and potential for wider application [9, 10]. Anesthesia recovery nursing focuses on the anesthesia emergence period, aiming to promote smooth recovery and reduce anesthesia-related complications such as agitation and delayed awakening. During general anesthesia, perioperative hypothermia occurs in a substantial proportion of patients, particularly among the elderly. Hypothermia can adversely affect anesthetic drug metabolism, coagulation function, and postoperative recovery quality, ultimately influencing surgical outcomes [11]. Therefore, active prevention of hypothermia and related adverse events is especially important in elderly patients undergoing general anesthesia.

Despite advances in anesthetic techniques and perioperative care, existing studies have mainly focused on pharmacological factors influencing anesthesia recovery, while the potential contribution of structured perioperative nursing interventions has not been systematically evaluated. In particular, evidence from randomized controlled studies examining the impact of meticulous, patient-centered nursing throughout the perioperative period on anesthesia recovery outcomes remains limited. Based on the above considerations, this study aimed to investigate the effects of perioperative meticulous nursing on recovery outcomes in patients undergoing general anesthesia.

Materials and methods

Ethical approval

Ethical approval was obtained from the ethics committee of the First Affiliated Hospital of Nanjing Medical University, with written informed consent signed by the patients.

Participants

Ninety patients with digestive system diseases who underwent surgery under general anesthesia in the First Affiliated Hospital of Nanjing Medical University from August 2024 to October 2024 were enrolled. Using a random number table, the patients were randomly allocated to a control group and an observation group, with 45 patients in each group. The CONSORT flow diagram is shown in Figure 1.

Inclusion criteria

1. Patients with digestive system diseases scheduled for elective surgery under general anesthesia, including gastric, duodenal, and biliary surgeries, with clear indications for surgery and general anesthesia. All patients received the same general anesthesia protocol, and all procedures were performed by the same surgical and anesthesia team. 2. Normal preoperative baseline vital signs, including body temperature, heart rate, respiratory rate, and blood pressure. 3. Ability to communicate normally, with clear consciousness and intact cognitive function. 4. Body mass index (BMI) between 18 and 29.0 kg/m^2. 5. American Society of Anesthesiologists (ASA) physical status classification I–II. 6. Complete clinical data available.

Exclusion criteria

1. Known allergy to anesthetic drugs or contraindications to surgery. 2. Evidence of infection detected during preoperative examination. 3. Severe psychiatric disorders or disorders of consciousness. 4. Presence of severe comorbid diseases involving the cardiovascular, cerebrovascular, pulmonary, hepatic, or renal systems, such as heart failure, arrhythmia, chronic obstructive pulmonary disease, bronchial asthma, stroke, liver cirrhosis, or renal failure. 5. Critically ill patients with a high risk of surgery failure. 6. Presence of malignant tumors requiring chemotherapy. 7. Comorbidities such as peripheral neuropathy, chronic pain disorders, coagulation abnormalities, or hematologic diseases. 8. Pregnancy or lactation.

Sample size calculation

Based on the results of a pilot study involving 20 patients, the mean time to full awakening

was 40.85 ± 13.26 minutes in the control group and 32.42 ± 9.21 minutes in the observation group. Sample size estimation was performed using PASS software (version 21.0.9; NCSS LLC, Kaysville, UT, USA). With a two-sided α level of 0.05, a β value of 0.10 (power = 90%), and an allocation ratio of 1:1 between the two groups, the required sample size was calculated to be 37 patients per group (74 patients in total). Considering a potential dropout rate of 20%, a total of 90 patients were ultimately enrolled, with 45 patients assigned to each group.

Randomization and blinding

Randomization was performed using a random number table method. First, the 90 enrolled patients were sequentially numbered from 1 to 90 according to the order of enrollment. To ensure reproducibility of the randomization process, a random seed was preset, and SPSS software was used to generate random numbers corresponding to each patient number. The generated random numbers were sorted in descending order, and the patients corresponding to the first 45 numbers were assigned to Group 1 (control group), while those corresponding to numbers 46–90 were assigned to Group 2 (observation group). Allocation concealment was implemented as follows: the randomization sequence generated by the software was printed by a quality control investigator and placed into sequentially numbered, opaque, sealed envelopes, which were kept by an independent randomization custodian. After a patient was enrolled, the investigator contacted the custodian by telephone, who then opened the next envelope in sequence and disclosed the group assignment.

Due to the nature of the nursing intervention, blinding of participants was not feasible. However, outcome assessors and data analysts were blinded to group allocation throughout data collection and statistical analysis.

Nursing and anesthesia procedures

Both groups received the same general anesthesia protocol. During anesthesia induction, patients were positioned appropriately and connected to a multifunctional monitoring system. The induction regimen consisted of intravenous administration of: midazolam injection (15 mg/3 mL), administered at a dose of 0.04 mg/kg; propofol emulsion injection (100 mg/10 mL), administered at

a dose of 2 mg/kg; sufentanil citrate injection (50 μg/10 mL), administered at a dose of 0.4 μg/kg; cisatracurium besylate for injection (5 mg per vial), administered at a dose of 0.2 mg/kg. After achieving adequate muscle relaxation, endotracheal intubation was gently performed with the assistance of a video laryngoscope or fiberoptic bronchoscope. Correct tube placement was confirmed, after which mechanical ventilation was initiated. Ventilation parameters, including tidal volume, respiratory rate, and inspiratory-to-expiratory ratio, were adjusted to maintain adequate gas exchange. During the maintenance phase of anesthesia, additional doses of sufentanil and cisatracurium besylate were administered intravenously as needed according to the surgical progress and the patients' vital signs. Dosages were adjusted to maintain an appropriate depth of anesthesia and ensure the smooth completion of the surgical procedure.

Control group: The control group received routine perioperative nursing combined with anesthesia recovery nursing. Routine perioperative nursing included: 1. Preoperative nursing: Nurses routinely assessed patients' medical history, history of drug allergies, and surgery-related risk factors. Basic health education was provided, including explanations of the surgical procedure and perioperative precautions, to help patients establish appropriate expectations. Intestinal preparation was performed as required, typically involving bowel cleansing and preoperative fasting, to ensure optimal surgical conditions. 2. Intraoperative nursing: Nurses closely monitored patients' vital signs throughout surgery, ensuring stability of body temperature, heart rate, blood pressure, and other parameters. They assisted anesthesiologists with anesthesia management and performed routine fluid management, primarily aiming to maintain basic hemodynamic stability. Fluids were administered to prevent obvious dehydration and hypotension and to meet the fundamental intraoperative circulating volume requirements. Crystalloid solutions were mainly used, and infusion strategies were generally estimated based on clinical experience or conventional formulas. In addition, nurses prepared surgical instruments, assisted during surgical procedures, maintained a sterile operative environment, and implemented infection prevention measures. 3. Postoperative nursing: Postoperative care focused on complication prevention and recovery

promotion. Nurses closely monitored vital signs and abdominal symptoms, observing for bleeding, infection, pain, or other abnormalities. Early mobilization was encouraged to promote gastrointestinal function recovery, and patients were guided to resume an appropriate diet. Antiemetic medications were administered to patients with postoperative nausea and vomiting. For postoperative pain, analgesic support was provided, with standardized drug types and dosages. Nurses also assisted patients in gradually regaining self-care ability to reduce the risk of postoperative complications.

Observation group: In addition to the routine nursing interventions provided to the control group, the observation group received perioperative meticulous nursing. The main measures were as follows: 1. Preoperative meticulous nursing: a. Precise preoperative assessment: Based on routine assessments, additional attention was given to patients' previous surgical history, drug allergy history, and specific risks of complications. Individualized preoperative preparation plans were developed for patients with special conditions such as hypertension or diabetes. b. Targeted preoperative health education: Before anesthesia, nurses conducted detailed and targeted health education by actively communicating with patients and their families. The surgical procedure and postoperative recovery process were explained thoroughly, with particular emphasis on potential sensory changes following anesthesia. The use and purpose of urinary catheters, nasogastric tubes, and drainage tubes were explained to enhance patients' understanding of the surgical process. c. Preoperative psychological counseling: Through one-to-one communication, nurses observed patients' emotional states and provided individualized reassurance to anxious patients, thereby enhancing surgical confidence and treatment compliance. d. Enhanced respiratory training: In addition to routine education, patients received deep-breathing and effective coughing training starting three days before surgery (2–3 sessions per day, 10–15 minutes per session). This intervention was particularly emphasized for patients with poor physical condition or impaired pulmonary function to reduce postoperative pulmonary complications. e. Individualized bowel preparation: Following medical orders, patients with intestinal diseases or weakened bowel function

received mild bowel preparation methods to avoid excessive intestinal stimulation. Nurses closely observed patient responses and promptly alleviated discomfort caused by preparation. 2. Intraoperative meticulous nursing: a. Refined sterile technique monitoring: Strict adherence to aseptic principles was maintained. The frequency of instrument counts and sterile field checks was increased to ensure operative sterility and prevent intraoperative infection. b. Meticulous intraoperative temperature management: Twenty minutes before surgery, the operating room temperature was adjusted to 22–24°C and humidity to 45–60% using air-conditioning, humidification/dehumidification, or fresh-air systems. Warm-air devices were directed toward the operating table. Based on anticipated surgical duration, thermal cotton blankets were prepared in advance. Infusion fluids and irrigation solutions were pre-warmed (e.g., maintained at 42°C). During skin disinfection, exposed skin areas were minimized and covered promptly with thermal blankets to reduce heat loss. Heat and moisture exchangers were installed in the endotracheal circuit to maintain inhaled gas temperature and humidity. Intermittent pneumatic compression devices were applied to promote circulation and maintain body temperature. c. Precise fluid management: Intraoperative fluid intake and output were closely monitored through close collaboration between physicians and nurses. For patients at risk of fluid or electrolyte imbalance, refined fluid adjustment strategies were implemented. Appropriate fluid types (including crystalloids, colloids, and blood products) were selected according to the patient's specific conditions, such as surgical type, underlying diseases, and hemodynamic status. A goal-directed fluid therapy strategy was adopted, and the infusion rate and volume were adjusted based on real-time hemodynamic monitoring parameters to achieve individualized fluid therapy. This approach ensured fluid balance and prevented postoperative edema and other related complications. 3. Postoperative meticulous nursing: a. Refined airway management: During the anesthesia recovery period, airway patency was carefully maintained. Oral and pharyngeal secretions were observed and removed using suction when necessary to prevent airway obstruction. Individualized oxygen therapy was provided for patients with delayed recovery to maintain normal oxygen saturation. b. Detailed observation of

consciousness recovery: Patients' recovery of consciousness was carefully assessed, including response to commands, clarity of speech, pupil reflexes, and limb movement, to evaluate neurological recovery and prevent neurological complications. c. Precision pain management: Postoperative pain was evaluated using the Visual Analog Scale (VAS). Individualized analgesic strategies, including pharmacological and non-pharmacological measures (e.g., music therapy and cold application), were implemented according to medical orders without compromising respiration or alertness. Analgesic types and dosages were dynamically adjusted to prevent blood pressure fluctuations caused by severe pain. d. Early prevention of postoperative complications: For prevention of postoperative nausea and vomiting, nurses increased observation frequency, adjusted patient positioning, guided deep breathing, administered antiemetic medications as prescribed, and evaluated intervention effectiveness. To prevent postoperative shivering, warming devices such as thermal blankets were used and environmental temperature was maintained; antishivering medications were administered when necessary. Measures including environmental quietness, airway patency, pain control, psychological support, positioning adjustment, and early monitoring were also implemented to promptly identify and control agitation. e. Refined positioning and activity management: After recovery, patients were assisted in early position changes to prevent pressure injuries and pulmonary complications. Simple lower-limb exercises were guided to prevent deep vein thrombosis. f. Personalized psychological support: During the recovery period, nurses provided calm verbal reassurance and addressed patient concerns to alleviate fear and discomfort, reduce psychological burden, and promote emotional stability and recovery.

Anesthesia recovery nursing was provided to patients in both groups, including the following measures: 1. Airway management: Ensuring airway patency, promptly clearing oral secretions, preventing aspiration caused by vomiting, and administering supplemental oxygen when necessary to avoid asphyxia or hypoxia. 2. Vital sign monitoring: Close monitoring of blood pressure, heart rate, respiratory rate, and oxygen saturation. Any abnormalities were managed promptly and reported to ensure stable recovery. 3. Assessment of consciousness and neurological function:

Observation of the level of consciousness to determine the stage of recovery, along with evaluation of pupil reflexes, muscle strength, and neurological responses. Symptoms such as dizziness or nausea were carefully monitored to prevent postoperative cognitive dysfunction. Both groups received nursing care until hospital discharge. The differences between routine nursing and meticulous nursing interventions are summarized in Supplementary Table 1.

Observation indicators

Quality of anesthesia recovery: The quality of anesthesia recovery was evaluated by recording the time to resume spontaneous breathing, time to regain consciousness, time to endotracheal extubation, and time to achieve full awakening in both groups. Time to full awakening was defined as the interval from discontinuation of all general anesthetic agents to the recovery of complete consciousness, spontaneous respiration, orientation, and the ability to respond appropriately to verbal commands.

Core body temperature: Core body temperature was recorded at four time points in both groups: before anesthesia induction (T0), 30 minutes after anesthesia induction (T1), at the end of surgery (T2), and 30 minutes after the end of surgery (T3).

Stress indicators: Before anesthesia induction and at the time of endotracheal extubation, 4 mL of fasting venous blood was collected from the cubital vein in both groups. After routine anticoagulation, samples were centrifuged at 3000 r/min for 15 minutes, and the supernatant was collected. Serum adrenaline (AD), norepinephrine (NE), and cortisol (Cor) levels were measured using enzyme-linked immunosorbent assay (ELISA) kits (Shanghai Xitang Biotechnology Co., Ltd., China).

Psychological status: Psychological status was assessed using the Self-Rating Anxiety Scale (SAS) and the Self-Rating Depression Scale (SDS) before nursing intervention (1 day preoperatively) and after nursing intervention (within 24 hours postoperatively). The standard scores for SAS and SDS were calculated by summing the scores of the 20 items and multiplying the total by 1.25, with the result rounded to the nearest whole number. Each item was scored on a

4-point Likert scale (1–4 points). Higher standard scores indicated more severe anxiety or depressive symptoms [12].

Adverse events: The incidence of adverse events within 24 hours postoperatively, including nausea and vomiting, hypothermia, shivering, and agitation, was recorded and compared between the two groups.

Nursing satisfaction: Nursing satisfaction was assessed at the time of hospital discharge using a department-developed satisfaction questionnaire. The total score ranged from 0 to 100 points and was classified into four levels: very satisfied (90–100 points), satisfied (70–89 points), average (60–69 points), and dissatisfied (0–59 points). Overall satisfaction was calculated as follows: Overall satisfaction (%) = (number of very satisfied + number of satisfied patients) / total number of patients × 100%.

Statistical methods

Statistical analysis was performed using SPSS 26.0 software. Qualitative data were described as number and percentage [n (%)], with comparisons made using the χ^2 test. The normality of quantitative data was assessed using the Shapiro–Wilk test. Quantitative data with a normal distribution were presented as mean ± standard deviation ($\bar{x}$ ± s) and analyzed using independent-samples or paired-samples t-tests. Quantitative data with a skewed distribution were described as median (P25, P75). Between-group comparisons were performed using the Mann–Whitney U test, and within-group comparisons were conducted using the Wilcoxon signed-rank test. A p-value < 0.05 was considered statistically significant.

Results

Baseline characteristics

There were no significant differences between the two groups in baseline characteristics, including age, BMI, duration of anesthesia, duration of surgery, sex, ASA classification, type of surgery, and educational level (all $p > 0.05$), indicating good comparability between the groups. The

total length of hospital stay in the observation group was significantly shorter than that in the control group ($p < 0.05$) (Table 1).

Anesthesia recovery quality

The observation group showed significantly shorter times to recovery of spontaneous breathing, regain of consciousness, endotracheal extubation, and full awaken compared to the control group ($p < 0.05$) (Table 2).

Core body temperature

There was no significant difference in core body temperature between the two groups at T0 ($p > 0.05$). At T1, T2, and T3, core body temperatures were lower than those at T0 in both groups; however, the observation group maintained significantly higher core body temperatures than the control group ($p < 0.05$) (Table 3).

Stress indicators

There were no significant differences in serum AD, NE, or Cor levels between the two groups at T0 ($p > 0.05$). At the time of endotracheal extubation, serum AD, NE, and Cor levels were significantly higher than pre-induction levels in both groups; however, these levels were significantly lower in the observation group than in the control group ($p < 0.05$) (Table 4).

Psychological status

No significant differences in SAS or SDS scores were observed between the two groups before nursing intervention ($p > 0.05$). After nursing intervention, SAS and SDS scores decreased in both groups, with significantly lower scores observed in the observation group compared with the control group ($p < 0.05$) (Table 5).

Adverse events

The incidence of postoperative nausea and vomiting, hypothermia, shivering, and agitation was significantly lower in the observation group than in the control group ($p < 0.05$) (Table 6).

Satisfaction

Nursing satisfaction in the observation group was 97.77% (44/45), which was significantly

higher than that in the control group (84.44%, 38/45) ($p < 0.05$) (Table 7).

Discussion

General anesthesia represents a critical perioperative experience for surgical patients, and its interaction with perioperative nursing care is multifaceted. Although advances in anesthetic techniques have markedly improved safety, general anesthesia remains associated with a spectrum of perioperative and postoperative complications that may influence patient recovery and experience [13, 14]. These considerations highlight the importance of perioperative nursing interventions that are informed by an understanding of anesthetic principles and potential complications. In this context, the present study investigated the effects of perioperative meticulous nursing on recovery outcomes in patients undergoing general anesthesia.

Routine nursing care provides essential support during hospitalization; however, it often focuses on basic task completion and may not sufficiently address the dynamic and individualized needs of patients throughout the perioperative period. Meticulous nursing, in contrast, emphasizes refinement, precision, and patient-centered care at each stage of the perioperative process. By integrating psychological support, targeted physical rehabilitation, and proactive complication prevention, meticulous nursing aims to optimize both physical and emotional recovery [15-17]. Previous studies have also demonstrated the benefits of meticulous nursing in other clinical settings, including improved functional outcomes and emotional well-being in patients with post-traumatic sepsis and elderly patients with coronary heart disease, supporting the broader applicability of this nursing model [15, 18].

All surgeries in this study were scheduled as the first or second cases in the morning, thereby minimizing the potential influence of circadian variation on stress hormone levels. At the time of tracheal extubation, levels of physiological stress markers—including AD, NE, and Cor—were elevated. This increase may be explained by the following mechanisms. First, mechanical airway stimulation during extubation directly activates the sympathetic–adrenal medullary system. Friction

and traction of the endotracheal tube on the glottis and tracheal mucosa can trigger airway defense reflexes via vagal afferent pathways, leading to excitation of the medullary sympathetic center and subsequent release of large amounts of AD and NE from the adrenal medulla. In addition, transient airway spasm during extubation may activate peripheral nociceptors, with signals transmitted through the spinal–thalamic pathway to the cerebral cortex, further enhancing sympathetic activation. Second, transient activation of the hypothalamic–pituitary–adrenal (HPA) axis may occur during extubation. Stress-related stimuli such as fear and coughing can act through the limbic system on the hypothalamus, promoting the release of corticotropin-releasing hormone, which in turn stimulates adrenocorticotropic hormone secretion from the pituitary and ultimately increases cortisol synthesis and release from the adrenal cortex. The lower levels of NE, AD, and Cor observed in the observation group at extubation may be explained by several factors. First, patients in the observation group received preoperative psychological interventions, which reduced anxiety levels and attenuated central stress activation. In addition, respiratory and effective coughing training initiated three days before surgery may have enhanced diaphragmatic strength and reduced the risk of respiratory suppression after extubation. Second, prophylactic antiemetic medications and non-pharmacological antiemetic measures were implemented postoperatively in the observation group, reducing the incidence of nausea and vomiting. This may have helped avoid increases in intra-abdominal pressure and sympathetic excitation associated with nausea and vomiting.

In this study, patients in the observation group showed shorter times to recovery of spontaneous breathing and consciousness compared with those in the control group. Possible explanations are as follows. First, patients in the observation group received preoperative respiratory and effective coughing training starting 3 days before surgery, which may have enhanced diaphragmatic function and contributed to faster recovery of spontaneous breathing after surgery. Second, more preventive measures were implemented postoperatively in the observation group to reduce complications such as nausea and vomiting, thereby decreasing the risk of hypoxia and delayed recovery of consciousness caused by postoperative complications. Third, meticulous

intraoperative temperature management was applied in the observation group, maintaining core body temperature at a higher level than in the control group. This may have avoided hypothermia-related slowing of drug metabolism and coagulation dysfunction, thus facilitating earlier recovery of spontaneous breathing. Finally, patients undergoing general anesthesia in the observation group received meticulous anesthesia recovery nursing, including interventions related to airway management, blood pressure, oxygen saturation, body position, and restraint level, which may have effectively shortened the recovery time of consciousness and spontaneous breathing.

In this study, adverse events were monitored within 24 hours postoperatively. Both the control group and the observation group received antiemetic medications after surgery. The differences in the incidence of postoperative nausea and vomiting between the two groups may be explained by several factors. First, the observation group received multimodal analgesia, which reduced the amount of analgesic medications used and thereby avoided nausea and vomiting induced by analgesics through stimulation of the chemoreceptor trigger zone. Second, patients in the observation group received more guidance on positioning and early activity, which may have promoted gastrointestinal motility and reduced gastric retention. Third, proactive prevention of nausea and vomiting was implemented in the observation group. Interventions were initiated when prodromal symptoms of nausea and vomiting appeared, thereby preventing progression to more severe symptoms.

In addition to anesthesia recovery outcomes, perioperative meticulous nursing also showed beneficial effects on core body temperature, psychological status, and patient satisfaction. Patients in the observation group maintained higher core body temperatures at key perioperative time points, which may be attributed to structured temperature monitoring and timely warming interventions. Maintenance of normothermia is clinically important, as perioperative hypothermia has been associated with delayed anesthetic drug metabolism, increased discomfort, and a higher incidence of complications such as shivering and agitation. Improvements were also observed in anxiety and depression scores, suggesting that meticulous nursing may help alleviate perioperative

psychological stress through enhanced communication, psychological support, and patient engagement. Furthermore, higher patient satisfaction in the observation group likely reflects the overall perception of more individualized, attentive, and timely nursing care. Although psychological outcomes and satisfaction are inherently subjective, they provide complementary information regarding patient-centered benefits of meticulous nursing during the perioperative period.

It should be emphasized that the "meticulous nursing" protocol implemented in this study does not represent refinement of a single nursing action, but rather a structured, multimodal perioperative comprehensive intervention integrating nursing measures, pharmacological management, and technical supportive strategies. This integrated nature reflects real-world perioperative practice, where multidisciplinary and multimodal approaches are often adopted to optimize patient recovery. While such a comprehensive design may enhance clinical effectiveness, it also increases the complexity of causal attribution. The observed improvements in anesthesia recovery quality, stress responses, and patient satisfaction are likely the result of synergistic interactions among multiple intervention components rather than a single isolated factor. For example, individualized analgesia may have reduced opioid consumption and respiratory suppression; active temperature management may have contributed to physiological stability; and the use of antishivering medications may have indirectly supported smoother emergence. These pharmacological and technical components may have partially contributed to the favorable outcomes observed in the intervention group. Furthermore, although differences in core body temperature were observed between groups, most patients remained within the normothermic range. Therefore, mild temperature fluctuations alone are unlikely to fully explain differences in anesthesia recovery time. It is more plausible that recovery outcomes were influenced by the combined effects of respiratory training, psychological support, individualized analgesia, temperature management, and refined postoperative airway care.

Several limitations of this study should be acknowledged. First, the sample size was relatively small, which may limit the statistical power and generalizability of the findings. Second, due to the

nature of the nursing intervention, blinding of nursing staff was not feasible, which may have introduced performance bias. Third, patient satisfaction was assessed using a locally developed questionnaire that has not undergone formal external validation, and measurement bias cannot be completely excluded. From a statistical perspective, although data normality was assessed using the Shapiro–Wilk test, corrections for multiple comparisons were not applied. Given that improvements were observed across multiple outcome measures, the possibility of type I error inflation should be considered when interpreting the findings. Importantly, because the intervention consisted of multiple integrated components, the current study design does not allow precise differentiation of the independent contribution of each element. The potential interaction effects among individualized analgesia, temperature management, airway care, and psychological interventions cannot be fully disentangled. Future studies employing factorial or component-analysis designs are warranted to clarify the relative contribution and interaction of individual intervention modules.

In summary, this study highlights that perioperative meticulous nursing is associated with improved anesthesia recovery quality, enhanced physiological stability, and reduced perioperative stress responses in patients undergoing general anesthesia. From a clinical perspective, these findings highlight the potential value of implementing structured, patient-centered nursing interventions as an adjunct to standard anesthesia management, particularly in patients at higher risk of delayed recovery or postoperative complications. By optimizing perioperative support rather than altering anesthetic drug regimens, meticulous nursing may contribute to safer anesthesia emergence, improved patient experience, and more efficient postoperative care. While these results are encouraging, further high-quality studies are required to confirm their clinical applicability and generalizability.

Declaration

Ethical approval and consent to participate

Ethical approval was obtained from the ethics committee of the First Affiliated Hospital of Nanjing Medical University, with informed consent signed by the patients.

Consent for publication

Not applicable.

Availability of data and materials

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Competing interests

The authors declared that they have no conflicts of interest regarding this work.

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Authors' contributions

N.W.Z. finished the study design, Y.T. finished the experimental studies, S.Y.L. finished the data analysis, J.W.G. finished the manuscript editing. All authors read and approved the final version of the manuscript.

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Legend

Figure 1. CONSORT flow diagram.