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Study on the Application Effect of Feedforward Control Combined with Family Awakening in Elderly Patients Undergoing Radical Lung Cancer Surgery during Anesthesia Recovery

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Abstract

Objective: To investigate the application effect of feedforward control combined with family awakening in elderly patients undergoing radical lung cancer surgery during the post-anesthesia care unit (PACU) recovery period, providing evidence-based support for reducing complications such as emergence agitation, hypothermia, hypoxemia, pain, and delirium, and improving recovery safety and humanistic nursing quality. **Methods:** A total of 340 elderly patients undergoing thoracoscopic radical lung cancer surgery from July to December 2024 were randomly divided into a control group (170 cases, conventional recovery nursing) and an intervention group (170 cases, feedforward control + family awakening). The intervention group implemented integrated measures, including preoperative risk assessment, perioperative stratified temperature management, airway safety management, multimodal analgesia, standardized family awakening, circulatory stability control, and delirium prevention. The incidence of agitation, Riker Sedation-Agitation Scale (SAS) scores, body temperature, pain scores (NRS, FLACC), hypoxemia, recovery time, and complication rates were compared between the two groups. **Results:** The incidence of agitation in the intervention group (7.65%) was significantly lower than that in the control group (22.94%). SAS scores, FLACC pain scores, and NRS scores were significantly lower in the intervention group ($P < 0.05$). The incidence of hypothermia, hypoxemia, nausea and vomiting, delirium, and pulmonary complications was significantly lower in the intervention group ($P < 0.05$). The recovery time of spontaneous breathing, eye-opening time, extubation time, and PACU stay time were significantly shorter

in the intervention group ($P < 0.05$). Body temperature, blood oxygen saturation, heart rate, and blood pressure were more stable at all time points. **Conclusion:** Feedforward control combined with family awakening can significantly reduce complications during anesthesia recovery in elderly patients undergoing radical lung cancer surgery, alleviate agitation and pain, shorten recovery time, and enhance recovery safety and comfort. This approach aligns with the Enhanced Recovery After Surgery (ERAS) and humanistic nursing concepts and is worthy of promotion in thoracic surgery anesthesia recovery nursing.

Keywords

Feedforward Control, Family Awakening; Elderly Patients, Radical Lung Cancer Surgery, Anesthesia Recovery Period, Agitation, Complications, Humanistic Nursing

1. Introduction

With the accelerating process of population aging, lung cancer has become one of the most common malignant tumors affecting elderly individuals [1]. Thoracoscopic radical resection has become the preferred treatment for early-stage lung cancer due to its advantages of minimal trauma, rapid recovery, and compliance with the concept of enhanced recovery after surgery (ERAS) [2] [3]. However, elderly patients often have impaired physiological reserve, multiple comorbidities, and declined hepatic and renal function. They are vulnerable to various adverse events during anesthesia emergence [4] [5], including emergence agitation, hypothermia, hypoxemia, severe pain, and delirium. These complications may lead to hemodynamic instability, an increased risk of unplanned extubation, falls, and other accidental injuries, as well as prolonged emergence time and hospital stay, which seriously threaten patient safety and hinder the achievement of ERAS goals [6]-[8].

Current routine care during anesthesia emergence is relatively passive and lacks prospective risk prediction, stratified interventions, and humanistic care [9] [10]. Feedforward control is a prospective risk management strategy that focuses on identifying, evaluating, and preventing risks before adverse events occur, which has been proven effective in reducing complications [11] [12]. Family-mediated awakening, as a humanistic nursing model, can relieve anxiety, fear, and emergence agitation in elderly patients through familiar voice and gentle touch, thereby promoting smooth and safe emergence from anesthesia [13] [14].

However, studies that combine feedforward control with family-mediated awakening and apply this integrated intervention to elderly patients undergoing radical lung cancer resection during anesthesia emergence remain scarce [15] [16]. Therefore, this study aimed to establish an optimized anesthesia emergence intervention model based on feedforward control combined with family-mediated

awakening, and to investigate its effects on the incidence of emergence agitation, hypothermia, hypoxemia, pain, and complications, as well as emergence time and hemodynamic stability.

This study intends to provide a reliable evidence-based and humanistic nursing strategy for improving the safety and quality of anesthesia emergence care for elderly patients with lung cancer.

This study was approved by the Medical Ethics Committee of the Sun Yat-sen University Cancer Center (Approval No. G2023-238). All study procedures were conducted in accordance with the Declaration of Helsinki and relevant national ethical regulations [17].

2. Materials and Methods

2.1. Study Subjects

A total of 340 elderly patients undergoing thoracoscopic radical lung cancer surgery at Sun Yat-sen University Cancer Center from July 1 to December 31, 2024, were selected [18] [19].

Inclusion criteria:

a) Age ≥ 65 years;

b) Diagnosed with primary lung cancer and scheduled for thoracoscopic radical lung cancer surgery;

c) General anesthesia with orotracheal intubation, ASA classification I - III;

d) Informed consent from patients and their families.

Exclusion criteria:

a) Severe cardiac, pulmonary, cerebral, hepatic, or renal dysfunction;

b) Contraindications to anesthesia or abnormal coagulation function;

c) Conversion to open thoracotomy during surgery or postoperative transfer to ICU;

d) Disturbance of consciousness, dementia, or hearing disorder.

Grouping: Patients were randomly divided into a control group (170 cases) and an intervention group (170 cases) using a random number table. There were no statistically significant differences in baseline characteristics between the two groups ($P > 0.05$), indicating comparability.

2.2. Methods

2.2.1. Control Group: Conventional Anesthesia Recovery Nursing

a) Preoperative visit and health education;

b) Intraoperative monitoring of vital signs, warmed intravenous fluids, and warming blankets;

c) Post-PACU monitoring of heart rate, blood pressure, blood oxygen, body temperature, and consciousness;

d) Airway management, oxygen therapy, suctioning, and assistance with extubation;

e) Pain observation, restraint nursing, and routine management.

2.2.2. Intervention Group: Feedforward Control Combined with Family Awakening Nursing

1) Establishment of a Feedforward Control Team

Comprising anesthesia nurses, head nurses, senior nurses, and anesthesiologists, the team systematically identified high-risk factors such as agitation, hypothermia, hypoxemia, pain, delirium, and delayed recovery, and developed stratified prevention measures and standardized protocols [20] [21].

2) Preoperative Risk Assessment and Standardized Family Awakening

a) Comprehensive assessment: Age, comorbidities, pulmonary function, nutritional status, thrombosis risk, hypothermia/hypoxemia risk factors [22] [23], and language type (Mandarin, Cantonese, Hakka, Teochew).

b) Standardized family awakening procedure:

Preoperative voice recording: One day before surgery, the responsible nurse guided family members to record a personalized awakening message (60 - 90 seconds) in a gentle tone and slow pace, including the patient's name, family identity, notification of successful surgery, explanation of the PACU setting, encouragement for slow awakening, cooperation with breathing, and avoidance of agitation, while conveying family support and care. Multilingual recordings (Cantonese, Mandarin, Hakka, Teochew) were saved on PACU playback devices.

Awakening timing: Initiated immediately upon PACU admission and stable vital signs, covering the unresponsive phase, eye-opening phase, coughing phase, pre-extubation phase, and post-extubation observation phase.

Multisensory awakening:

Auditory: Low-volume looping of family recordings at the bedside;

Tactile: Nurses gently holding the patient's hand or stroking the arm;

Verbal: Nurses softly calling the patient's name and providing orientation cues;

Environmental: Dimmed lighting and noise reduction (≤55 dB).

Stratified awakening strategy:

Deep sedation: Continuous voice + tactile stimulation;

Moderate sedation: Intermittent playback + timed verbal cues;

Agitation tendency: Focus on soothing, reducing strong stimuli.

Post-extubation reinforcement: Continued playback for 3 - 5 minutes to prevent re-agitation and delirium.

3) Core Feedforward Control Interventions

a) Temperature control: Preoperative pre-warming for 30 minutes; intraoperative warming blankets and fluid warming; postoperative continuous rewarming [24].

b) Airway and respiratory control: Pre-extubation thorough suctioning and lung recruitment; post-extubation moderate-flow oxygen to prevent hypoxemia [25].

c) Agitation and pain control: Multimodal analgesia, dynamic NRS/FLACC assessment, and optimized sedation depth.

d) Circulatory stability: Blood pressure and heart rate monitoring to prevent severe fluctuations.

e) Delirium prevention: Timed awakening, voice stimulation, temperature maintenance, and optimized anesthesia metabolism.

2.3. Observation Indicators

Agitation incidence, Riker SAS scores;

NRS and FLACC pain scores;

Body temperature, hypothermia incidence;

Blood oxygen saturation, hypoxemia incidence;

Spontaneous breathing recovery, eye-opening, extubation, and PACU stay times;

Nausea/vomiting, delirium, arrhythmia, pulmonary complications;

Hemodynamic stability.

2.4. Statistical Analysis

SPSS 26.0 was used. Measurement data were expressed as ($\overline{x} \pm s$) and analyzed by t-tests; count data were expressed as rates (%) and analyzed by χ^2 tests; repeated measures were analyzed by ANOVA. $P < 0.05$ indicated statistical significance.

3. Results

3.1. Baseline Characteristics

A total of 340 elderly patients were enrolled and randomized into the control group (n = 170) and intervention group (n = 170). No patients were excluded after randomization, and no missing outcome data were observed in this study. Baseline characteristics, including age, gender, BMI, ASA classification, and operation time, were comparable between the two groups (all $P > 0.05$), as presented in Table 1.

Table 1. Comparison of baseline characteristics between the two groups.

Index	Control Group (n = 170)	Intervention Group (n = 170)	t/χ^2	P
Age (years)	71.3 ± 4.5	70.9 ± 4.8	0.82	>0.05
Gender (male/female)	92/78	89/81	0.21	>0.05
BMI (kg/m^2)	23.6 ± 3.2	23.4 ± 3.5	0.57	>0.05
ASA classification (II/III)	131/39	128/42	0.27	>0.05
Operation time (min)	118.5 ± 22.3	116.8 ± 23.6	0.69	>0.05

3.2. Primary Outcome: Emergence Agitation and Sedation Status

Compared with the control group, the intervention group showed a significantly lower incidence of emergence agitation (7.65% vs 22.94%, $\chi^2 = 15.72$, $P < 0.001$). The relative risk (RR) was 0.334, with a 95% confidence interval (CI) of 0.184 to 0.606. Meanwhile, Riker Sedation-Agitation Scale (SAS) scores at all time points (T1, T2, T3) were significantly lower in the intervention group (all $P < 0.05$). Details are shown in Table 2.

Table 2. Comparison of agitation incidence and SAS scores.

Index	Control Group	Intervention Group	χ^2/t	P
Incidence of agitation [n (%)]	39 (22.94)	13 (7.65)	15.72	<0.05
SAS (T1)	4.6 ± 1.2	3.2 ± 0.9	9.88	<0.05
SAS (T2)	4.3 ± 1.1	2.9 ± 0.8	10.21	<0.05
SAS (T3)	3.9 ± 1.0	2.6 ± 0.7	11.35	<0.05

SAS = Riker Sedation-Agitation Scale.

3.3. Pain Scores

Pain scores including Numerical Rating Scale (NRS) and Face, Legs, Activity, Cry, Consolability (FLACC) scores were both significantly lower in the intervention group than those in the control group (both $P < 0.05$), indicating better analgesic effects. Detailed comparisons are listed in Table 3.

Table 3. Comparison of NRS and FLACC pain scores ($\bar{x} \pm s$).

Index	Control Group	Intervention Group	t	P
NRS	4.6 ± 1.3	2.2 ± 0.8	14.62	<0.05
FLACC	3.8 ± 1.2	1.6 ± 0.6	12.37	<0.05

NRS = Numerical Rating ScaleFLACC = Face, Legs, Activity, Cry, Consolability Scale.

3.4. Hypothermia and Hypoxemia

The incidence of hypothermia was 8.24% in the intervention group versus 24.71% in the control group ($\chi^2 = 18.56$, $P < 0.001$, RR = 0.334, 95%CI: 0.186 - 0.598). The incidence of hypoxemia in the PACU was 5.29% vs 17.06% ($\chi^2 = 12.44$, $P < 0.001$, RR = 0.310, 95%CI: 0.152 - 0.631). Hypoxemia at 2 hours after ward transfer was also significantly lower (2.35% vs 10.59%, $P < 0.05$). Data are presented in Table 4.

Table 4. Comparison of the incidence of hypothermia and hypoxemia between the two groups [n (%)].

Index	Control Group	Intervention Group	χ^2	P
Hypothermia	42 (24.71)	14 (8.24)	18.56	<0.05
Hypoxemia in PACU	29 (17.06)	9 (5.29)	12.44	<0.05
Hypoxemia at 2 h after returning to ward	18 (10.59)	4 (2.35)	10.18	<0.05

3.5. Recovery Time

All recovery indicators including spontaneous breathing recovery time, eye-opening time, extubation time, and PACU stay time were significantly shorter in the intervention group (all $P < 0.05$). Table 5 shows the detailed comparison.

Table 5. Comparison of recovery time between the two groups ($\bar{x} \pm s$, min).

Index	Control Group	Intervention Group	t	P
Spontaneous breathing recovery time	6.8 ± 2.1	4.2 ± 1.3	12.65	<0.05
Eye opening time	9.5 ± 2.8	6.1 ± 1.7	11.93	<0.05
Extubation time	13.6 ± 3.5	9.2 ± 2.2	10.77	<0.05
PACU stay time	48.5 ± 10.2	35.8 ± 8.6	11.42	<0.05

3.6. Individual Complications and Total Complication Rate

Individual complications were separately analyzed and compared. The incidences of agitation, hypothermia, hypoxemia, delirium, nausea/vomiting, and pulmonary complications were all significantly lower in the intervention group (all $P < 0.05$). The total complication rate was 17.06% in the intervention group and 40.00% in the control group ($\chi^2 = 22.81$, $P < 0.001$, RR = 0.426, 95%CI: 0.294 - 0.618). Detailed data are listed in Table 6.

Table 6. Comparison of individual complications and total complication rate [n (%)].

Complication	Control (n = 170)	Intervention (n = 170)	χ^2	P
Emergence agitation	39 (22.94)	13 (7.65)	15.72	<0.001
Hypothermia	42 (24.71)	14 (8.24)	18.56	<0.001
Hypoxemia	29 (17.06)	9 (5.29)	12.44	<0.001
Delirium	21 (12.35)	6 (3.53)	8.17	0.004
Nausea/vomiting	25 (14.71)	8 (4.71)	9.12	0.002
Pulmonary complications	12 (7.06)	2 (1.18)	7.41	0.007
Total complications	68 (40.00)	29 (17.06)	22.81	<0.001

4. Discussion

4.1. Family Affection Awakening Can Quickly Relieve Agitation and Reduce Delirium

Elderly patients are often confused, unfamiliar with the environment, and prone to fear, agitation, and delirium during the recovery period of general anesthesia. Family voice has four major functions: high familiarity, emotional attachment, sense of security, and orientation recovery, which can quickly reduce stress responses and reduce the risks of struggling, extubation, and falling from the bed.

4.2. The Combination of Family Affection Awakening and Feedforward Control Achieves Dual Improvement of "Safety + Humanization"

Feedforward control prevents hypothermia, hypoxia, and pain in advance; family affection awakening accelerates consciousness recovery and shortens delayed awakening. The two work together to make recovery more stable, faster, and safer.

4.3. Multilingual Family Affection Awakening Is More Suitable for Clinical Practice

This study supports recording in Mandarin, Cantonese, Hakka, and Chaozhou dialects, which is more in line with the language habits of elderly patients and leads to more stable awakening effects.

4.4. Clinical Promotion Value

Family affection awakening is cost-free, non-invasive, easy to operate, and highly compliant; feedforward control is standardized, reproducible, and quality-controllable. The combined model is suitable for widespread promotion in thoracic surgery, PACU, elderly surgery, and oncological surgery.

5. Conclusions

5.1. Feedforward Control Combined with Family Affection Awakening Can Significantly Reduce Various Complications during Anesthesia Recovery in Elderly Patients Undergoing Radical Resection of Lung Cancer

The results of this study confirm that combining feedforward control, which focuses on risk prediction and early intervention, with family affection awakening characterized by emotional comfort and multi-sensory stimulation, can simultaneously reduce the incidence of multiple adverse events such as agitation, pain, hypothermia, hypoxemia, delirium, nausea and vomiting, and pulmonary complications. The total complication rate in the intervention group was only 17.06%, much lower than 40.00% in the control group, indicating that this model can reduce risks during anesthesia recovery from the source and provide a reliable guarantee for the early postoperative safety of elderly patients with lung cancer.

5.2. Family Affection Awakening Can Effectively Improve the Recovery Experience of Elderly Patients and Strengthen the Value of Humanistic Nursing

Through familiar family voice, multi-sensory stimulation, and orientation awakening, family affection awakening significantly reduces fear, anxiety, and agitation during the recovery period, and significantly lowers SAS agitation scores, NRS and FLACC pain scores. This model not only embodies the patient-centered care concept but also introduces the family support system into perioperative care, making up for the lack of humanistic care in traditional recovery nursing, especially suitable for the elderly with decreased cognitive function and sensitive stress responses.

5.3. The Combined Intervention Model Can Significantly Accelerate the Anesthesia Recovery Process and Improve PACU Operation Efficiency

Studies have shown that the spontaneous breathing recovery time, eye opening

time, extubation time, and PACU stay time in the intervention group are significantly shorter than those in the control group, suggesting that feedforward control lays a physiological foundation for rapid recovery through temperature management, airway protection, and circulatory stability, while family affection awakening accelerates consciousness recovery and shortens delayed awakening. The synergistic effect of the two can effectively shorten the patient's stay in the anesthesia care unit, improve the bed turnover efficiency of the department, and conform to the core goal of Enhanced Recovery After Surgery (ERAS).

5.4. Multilingual Family Affection Awakening Is More Suitable for Clinical Practice and Has Broad Promotion Potential

Aiming at the linguistic characteristics of South China, Hong Kong SAR, and Macao SAR, this study supports voice recording in Mandarin, Cantonese, Hakka, and Chaozhou dialects, making awakening intervention closer to the patients'daily language environment and improving intervention compliance and effectiveness. This method is easy to operate, non-invasive, cost-free, and easy to standardize, and can be widely used in thoracic surgery, PACU, elderly surgery, and perioperative oncological nursing in hospitals at all levels.

5.5. The Combined Model of Feedforward Control and Family Affection Awakening Provides a New Paradigm for Perioperative Nursing of Elderly Tumor Patients

This study deeply integrates prospective risk management with humanistic care, and constructs a closed-loop nursing model of "prediction-prevention-awakening-comfort-stabilization", breaking through the passive nursing mode of traditional "monitoring-response". This model not only improves nursing quality and safety but also enhances nurses' risk prediction ability, promotes the development of anesthesia recovery nursing towards refinement, predictability, and humanization, and provides practical and theoretical support for the improvement of the perioperative nursing system for elderly thoracic surgery patients.

5.6. Overall, Feedforward Control Combined with Family Affection Awakening Is Safe, Effective, Economical, and Easy to Implement, with High Clinical Value

This model does not require a large amount of medical resources and equipment investment, and can significantly improve recovery outcomes only by optimizing nursing processes, strengthening risk prevention and control, and integrating family emotional support. It is suitable for promotion in hospitals at all levels. Its comprehensive advantages in reducing complications, shortening recovery time, and improving comfort and safety make it an ideal nursing plan for elderly patients undergoing radical resection of lung cancer during anesthesia recovery.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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