Application of an Integrated Clinical Rehabilitation Pathway Based on the TIME Model in Perioperative Patients Undergoing Hepatobiliary Surgery

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Abstract [**Objectives**] To explore the effects of applying an integrated clinical rehabilitation pathway based on the TIME model in perioperative patients undergoing hepatobiliary surgery. [**Methods**] Using a convenience sampling method, 120 patients scheduled for elective hepatobiliary surgery at a tertiary Grade A hospital from June 2023 to June 2025 were enrolled as study participants. They were randomly assigned, via a random number table, to a control group ($n = 60$) or an observation group ($n = 60$). The control group received routine Enhanced Recovery After Surgery (ERAS) care. The observation group received an integrated clinical rehabilitation nursing pathway based on the TIME model, in addition to the routine care. Postoperative pulmonary complication rates, indicators of recovery progress, cardiopulmonary function indices (pre- and postoperatively), and comfort status were compared between the two groups. [**Results**] The incidence of postoperative pulmonary complications was significantly lower in the observation group than in the control group ($P < 0.05$). The time to first ambulation, time to first flatus, and postoperative hospital stay were all significantly shorter in the observation group compared to the control group ($P < 0.05$). On postoperative day 3 (POD3), maximal inspiratory pressure (MIP) and the 6-minute walk distance (6MWD) were significantly better in the observation group than in the control group ($P < 0.05$). The comfort score on POD3 was also significantly higher in the observation group ($P < 0.05$). [**Conclusions**] The integrated clinical rehabilitation pathway based on the TIME model can effectively reduce the incidence of postoperative pulmonary complications, accelerate postoperative recovery, improve cardiopulmonary function, and enhance patient comfort in individuals undergoing hepatobiliary surgery. This approach demonstrates substantial value for clinical promotion.

Key words TIME model, Perioperative nursing, Integrated clinical rehabilitation, Enhanced Recovery After Surgery (ERAS), Hepatobiliary surgery

1 Introduction

Hepatobiliary surgeries, primarily consisting of major and intermediate procedures such as hepatectomy and radical resections for biliopancreatic tumors, are characterized by complex anatomical structures, significant surgical trauma, and substantial stress responses[1]. Patients are predominantly middle-aged and elderly, often with comorbidities such as liver cirrhosis, malnutrition, and underlying cardiopulmonary diseases. Consequently, they are at high risk for postoperative complications, including pulmonary infections, atelectasis, and delayed recovery of gastrointestinal function, all of which severely impact prognosis[2]. Traditional perioperative management models, which often prioritize treatment over rehabilitation, tend to implement rehabilitation interventions in a delayed and fragmented manner, failing to meet the demands of modern fast-track surgery.

Although the Enhanced Recovery After Surgery (ERAS) concept has been widely promoted, specific clinical practices often lack specialty-targeted nursing assessments. Rehabilitation interventions, such as breathing exercises and early mobilization, are frequently executed based on experience rather than precise, quantifiable standards[3]. Prehabilitation, a core and evolving component of ERAS, emphasizes optimizing a patient's physiological reserve during the preoperative period. The TIME model, proposed by West China Hospital of Sichuan University, provides a precise assessment tool for perioperative pulmonary rehabilitation in abdominal surgery through four dimensions: Airway status (T), Inspiratory muscle function (I), Mobility (M), and respiratory Oxygen consumption (E)[4]. The integrated clinical rehabilitation model breaks down disciplinary barriers between clinical practice and rehabilitation, emphasizing multidisciplinary team (MDT) collaboration and embedding rehabilitation assessment and interventions throughout the entire diagnostic and treatment process[5].

Currently, there is limited reported research integrating the TIME prehabilitation assessment with the concept of integrated clinical rehabilitation to form a standardized nursing pathway for application in hepatobiliary surgery. This study aimed to construct and implement an integrated clinical rehabilitation nursing pathway based on the TIME model and to evaluate its effects in perioperative patients undergoing hepatobiliary surgery, thereby providing an evidence base for specialized nursing practice.

2 Subjects and methods

2.1 Study design and participants This prospective, single-center, randomized controlled trial was conducted in the Department of Hepatobiliary Surgery of a tertiary Grade A hospital from June 2023 to June 2025. A total of 120 patients scheduled for elective hepatobiliary surgery were enrolled using convenience sampling.

2.1.1 Inclusion criteria. Patients were included if they: (i) were aged 18 to 75 years; (ii) had an indication for elective major or intermediate hepatobiliary surgery (*e.g.*, partial hepatectomy,

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radical resection of bile duct cancer); (iii) were classified as American Society of Anesthesiologists (ASA) physical status II-III; and (iv) provided informed consent voluntarily.

2.1.2 Exclusion criteria. Patients were excluded if they: (i) had severe preoperative cardiopulmonary dysfunction and could not tolerate the training regimen; (ii) had psychiatric disorders or cognitive/communication barriers; (iii) experienced severe intra-operative hemorrhage or required transfer to the intensive care unit (ICU) for monitoring; or (iv) were transferred to another hospital or withdrew from the study mid-way.

Participants were randomly assigned to a control group or an observation group ($n=60$ each) using a random number table. Baseline characteristics showed no significant differences between groups ($P>0.05$), indicating good comparability (Table 1).

Table 1 Comparison of baseline characteristics between the two groups ($n=60$)

Group	Age (years, $\bar{x}\pm s$)	Gender (Male/Female)	BMI ($\bar{x}\pm s$)	Type of surgery			Comorbidities	
				Partial hepatectomy	Radical resection of biliary tract tumor	Pancreatico-duodenectomy	Hypertension/Diabetes	No comorbidities
Control	55.32 ± 8.41	36/24	23.15 ± 2.64	32.000	18	10	22.000	38
Observation	54.87 ± 9.02	35/25	22.89 ± 2.71	30.000	20	10	24.000	36
Statistical value	0.283	0.033	0.531	0.153			0.068	
P value	0.778	0.856	0.596	0.926			0.794	

2.2 Interventions The same team of surgeons and anesthesiologists performed all operations and administered anesthesia. Basic treatments followed the *Chinese Expert Consensus and Pathway Management Guidelines for Enhanced Recovery After Surgery (2023 Edition)*[1].

2.2.1 Control group. Routine ERAS nursing care was implemented. (i) Preoperative: Routine health education, verbal instructions on deep breathing and effective coughing, routine bowel preparation, and nutritional support. (ii) Postoperative: Routine analgesia via a patient-controlled analgesia (PCA) pump; assistance with turning in bed 6 h postoperatively; encouragement to ambulate once vital signs stabilized; removal of various tubes as prescribed; and initiation of a clear liquid diet after passage of flatus.

2.2.2 Observation group. In addition to the routine ERAS care, an integrated clinical rehabilitation nursing pathway based on the TIME model was implemented. An MDT comprising surgeons, anesthesiologists, specialized nurses, rehabilitation therapists, and dietitians was formed to jointly develop a standardized pathway based on literature review and expert consensus.

(i) Preoperative Prehabilitation Assessment and Intervention (from admission to 1 day before surgery): ① TIME Model Assessment: Specialized nurses used the TIME scale to assess patients' airway status (T), inspiratory muscle function (I), mobility (M), and respiratory oxygen consumption (E) to identify high-risk individuals. ② Respiratory Prehabilitation: For patients with abnormalities in the I dimension, resistance training was conducted using an inspiratory muscle trainer. The initial load was set at 30% of the maximal inspiratory pressure (MIP), performed twice daily for 15 min per session. Instructions were also given for pursed-lip breathing and diaphragmatic breathing. ③ Exercise Prehabilitation: Based on the M and E dimension assessments, low-risk patients performed 30 min/day of moderate-intensity walking. High-risk patients performed bed-based resistance and sitting balance training. ④ Nutritional and Psychological Interventions: Dietitians guided oral nutritional supplement (ONS) intake. Psychological nurses screened patients using the Self-Rating Anxiety Scale (SAS) and implemented cognitive interventions.

(ii) Intraoperative Cooperative Protection: Nurses cooperated with anesthesiologists to implement lung-protective ventilation strategies (low tidal volume with positive end-expiratory pressure), strict goal-directed fluid management, and the use of warming blankets to maintain normothermia.

(iii) Postoperative Early Rehabilitation (from surgery to discharge): ① Precise Respiratory and Airway Management: Patients were placed in a semi-recumbent position (30° – 45°) postoperatively. A vibrating sputum expectoration device was used to assist with secretion clearance every 2 h. Aerosol inhalation was administered three times daily. The preoperative respiratory training protocol was continued. ② Stepwise Exercise Rehabilitation: Ankle pump exercises and limb flexion/extension in bed were initiated 6 h postoperatively. Sitting up and standing by the bedside were encouraged at 24 h, followed by walking in the corridor at 48 h postoperatively. A safety threshold was set at a heart rate ≤ (baseline + 30%) without symptoms of chest tightness or shortness of breath. Rehabilitation therapists and nurses jointly supervised and evaluated these activities. ③ Gastrointestinal and Pain Rehabilitation: Multimodal analgesia (combining incisional nerve block, intravenous analgesia, and non-steroidal anti-inflammatory drugs) was used to maintain a Numeric Rating Scale (NRS) pain score ≤3. Chewing gum was initiated 6 h postoperatively to stimulate gastrointestinal hormone secretion, and a clear fluid diet was started at 24 h postoperatively.

(iv) Discharge and Continuous Rehabilitation: Home-based rehabilitation prescriptions were formulated. Guidance for home-based respiratory and aerobic training was provided via a WeChat follow-up system, with instructions for regular outpatient reviews.

2.3 Evaluation indicators

2.3.1 Incidence of Postoperative Pulmonary Complications (PPCs). The occurrence of pulmonary infections, atelectasis, and respiratory interventions necessitated by pleural effusion was recorded in both groups from the end of surgery until discharge. Diagnostic criteria referred to the *Chinese Expert Consensus on Perioperative Pulmonary Protection*[6].

2.3.2 Recovery progress indicators. The time to first ambulation, time to first flatus, and postoperative hospital stay were recorded for both groups.

2.3.3 Cardiopulmonary function indicators. Maximal Inspiratory Pressure (MIP): Measured using a portable pulmonary function device to reflect inspiratory muscle strength. 6-Minute Walk Distance (6MWD): Conducted according to American Thoracic Society (ATS) guidelines to assess exercise tolerance. Measurements were taken at admission (pre-intervention) and on POD3.

2.3.4 Comfort score. Assessed using the General Comfort Questionnaire (GCQ), which includes 28 items across four dimensions (physiological, psychological, sociocultural, and environmental). A 4-point Likert scale (1 – 4) was used, with total scores ranging from 28 to 112; higher scores indicate greater comfort. Assessment was performed on POD3.

2.4 Statistical methods Data were analyzed using SPSS 26.0 software. Normally distributed continuous data are presented as mean ± standard deviation ($\bar{x} \pm s$). Intergroup comparisons were performed using independent samples *t*-tests, and intragroup comparisons used paired samples *t*-tests. Categorical data are presented as frequencies and percentages (%), compared using the *Chi*-square test or Fisher's exact test. A P value <0.05 was considered statistically significant.

3 Results and analysis

3.1 Comparison of the incidence of PPCs In the observation group, 3 cases (5.00%) of PPCs occurred (2 atelectasis, 1 pulmonary infection). In the control group, 11 cases (18.33%) occurred (5 atelectasis, 4 pulmonary infection, 2 requiring respiratory intervention for pleural effusion). The incidence of PPCs was significantly lower in the observation group ($\chi^2 = 4.227$, $P = 0.040$).

3.2 Comparison of recovery progress indicators The time to first ambulation, time to first flatus, and postoperative hospital stay were all significantly shorter in the observation group compared to the control group ($P<0.05$) (Table 2).

Table 2 Comparison of recovery progress indicators between the two groups ($n=60$, $\bar{x} \pm s$)

Group	Time to first ambulation // h	Time to first flatus // h	Postoperative hospital stay // d
Control	28.45 ± 6.32	52.36 ± 9.18	8.54 ± 2.16
Observation	18.72 ± 4.15	38.25 ± 7.64	6.21 ± 1.45
t value	9.863	9.072	6.823
P value	<0.001	<0.001	<0.001

3.3 Comparison of preoperative and postoperative cardiopulmonary function indicators At admission, there were no significant differences in MIP and 6MWD between the two groups ($P>0.05$). On POD3, both MIP and 6MWD decreased compared to admission values in both groups ($P<0.05$). However, the MIP and 6MWD in the observation group were significantly higher than those in the control group on POD3 ($P<0.05$) (Table 3).

Table 3 Comparison of cardiopulmonary function indicators before and after surgery between the two groups ($n=60$, $\bar{x} \pm s$)

Group	MIP (cmH_2O)	6MWD (m)
	At admission	POD3
Control	68.45 ± 8.12	52.36 ± 6.45
Observation	67.92 ± 8.56	60.12 ± 7.23
t value	0.348	6.146
P value	0.729	<0.001

3.4 Comparison of postoperative comfort scores The GCQ score on POD3 in the observation group (85.36 ± 6.42) was significantly higher than that in the control group (76.21 ± 7.15), with a statistically significant difference ($t = 7.342$, $P<0.001$).

4 Discussion

4.1 The integrated rehabilitation pathway reduces postoperative pulmonary complications Due to factors such as general anesthesia with endotracheal intubation, diaphragmatic irritation, incisional pain, and traction on abdominal organs during hepatobiliary surgery, the incidence of PPCs can be as high as 15% – 30%[7]. The results of this study showed a significantly lower incidence of PPCs in the observation group compared to the control group ($P<0.05$). Traditional nursing often employs a "one-size-fits-all" approach to respiratory training, relying on verbal instruction without specificity. This study introduced the TIME model to precisely assess patients' inspiratory muscle function (I dimension) and airway status (T dimension) preoperatively, identifying high-risk patients. Targeted interventions, such as resistance training with an inspiratory muscle trainer, were then implemented, effectively enhancing inspiratory muscle strength[8]. Simultaneously, the intraoperative lung-protective ventilation strategy, combined with early postoperative semi-recumbent positioning and vibration sputum expectoration, formed a closed-loop management system of "prehabilitation-intraoperative protection-postoperative intensification". This approach effectively maintained small airway patency and promoted secretion clearance. These findings are consistent with conclusions from prior applications of the TIME theory in abdominal surgery[4].

4.2 The pathway accelerates postoperative recovery and shortens hospital stay In this study, the time to first ambulation, time to first flatus, and postoperative hospital stay were significantly shorter in the observation group ($P<0.05$). In routine ERAS care, patient compliance with early ambulation is often poor due to pain fear and lack of quantified guidance[9]. The integrated clinical rehabilitation pathway in this study emphasizes the "co-deployment of medical treatment and rehabilitation". By assessing mobility (M dimension) and respiratory oxygen consumption (E dimension), a stepwise exercise protocol with a safety threshold (heart rate ≤ baseline + 30%) was developed. Nurses and rehabilitation therapists jointly managed key milestones at 6, 24, and 48 h postoperatively, transforming early mobilization from a suggestive measure to a supervised, mandatory component of medical orders[5]. Furthermore, multimodal analgesia combined with gastrointestinal rehabilitation interventions (*e. g.*, chewing gum) effectively alleviated pain-related stress and promoted the recovery of intestinal peristalsis, thereby shortening hospital stay and optimizing the use of medical resources.

4.3 Prehabilitation preserves cardiopulmonary function and improves comfort Patients undergoing hepatobiliary surgery often present with conditions like liver cirrhosis and malnutrition, leading to reduced cardiopulmonary reserve. This study showed that although MIP and 6MWD decreased in both groups on POD3 compared to admission, the decline was significantly less pronounced in the observation group ($P < 0.05$). This suggests that the "biological memory" effect generated by preoperative prehabilitation played a crucial protective role postoperatively[10]. Targeted preoperative aerobic and resistance training improved skeletal muscle mitochondrial oxidative capacity and cardiopulmonary endurance, thereby enhancing patients' tolerance to surgical trauma[11]. Regarding comfort, the integrated pathway focused not only on the recovery of physiological indicators but also on alleviating psychological stress and physical discomfort through MDT-led psychological interventions, refined pain management, and environmental optimization, embodying the concept of "holistic nursing"[12].

4.4 Limitations and future directions This study is a single-center trial with a limited sample size and did not include long-term follow-up of patients' quality of life (*e. g.*, at 1 and 3 months postoperatively). Future research should consider multi-center, large-sample randomized controlled trials. The introduction of wearable devices for remote dynamic monitoring of parameters such as heart rate, blood oxygen saturation, and step counts during the home-based continuous rehabilitation phase could be valuable[13]. This would further improve the out-of-hospital closed-loop management of the integrated clinical rehabilitation pathway for hepatobiliary surgery patients.

5 Conclusions

The integrated clinical rehabilitation nursing pathway based on the TIME model deeply integrates precise prehabilitation assessment with multidisciplinary, whole-process rehabilitation interventions. It effectively addresses deficiencies in traditional perioperative care for hepatobiliary surgery, such as delayed rehabilitation and a lack of quantified standards. This pathway demonstrates significant advantages in reducing postoperative pulmonary complications, accelerating the recovery of gastrointestinal function, preserving cardiopulmonary function, and enhancing patient comfort. Therefore, it is worthy of further clinical promotion and application.

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