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Original Article

Continuous humidification enhances postoperative recovery in laryngeal cancer patients undergoing tracheotomy

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Abstract: Objective: To investigate the effects of perioperative continuous humidification on patients with laryngeal cancer undergoing tracheotomy. Methods: Eighty patients with laryngeal cancer underwent tracheotomy in our hospital were selected as the subjects and divided into the observation group and the control group according to random table method. Patients in the control group were given routine tracheotomy care, including regular open endotracheal suction, tracheotomy nursing, oral care, dietary intervention, etc., while those in the observation group were given continuous airway humidification on the basis of the control group. The differences in sputum pH, viscosity, comfort, cough frequency, and respiratory ventilation were compared between the two groups at three postoperative time points. The incidence of complications such as pulmonary infection, bloody sputum and sputum crust, and the improvement of clinical symptoms were compared between the two groups. Results: The sputum pH of patients in the observation group was higher than that in the control group at the 4th and 7th postoperative days (P<0.001). The observation group showed significantly lower percentage of grade 3 viscous sputum and higher comfort scores than the control group at the 7th postoperative day (P=0.020, P<0.001). The observation group showed lower cough frequency and higher airway patency than the control group at the 4th and 7th postoperative days (P<0.001, P<0.001, P<0.001, P=0.007). Conclusion: Perioperative continuous airway humidification in patients with laryngeal cancer undergoing tracheotomy could reduce sputum consistency and cough frequency, improve comfort and respiratory patency of patients, and has positive significance in accelerating their postoperative rehabilitation.

Keywords: Laryngeal cancer, tracheotomy, perioperative care, continuous airway humidification, feasibility analysis

Introduction

Laryngeal cancer is a common malignant tumor. Its incidence accounts for about 1-2% of systemic tumors and 10-12% of otorhinolaryngological malignancies in China, which is second only to nasopharyngeal cancer and nasal cavity cancer, and the prevalence of laryngeal cancer varies across different regions, with a slightly higher incidence in the north of China than in the south [1, 2]. An epidemiological survey of 1234 patients with laryngeal cancer in 12 tertiary hospitals in Shaanxi Province in 2015 showed that the prevalence of laryngeal cancer in China was increasing year by year, especially among young population [3]. The etiology of laryngeal cancer remains unknown, but it is closely related to smoking, alcohol consumption, air pollution, and viral infection. Laryngectomy is still the main treatment option for laryngeal cancer [4].

Regardless of total or partial laryngectomy, the tracheostomy is required after surgery, which damages the protective natural barrier of respiratory tract, and cannot warm, humidify and filter the inhaled air when breathing. Studies have shown that the upper respiratory tract has strong non-specific defense function. On the one hand, respiratory secretions can be expelled with the movement of cilia, such as harmful substances in the air, dust, *etc*., reduc-

ing the risk of lung infection, and on the other hand, the upper airway mucosa can also warm and humidify the inhaled air, reducing the stimulation intensity of external factors to respiratory tract [5]. However, the upper airway care is neglected in tracheostomy patients, increasing the incidence of complications. A retrospective analysis of 98 patients undergoing tracheostomy showed that 28.57% of patients had complications such as pulmonary infection and cough, which delayed the recovery [6]. Airway humidification is a method of artificially warming and humidifying respiratory gas for patients undergoing mechanical ventilation by manually dispersing the humidified solution and mixing it into the inhaled gas, which can significantly improve sputum consistency in patients with tracheotomy and also has positive implications to reduce the rate of pulmonary infection [7]. A controlled study of 77 patients with tracheotomy showed that airway humidification reduced the rate of pulmonary infection from 25.00% to 13.51%, with a significant before-and-after difference [8]. Although existing studies have confirmed the effectiveness of airway humidification intervention in patients undergoing tracheotomy for laryngeal cancer, there is still a lack of clinical studies on sputum pH value, sputum viscosity, postoperative comfort, cough frequency and other aspects after continuous airway humidification in patients with laryngeal cancer undergoing tracheotomy, which is difficult to provide more detailed theoretical guidance for the clinical intervention in such patients. The aim of this study was to investigate the effect of continuous airway humidification on patients with laryngeal cancer undergoing tracheotomy as well as the effect of airway humidification on the incidence of complications, to provide a theoretical basis for improving the prognosis of tracheotomized patients.

Materials and methods

Baseline data

Eighty patients with laryngeal cancer who underwent tracheotomy in our hospital from January 2018 to January 2020 were divided into the observation group (n=40, receiving continuous humidification) and the control group (n=40, receiving routine tracheotomy care) according to random table method. In this study, the sample size was determined by referring to the number of patients who met the inclusion and exclusion criteria during the study period, as well as the research of Noordzij et al. [9] on sample size determination.

Inclusion criteria: (1) patients who were confirmed of the diagnosis of laryngeal cancer by pathological examination and were treated with tracheotomy; (2) patients with age ≥18 years; (3) patients with a duration of tracheal intubation ≥5 days; (4) patients with clear consciousness and good compliance.

Exclusion criteria: (1) those who were comorbid with combined psychiatric disorders; (2) those who were comorbid with combined severe pulmonary, respiratory, or cardiac disorders; (3) those who were comorbid with repeated vomiting resulting in fluid loss; (4) those with incisional infections; (5) those who were comorbid with coagulation dysfunction; (6) those who were comorbid with systemic infections; (7) those who were comorbid with abnormal upper airway anatomy; (8) those who received a second surgery for laryngeal cancer.

Elimination criteria: (1) those who voluntarily requested to withdraw during the study; (2) those who died during the study; (3) those whose condition became critical during the study, and tracheotomy was terminated.

The research was approved by the Ethics Committee of Ganzhou People's Hospital (approval number 2018NCT09), and the patients or their families signed a written informed consent before joining the investigation.

Intervention methods

After the clinical diagnosis was confirmed, allopathic treatment, anti-infection, fluid management, and nutritional support were adopted. In the control group, patients underwent tracheotomy without continuous airway humidification, and only received routine nursing measures, including raising the head of the bed, maintaining room temperature and humidity, regular open endotracheal suction, monitoring blood oxygen saturation, tracheotomy nursing, oral care, dietary intervention, *etc*. Patients in the study group were additionally given continuous airway humidification as follows. Venturi heated humidifier system (Model PB840, Tyco International Ltd.) was used for continuous air-

way humidification in patients of the study group, including a humidifier, an air-oxygen blender, a respiratory circuit, *etc*. The tank was first installed on the matching humidifier before intervention, and after accessing sterile distilled water, the humidified gas was mixed with oxygen at an oxygen flow rate of 6 L/min [10]. The humidification was administrated continuously for 7 days. The nursing measures were the same as those in the control group.

Outcome measurement

(1) The sputum pH at the 1st, 4th, and 7th postoperative days was measured using a portable pH detector (Shanghai Yidian Scientific Instruments Co., Ltd.). Three consecutive values were averaged as the final result. (2) Sputum viscosity at the 1st, 4th and 7th postoperative days was measured, which was the main outcome measurement. The sputum viscosity was graded according to the American AAR 2010 guidelines [11]. Grade I: sputum is rice-soup-like or foamy, and no sputum is retained at the junction of glass after aspiration; Grade II: a small amount of sputum is retained at the junction of glass after aspiration, but it is easily washed away with water. Grade III: sputum is viscous and yellow, and a large amount of sputum is retained at the junction of glass, and it is not easily rinsed away. (3) The level of comfort at the 1st, 4th, and 7th postoperative days was measured by an in-hospital homemade scale ranging 0-10, with 0 being the best and 10 being the most severe. (4) The respiratory patency, cough frequency and respiratory patency at the 1st, 4th, and 7th postoperative days were compared using a visual analog scale ranging 0-10, with 0 being the best and 10 being the most severe. (5) Postoperative pulmonary infection, bloody sputum and sputum crust, and pulmonary infection were evaluated according to Diagnostic Criteria for Hospital Infection [12]. Bloody sputum was determined as the presence of bright red or dark red bloody secretions in the sputum visible to the naked eye, and sputum crust was determined as the presence of granular or lumpy dry sputum visible to the naked eye.

Statistical methods

SPSS 20.0 was adopted for statistical analysis. The measurement data were expressed as mean ± standard deviation ($\overline{x}$±sd), and the difference in sputum pH and level of comfort after surgery between the two groups were compared using Student's t-test. The counting data, including the incidence rate of pulmonary infection and sputum scabs, were expressed as [n (%)], and the differences between groups were compared using the chi-square test. Repeated measures ANOVA followed by post hoc Bonferroni test was used for comparison among multiple groups. Figures were plotted using Graphpad Prism 8.0. $P<0.05$ indicated that the difference was statistically significant [13].

Results

Comparison of baseline data

Patients were screened strictly according to the inclusion and exclusion criteria, and there was no significant difference in gender, age, smoking, time since quitting smoke, and body mass index (BMI) (all $P>0.05$) (**Table 1**).

Comparison of postoperative sputum pH

The difference in sputum pH between the two groups was not statistically significant ($P>0.05$) at the 1st postoperative day. The sputum pH of patients in the observation group was significantly higher than that in the control group at the 4th and 7th postoperative days ($P<0.001$, $P<0.001$, **Figure 1**).

Comparison of postoperative sputum viscosity

The difference in sputum viscosity between the two groups was not significant ($P>0.05$) at the 1st postoperative day, and the percentage of Grade III sputum viscosity in the observation group was significantly lower than that in the control group at the 4th and 7th postoperative days ($P=0.020$) (**Table 2**).

Comparison of the complication rate

The two groups did not differ in terms of complications including pulmonary infection, bloody sputum and sputum crust at the 1st, 4th, and 7th postoperative days (all $P>0.05$) (**Table 3**).

Comparison of postoperative comfort

The difference in comfort scores between the two groups at the 1st and 4th days of intervention was not significant (all $P>0.05$). The level of

Table 1. Comparison of baseline data ($\bar{x}\pm sd$)/[n (%)]

Baseline data		Observation group (n=40)	Control group (n=40)	t/χ^2	*P*
Gender	Male	26	23	0.474	0.491
	Female	14	17		
Mean age (years)		50.19±2.32	49.89±2.66	0.538	0.592
Average weight (kg)		65.19±3.42	65.32±2.98	0.181	0.857
Average BMI (kg/m^2)		23.29±2.32	23.19±2.44	0.188	0.851
Daily smoking	<20 pcs	12	11	0.061	0.805
	≥.8 pcs	28	29		
Time since quitting smoke	<1 month	30	32	0.287	0.592
	≥. month	10	8		
Hypertension	Yes	6	5	0.105	0.745
	No	34	35		
Diabetes	Yes	2	3	0.213	0.644
	No	38	37		
Current staging	I-II	14	15	0.054	0.816
	III-IV	26	25		

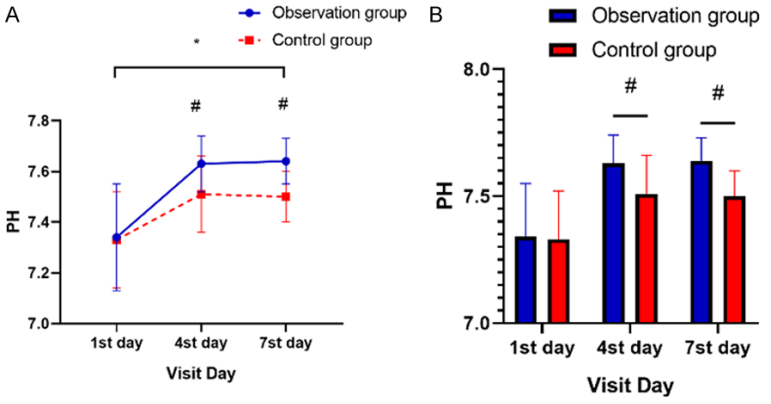

Figure 1. Comparison of postoperative sputum pH. The sputum pH of patients in the observation group was significantly higher than that in the control group at the 4th and 7th postoperative days ($P<0.05$). #indicated that compared with the control group, $P<0.05$; *indicated that compared with the same index within the same group before and after treatment, $P<0.05$.

comfort was decreased significantly in both groups compared with those before treatment, and the comfort score at the 7th day of intervention was significantly lower than that at the 1st day of intervention ($P<0.001$), while the comfort score of the observation group was higher than that of the control group at the 7th day of intervention ($P<0.001$) (**Figure 2**).

Comparison of postoperative cough frequency

The difference in cough frequency between the two groups was not statistically significant at the 1st postoperative day ($P>0.05$). The cough frequency in the observation group was significantly lower than that in the control group at the 4th and 7th postoperative days ($P<0.001$) (**Figure 3**).

Comparison of postoperative respiratory patency

The difference in respiratory patency between the two groups was not statistically significant at the 1st postoperative day ($P>0.05$). The respiratory patency of the observation group was significantly higher than that in the control group at the 4th and 7th postoperative days ($P<0.001$, $P=0.007$) (**Figure 4**).

Discussion

Laryngeal cancer is a kind of throat cancer and one of the most common forms of head and neck cancer, which mainly affects patients aged 50-70 years old in China, with a higher incidence in males than in females, and a high incidence in northeastern and northern China [14]. In recent years, with the aging of the population and the aggravation of environmental

Table 2. Comparison of postoperative sputum viscosity

Group	n	1st postoperative day			4th postoperative day			7th postoperative day		
		I	II	III	I	II	III	I	II	III
Observation group	40	20	20	0	33	6	1	28	10	2
Control group	40	21	19	0	24	10	6	17	14	9
χ^2	-		0.677			5.992			7.810	
P	-		0.982			0.049			0.020	

Table 3. Comparison of complication

Group	n	1st postoperative day			4th postoperative day			7th postoperative day		
		Pulmonary infection	Bloody sputum	Sputum crust	Pulmonary infection	Bloody sputum	Sputum crust	Pulmonary infection	Bloody sputum	Sputum crust
Observation group	40	1	0	0	1	0	0	1	0	0
Control group	40	2	0	0	3	1	0	4	0	1
χ^2	-		0.197			0.211			0.209	
P	-		0.889			0.832			0.843	

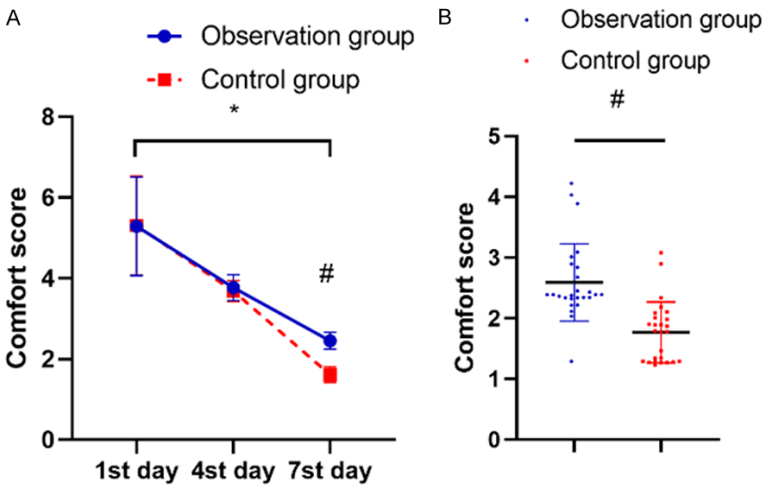

Figure 2. Comparison of postoperative comfort. The difference between the two groups in comfort scores was not statistically significant at the 1st and 4th postoperative days (A). At the 7th postoperative day, the comfort score of patients in the observation group was significantly higher than that in the control group (B). #indicated that compared with the control group, $P<0.05$; *indicated that compared with the same index within the same group before and after treatment, $P<0.05$.

pollution, the prevalence rate of laryngeal cancer patients has been increasing year by year. The majority of patients with laryngeal cancer are adult males, with the onset age of more than 40 years old, and the occurrence mostly concentrated in heavy industrial cities. The etiology of laryngeal cancer is still unclear, and it is still recommended to carry out comprehensive intervention measures, mainly surgical treatment, supplemented by radiotherapy and chemotherapy, for patients with laryngeal cancer, among which the surgical treatment is mainly laryngectomy and preventive tracheotomy. The overall 5-year survival rate of patients with laryngeal cancer after laryngectomy is about >60% [15]. It is found that laryngectomy can not only destroy the normal physiological and anatomical structure of the larynx, weaken the function of the respiratory tract, but also destroy the normal humidification, warming and filtration of the respiratory tract. The loss of natural barriers of the upper airway results in dry air entering the lower airway without oral and nasal humidification and filtration, which leads to the retention of dried secretions and increased incidence of complications such as airway obstruction and pulmonary atelectasis [16]. Airway humidification has been reported to have a significant impact on the prognosis of patients with laryngeal cancer, and effective airway humidification has always been the main direction of research [17].

In this study, different subgroups were established to investigate the effect of continuous airway humidification on the outcome of pa-

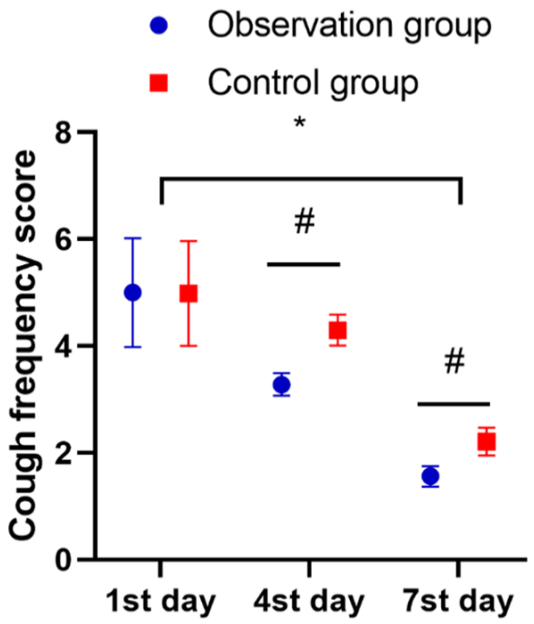

Figure 3. Comparison of postoperative cough frequency. The difference in cough frequency scores between the two groups was not significant at the 1st postoperative day ($P>0.05$), and cough frequency of patients in the observation group was significantly lower than that of patients in the control group at the 4th and 7th postoperative days ($P<0.05$). #indicated that compared with the control group, $P<0.05$; *indicated that compared with the same index within the same group before and after treatment, $P<0.05$.

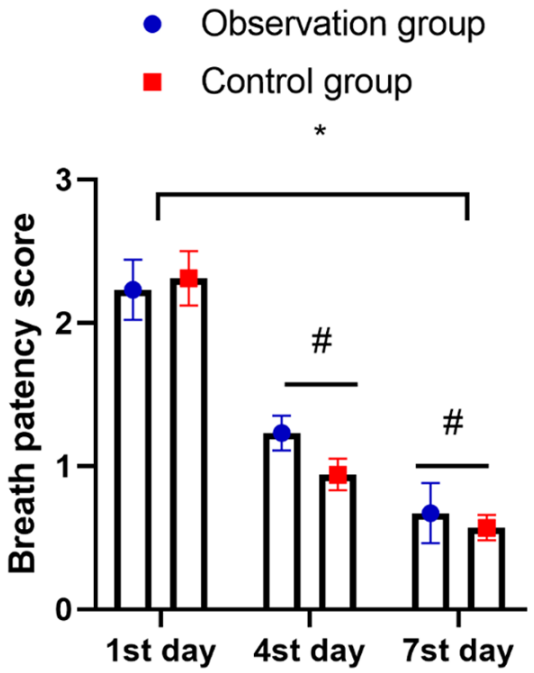

Figure 4. Comparison of postoperative respiratory patency between the two groups. The difference between the two groups in respiratory patency scores was not statistically significant at the 1st postoperative day, and the respiratory patency scores of patients in the observation group were significantly higher than those in control group at the 4th and 7th postoperative days ($P<0.05$). #indicated that compared with the control group, $P<0.05$; *indicated that compared with the same index within the same group before and after treatment, $P<0.05$.

tients with laryngeal cancer undergoing tracheotomy, and the results showed that patients in the observation group who underwent continuous airway humidification had significantly higher pH at the 4th and 7th postoperative days compared to patients in the control group who did not receive continuous airway humidification. It has been found that sputum is composed of water, acidic glycoproteins, bacteria, foreign bodies, *etc*., and acidic glycoproteins are three-dimensional gel networks formed by the interaction of hydrogen bonds, disulfide bonds, *etc*., thus the pH will affect the viscosity of sputum to some extent [18]. A study of postoperative nursing for patients with laryngeal cancer has confirmed that these patients are more prone to sputum callus and phlegm due to the lack of respiratory tract moisture, and patients tend to have acid sputum, which can significantly increase the viscosity of sputum, while proper airway wetting can significantly reduce the viscosity of sputum, accelerate the discharge of sputum, and reduce the incidence of events such as pulmonary infection, which is consistent with the results of this study [19]. The findings of this study suggested that the sputum pH was higher in the observation group after receiving the continuous airway humidification than in the control group, which echoed the result that the sputum viscosity was lower in the observation group than in the control group at the 4th and 7th postoperative days. In this study, the authors found that the pH value of normal human airway mucosa was acidic, with an average pH value of 6.2-7.4, and the respiratory tract of patients underwent tracheotomy was in a highly secretory state, resulting in an acidic state, and the higher the pH, the less consistency the sputum [20]. In this study, the sputum pH of the observation group was higher than that of the control group, indicating that continuous airway humidification could improve the sputum consistency in patients with laryngeal cancer after tracheotomy, which has positive significance for their prognosis.

It was also found that continuous airway humidification could improve comfort of patients, reduce their cough frequency, and improve their ventilation. A study focused on patients with non-mechanical ventilation showed that continuous airway humidification via a micropump could reduce the rate of pulmonary infections from 12.28% on the 3rd day of intervention to 8.17% on the 5th day of intervention, and the incidence of sputum crust from 20.00% to 10.00%, with a significant decrease after intervention [21]. The reason may be that the airway muscles of patients undergoing tracheotomy are often in a state of tense, and choking is easy to occur under air stimulation, which to a certain extent affects the experience of patients and reduces the subjective comfort of patients. Airway humidification is helpful to improve the inflammatory response of the body and inhibit histamine-induced smooth muscle contraction, thus ensuring respiratory patency [22, 23]. At the same time, airway humidification also has the function of lubricating the airway and accelerating cilia movement, which can improve the patient's choking sensation by accelerating sputum discharge, ultimately affecting the subjective experience of patient [24].

This study compared the effects of continuous airway humidification on the clinical nursing effect of patients with laryngeal cancer undergoing tracheotomy, providing a reference for further improving the clinical nursing of patients with tracheotomy, which has certain innovation. The limitation of this study is the small sample size, which may lead to the lack of comprehensiveness of the results. It is planned to carry out a large sample and multicenter study in the next step. The inner limitation of this study is that the study design only focused on the objective indicators of patients (such as sputum pH, sputum viscosity, *etc*.), ignoring the postoperative experience of patients, and the observation indicators are relatively weak (only comfort). In the next step, it is planned to demonstrate in more detail the influence of airway humidification on patients' own experience. Finally, the research site of this study was limited to ICU environment, which lacks guiding significance for treatment in general wards. If conditions permit, it is planned to carry out airway humidification intervention for patients with tracheotomy in general wards in the next step, so as to lay a better foundation for the promotion of airway humidification in clinical practice.

In conclusion, continuous airway humidification in patients with laryngeal cancer undergoing tracheotomy during the perioperative period can reduce sputum consistency and cough frequency, improve patient comfort and respiratory patency, and has positive significance for accelerating postoperative rehabilitation of patients.

Disclosure of conflict of interest

None.

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