

Effect of Clinical Pathway-Based Airway Management on Early Rehabilitation in Patients with Severe Traumatic Brain Injury

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Abstract: *Objective:* To investigate the effect of clinical pathway-oriented airway management on early rehabilitation in patients with severe traumatic brain injury (sTBI) undergoing tracheotomy. *Methods:* A total of 146 sTBI patients were randomly divided into observation group (n = 73) and control group (n = 73). The control group received routine nursing care, while the observation group was implemented with clinical pathway-based airway management. All patients were evaluated for outcome indicators, airway humidification and complications after 8 weeks of intervention. *Results:* After intervention, the observation group had significantly higher airway humidification satisfaction (87.5%, $p < 0.05$), lower incidence of pulmonary infection (30.0%, $p < 0.05$) and lower incidence of airway bleeding (27.5%, $p < 0.01$) than the control group. The sputum aspiration frequency [2 (1,2), $p < 0.01$], single-patient tracheotomy care time [4 (3,5) min, $p < 0.01$], and tracheostomy cannula indwelling time (35.80 ± 18.22 d, $p < 0.01$) in the observation group were significantly lower or shorter than those in the control group. The successful decannulation rate was significantly higher (47.5%, $p < 0.05$). *Conclusion:* Clinical pathway-based airway management can effectively improve sputum characteristics, reduce pulmonary infection and airway bleeding, shorten tracheostomy cannula indwelling time, improve decannulation success rate and promote prognosis in sTBI patients with tracheotomy.

Keywords: Clinical pathway; Severe craniocerebral injury; Tracheotomy; Airway management

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1. Introduction

Approximately 20% of craniocerebral trauma is severe traumatic brain injury, which is often accompanied by varying degrees of coma, rapid disease progression and high mortality^[1]. Tracheotomy is widely used to maintain ventilation, but post-operative complications such as pulmonary infection are common due to impaired cough reflex, poor secretion management, aspiration and prolonged bed rest, with an incidence rate up to 68.5%^[2]. In clinical practice, airway management faces potential risks, high nursing workload and low

efficiency^[3]. Rehabilitation clinical pathway is a standardized and evidence-based service process formulated by physicians, nurses and therapists, covering the whole process from admission to discharge, aiming to improve medical resource utilization^[4]. This study developed and applied a clinical pathway-oriented airway management program, and explored its effect on early rehabilitation of sTBI patients with tracheotomy.

2. Objects and methods

2.1. Research objects

Convenience sampling was used to select patients with severe craniocerebral injury hospitalized in the Intensive Rehabilitation Medicine Department of our hospital from March 2024 to June 2025. They were divided into observation group and control group by random number table method.

Sample size estimation: According to preliminary experiments and literature review, the incidence of ventilator-associated pneumonia (VAP) in the control group was expected to be 45%, which could be reduced to 25% after intervention. With $\alpha = 0.05$ (two-sided), $\beta = 0.2$ (power 80%), the calculated sample size was about 65 cases per group. Considering a 20% loss to follow-up rate, 73 cases were finally included in each group, with a total of 146 cases.

2.1.1. Inclusion criteria

- (1) Met the diagnostic criteria of severe craniocerebral injury, with Glasgow Coma Scale (GCS) score of 3–8 on admission^[5];
- (2) Aged 18–75 years;
- (3) Admitted within 24 hours after injury, with expected hospital stay ≥ 7 days;
- (4) Underwent tracheotomy after injury;
- (5) non-mechanical ventilation via tracheotomy on admission.

2.1.2. Exclusion criteria

- (1) History of severe chronic obstructive pulmonary disease or neuromuscular disease;
- (2) Moribund state (GCS score 3 with fixed and dilated bilateral pupils);
- (3) Combined with severe injury or functional failure of other vital organs.

2.1.3. Study details

This study was approved by the Hospital Ethics Committee (2023KY448). All guardians or legal representatives of patients understood the content and signed informed consent. There were no significant differences in gender, age, disease diagnosis, GCS score and other general data between the two groups ($p > 0.05$), indicating comparability (**Table 1**).

Table 1. Comparison of general characteristics between the two groups

Group	n	Gender /n		(Age, $\bar{x} \pm s$)	Etiology (n)			GCS score (points, $\bar{x} \pm s$)
		Male	Female		Cerebral infarction	Cerebral hemorrhage	Craniocerebral injury	
Control	73	48	25	58.50 \pm 14.20	12	35	26	5.80 \pm 1.50
Observation	73	50	23	60.10 \pm 13.50	10	37	26	5.90 \pm 1.60
t/χ^2 -value		0.112		0.695		0.224		0.387
p -value		0.738		0.488		0.894		0.699

2.2. Intervention methods

2.2.1. Intervention in the observation group

(1) Establishment of an airway management subspecialty team

The team consisted of 3 rehabilitation specialist nurses (1 associate chief nurse and 2 nurse-in-charges), 1 associate chief physician in rehabilitation, and 2 respiratory therapists, all with more than 5 years of experience in rehabilitation department. The associate chief nurse served as the team leader, responsible for organizing meetings and supervising implementation. Team members jointly completed airway assessment and formulated nursing plans and health education. Rehabilitation specialist nurses implemented measures and provided timely feedback. Therapists collaborated with nurses in respiratory function training, and attending physicians were responsible for clinical treatment.

(2) Development of clinical pathway-oriented airway management program

Based on Clinical Pathway of Rehabilitation Nursing and Expert Consensus on Airway Management for Severe Neurosurgical Patients in China, the PIPOST model (Population, Intervention, Professional, Outcome, Setting, Type of evidence) of JBI Evidence-Based Nursing Center was used to construct structured evidence-based nursing questions [6-8]. According to the characteristics of intensive rehabilitation, physicians, nurses and therapists jointly developed a clinical pathway form for patients with severe craniocerebral injury after tracheotomy. The pathway took time as the horizontal axis, divided into three consecutive stages, and took assessment, nursing measures, medical measures, rehabilitation therapy and health education as the vertical axis to formulate a standardized process. Refer **Table 2**.

Table 2. Clinical pathway form for airway management in patients with severe craniocerebral injury after tracheotomy

Patient Name: _____ Medical Record No.: _____ Date of Admission: _____

GRS-R Score: _____

Duration: From admission to decannulation/transfer

Goals: Satisfactory airway humidification without scab formation; reduced pulmonary infection and airway bleeding; successful decannulation or preparation for decannulation

Time	Stage 1 (Acute Unstable Phase)	Stage 2 (Stable Rehabilitation Phase)	Stage 3 (Decannulation Transition Phase)
Core Goals	Establish baseline, stabilize vital signs, prevent early complications	Enhance airway clearance, control infection, initiate early rehabilitation	Assess decannulation criteria, strengthen functional training, prepare for decannulation/capping
Assessment	<input type="checkbox"/> Monitor vital signs, SpO ₂ , consciousness, pupils <input type="checkbox"/> Assess cough and swallowing reflex <input type="checkbox"/> Check tracheostomy tube fixation, cuff pressure (q4h) <input type="checkbox"/> Assess sputum characteristics, quantity, bleeding <input type="checkbox"/> Assess stoma skin and dressing <input type="checkbox"/> Auscultate lungs	<input type="checkbox"/> Daily assessment of consciousness and ICP <input type="checkbox"/> Dynamic assessment of sputum and humidification <input type="checkbox"/> Assess subglottic secretions <input type="checkbox"/> Assess signs of pulmonary infection <input type="checkbox"/> Assess airway bleeding risk	<input type="checkbox"/> Systematically assess decannulation/capping: - consciousness - spontaneous breathing, cough - swallowing - infection control - airway patency <input type="checkbox"/> Assess sitting balance

Time	Stage 1 (Acute Unstable Phase)	Stage 2 (Stable Rehabilitation Phase)	Stage 3 (Decannulation Transition Phase)
Nursing	<input type="checkbox"/> Head elevation 30° <input type="checkbox"/> Cuff pressure 25–30 cmH ₂ O, q4h <input type="checkbox"/> Individualized airway humidification <input type="checkbox"/> Sterile suction as needed <input type="checkbox"/> Subglottic suction if applicable <input type="checkbox"/> Oral care twice daily	<input type="checkbox"/> Semi-recumbent position, reposition q2h <input type="checkbox"/> Continue cuff monitoring <input type="checkbox"/> Adjust humidification <input type="checkbox"/> Airway clearance : manual vibration if ICP stable; Subglottic suction q6h <input type="checkbox"/> Oral care, increased frequency if needed	<input type="checkbox"/> Capping trial if eligible; Emergency equipment at bedside <input type="checkbox"/> Post-decannulation care: observe breathing, SpO ₂ , swallowing <input type="checkbox"/> Stoma dressing care <input type="checkbox"/> Continue humidification if not decannulated
Medical	<input type="checkbox"/> Complete blood tests, CRP, PCT, sputum culture <input type="checkbox"/> Anti-infection and expectorant drugs <input type="checkbox"/> Evaluate bronchoscopy	<input type="checkbox"/> Adjust antibiotics based on drug sensitivity <input type="checkbox"/> Supportive treatment	<input type="checkbox"/> Comprehensive decannulation assessment <input type="checkbox"/> Informed consent <input type="checkbox"/> Decannulation or capping
Rehabilitation	<input type="checkbox"/> Passive limb exercises (if ICP stable) <input type="checkbox"/> Abdominal breathing training if cooperative	<input type="checkbox"/> Daily awakening (if sedated) <input type="checkbox"/> Airway clearance techniques <input type="checkbox"/> Passive limb and trunk exercises 1–2 times daily	<input type="checkbox"/> Swallowing training <input type="checkbox"/> Sitting balance training (60–90° head elevation) <input type="checkbox"/> Cough training if cooperative
Health Education	<input type="checkbox"/> Explain tracheotomy purpose, risks and care <input type="checkbox"/> Importance of repositioning <input type="checkbox"/> Keep stoma dressing clean and dry	<input type="checkbox"/> Guide family to identify abnormal breathing and sputum <input type="checkbox"/> Early mobilization to prevent infection <input type="checkbox"/> Family involvement in basic care	<input type="checkbox"/> Explain decannulation/capping process and risks <input type="checkbox"/> Post-decannulation precautions <input type="checkbox"/> Discharge guidance for home care
Variation	<input type="checkbox"/> No <input type="checkbox"/> Yes:	<input type="checkbox"/> No <input type="checkbox"/> Yes:	<input type="checkbox"/> No <input type="checkbox"/> Yes:
Variation	<input type="checkbox"/> No <input type="checkbox"/> Yes:	<input type="checkbox"/> No <input type="checkbox"/> Yes:	<input type="checkbox"/> No <input type="checkbox"/> Yes:

(3) Implementation and supervision

The clinical pathway was implemented from admission to decannulation. The team provided training and assessment. Head nurses or specialist nurses supervised implementation using a checklist and continuously optimized the process to ensure homogeneous quality^[9].

2.2.2. Intervention in the control group

Routine rehabilitation airway care was provided: responsible nursing, antibiotics, expectorants and bronchodilators as ordered, head elevation 30–45°, repositioning and back percussion q2h, vibration sputum excretion once daily, suction as needed, passive exercise for 30 minutes daily, and continuous enteral nutrition^[10].

2.3. Outcome measures

2.3.1. Patient outcomes

- (1) Tracheostomy tube indwelling time (days from admission to removal).
- (2) Successful decannulation rate: no re-intubation/tracheotomy within 72 hours after decannulation.

2.3.2. Airway humidification effect

- (1) Satisfactory
Thin sputum, smooth suction, no scab, clear airway.
- (2) Insufficient
Thick sputum, difficult suction, possible scab, dyspnea.

(3) Excessive

Watery sputum, frequent suction, increased cough, restlessness.

2.3.3. Complications

(1) Pulmonary infection

≥ 2 of fever (> 38.0 °C), abnormal WBC, positive sputum culture, new chest imaging lesions [11].

(2) Airway bleeding: bleeding during suction/cough, volume <10 mL [12].

2.4. Statistical methods

SPSS 22.0 was used. Measurement data with normal distribution were expressed as (x̄ ± s) and compared by t-test; non-normal data were expressed as median and interquartile range M (P₂₅, P₇₅) and compared by rank-sum test. Enumeration data were expressed as frequency and percentage, compared by χ² test. p < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of outcome indicators

As shown in Table 3, the observation group had significantly fewer aspiration times, shorter single-patient tracheotomy care time and shorter tracheostomy cannula indwelling time than the control group (p < 0.001).

Table 3. Comparison of suction times, nursing time per patient and tracheostomy tube indwelling time (x̄ ± s)

Group	n	Suction times (n)	Nursing time per patient (min)	Indwelling time (d)
Control	73	3 (2,4)	6 (5,7)	58.50 ± 14.20
Observation	73	2 (1,2)	4 (3,5)	35.80 ± 18.22
z/t-value		-5.201	-5.412	-6.521
p-value		< 0.001	< 0.001	< 0.001

3.2. Comparison of airway humidification effect

Table 4 demonstrates that airway humidification satisfaction was significantly higher in the observation group after intervention (p < 0.05).

Table 4. Comparison of airway humidification effect [n(%)]

Group	n	Before intervention		After intervention		χ ² -value	p-value
		Satisfactory	insufficient excessive	Satisfactory	insufficient excessive		
Control	73	40 (54.8)		48 (65.8)		1.875	0.392
		26 (35.6)		18 (24.7)			
		7 (9.6)		7 (9.6)			
Observation	73	38 (52.1)		64 (87.7)		12.542	0.002
		33 (45.2)		9 (12.3)			
		2 (2.7)		0 (0.0)			
χ ² -value		2.103		7.215			
p-value		0.349		0.027			

3.3. Comparison of complications and decannulation rate

The incidences of complications and successful decannulation rate are summarized in **Table 5**

Table 5. Comparison of complications and successful decannulation rate [n(%)]

Group	n	Pulmonary infection	Airway bleeding	Successful decannulation rate
Control	73	40(54.8)	46(63.0)	18(24.7)
Observation	73	22(30.1)	20(27.4)	35(47.9)
χ^2 -value		0.112	18.764	8.896
P-value		0.003	< 0.001	0.003

4. Discussion

4.1. Clinical pathway-oriented airway management improves humidification and reduces complications

Patients with severe traumatic brain injury complicated by tracheotomy lose the physiological functions of airway heating and humidification. Combined with airway mucosal injury, impaired ciliary movement, prolonged bed rest and absence of voluntary cough reflex, these factors result in difficult sputum excretion and recurrent pulmonary infection, thus leading to inadequate airway clearance^[13,14]. A study by He Yanbin et al, showed that tracheal extubation is closely associated with consciousness state, cough reflex and airway secretions^[15,16]. In this study, phased and standardized management based on clinical pathways yielded significantly better outcomes in the observation group, including a higher satisfaction rate of airway humidification (87.5%) and lower incidence rates of pulmonary infection (30.1%) and airway hemorrhage (27.4%), compared with the control group ($p < 0.05$). These results suggest that a clinical pathway-oriented protocol can effectively reduce airway-related complications and improve nursing quality, which is consistent with the findings of Hu Na et al^[17].

Clinical pathways provide procedural guidance for the medical team, clarify rehabilitation priorities at each stage, facilitate effective communication among healthcare providers, patients and their families, enhance team execution and risk anticipation capabilities, and ultimately achieve homogeneous nursing care.

4.2. Clinical pathway promotes early rehabilitation and improves prognosis

The clinical pathway established in this study acted as a bridge that integrated the distinctive expertise of multidisciplinary team members (physicians, nurses, and therapists) into a linear workflow^[18]. It clarified the priorities and challenges at each step to prevent omissions in care delivery. The protocol was implemented mainly by rehabilitation specialist nurses, with regular evaluation, collaboration, and continuous process optimization among physicians, nurses and therapists, while the head nurse was responsible for overall coordination. The results demonstrated that the observation group had significantly fewer suctioning times and shorter nursing time per patient than the control group ($p < 0.01$). The duration of tracheostomy tube indwelling was shortened to (35.80 ± 18.22) days, and the successful decannulation rate increased to 47.9% ($p < 0.05$). These findings indicate that the clinical pathway-based intervention can effectively shorten the duration of tube placement, fulfill the desire of patients and their families for safe and early decannulation, reduce clinical nursing workload, optimize working hours, and improve work efficiency. The integrated nursing process, ranging from condition assessment and intervention implementation to supervision and

feedback, significantly improved the quality of airway management and promoted early rehabilitation of patients.

5. Conclusion

Clinical pathway-oriented airway management significantly improves airway management quality, reduces complications, and increases decannulation rate in patients with severe craniocerebral injury after tracheotomy, with strong clinical operability. Variations may affect implementation; future promotion should focus on reducing negative variations.

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Disclosure statement

The authors declare no conflict of interest.

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