

Original Article

Exploring the effects of continuous airway humidification on nursing care and complications in patients with tracheotomy

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Abstract: Objective: To explore the clinical effects of continuous airway humidification in patients with tracheotomy. Methods: A total of 80 patients who underwent tracheotomy in our hospital were enrolled and divided into the study group (n=40, received continuous airway humidification and conventional nursing measures) and the control group (n=40, received conventional nursing measures). The temperature and humidity of inhaled gas, sputum viscosity, respiratory function-related indicators, patients' comfort, and the incidence of complications were compared. Results: The humidity of the inhaled gas in the study group on the 1st to 7th day of intervention was significantly higher than that in the control group ($P < 0.05$). On the 5th day and the 7th day of intervention, the number of cases of sputum viscosity below degree III in the study group was higher than that in the control group ($P < 0.05$). On the 7th day of intervention, the study group had lower RR and higher PaO₂ and patient comfort than the control group ($P < 0.05$). The incidence of complications in the study group was lower than that in the control group ($P < 0.05$). The average daily number of sputum suction, ICU indwelling time, tracheal extubation time and duration of tracheotomy in the study group were all significantly lower than those in the control group ($P < 0.05$). Conclusion: Continuous airway humidification for patients with tracheotomy helps reduce sputum viscosity and improve respiratory function and patients' comfort. It also helps reduce the incidence of complications and improves prognosis, indicating that continuous airway humidification is worthy of clinical application.

Keywords: Continuous airway humidification, tracheotomy, nursing effect, complications

Introduction

Tracheotomy refers to an incision of the jugular trachea and inserting a metal or silicone tracheal tube to relieve symptoms such as laryngeal dyspnea, respiratory dysfunction, and retained secretions of lower respiratory tract. Tracheotomy is currently a common clinical assistance for critically ill patients. It is of great significance in saving the lives of critically ill patients. It is also a preoperative intervention of surgery for respiratory obstruction such as laryngeal cancer [1].

Tracheotomy is a traumatic operation to the body. Incision of the trachea and insertion of a tracheal tube will inevitably cause obvious irritation and damage to the airway mucosa and surrounding tissues. Under normal conditions,

the upper respiratory tract can warm, humidify, clean and filter the inhaled air. Studies have shown that the upper respiratory tract has a strong non-specific defensive function. On the one hand, the airway mucosa will expel respiratory secretions, harmful substances in the air, and dust, etc., by the normal movement of cilia to reduce the risk of pulmonary infection. On the other hand, the mucosa of the upper respiratory tract can also warm and humidify the inhaled air, reducing the stimulating intensity of environmental air to the respiratory tract [2, 3]. However, for patients with tracheotomy, because the air will directly enter the trachea, the function of upper respiratory tract is weakened, which will lead to a significant increase in various complications. A review of 98 patients with tracheotomy showed that 28.57% of these patients had complications such as pulmonary

infection and cough, which delayed the recovery process to a certain extent. Airway humidification refers to a measure of artificially filling a humidified fluid into the inhaled gas, so as to supply a certain amount of humidity to the gas of the respiratory tract and lungs of patients with tracheotomy. This measure has been proven to significantly alleviate the sputum viscosity of patients with tracheotomy and have a positive effect on reducing the rate of pulmonary infection [4, 5]. A study of 77 patients undergoing tracheotomy showed that the rate of pulmonary infection was significantly reduced from 25.00% to 13.51% by using airway humidification [6]. Other research has pointed out that it was extremely necessary to carry out airway humidification for patients undergoing tracheotomy after craniocerebral injury. Due to the long duration of mechanical ventilation in such patients, the use of non-humidified gas may cause airway obstruction and endanger the patient's life and health [7]. This study aims to explore the feasibility and necessity of continuous airway humidification for patients with tracheotomy, and analyse the effect of airway humidification on the incidence of complications in patients with tracheotomy, in order to provide a theoretical basis for improving the prognosis of patients with tracheotomy.

Material and methods

General information

A total of 80 patients who received tracheotomy in our hospital from March 2018 to March 2020 were enrolled and divided into the study group (n=40) and the control group (n=40) according to the difference in intervention measures.

Inclusion criteria: (1) Patients undergoing tracheotomy; (2) ≥ 18 years old; (3) Treatment of 5 days or longer of tracheal intubation; (4) Clear consciousness, able to express subjective thoughts and cooperate with treatment; (5) Approval by the Ethics Committee of Ganzhou People's Hospital; (6) Voluntary signing of informed consent by the patients or their family members.

Exclusion criteria are as below: (1) Combined with mental illness; (2) Combined with severe pulmonary, respiratory or cardiac disease; (3)

Combined with repeated vomiting resulting in fluid loss; (4) Combined with infection of incision; (5) Combined with coagulopathy; (6) Combined with systemic infection; (7) Positive results of sputum culture; (7) Voluntary withdrawal during the study; (8) Death during the study; (9) Patients who gave up tracheostomy during the study because of their critical condition.

Interventional methods

After the clinical diagnosis was confirmed, interventional measures such as etiological treatment, anti-infection treatment, fluid management and nutritional support were given in both groups. Patients in the control group did not receive continuous airway humidification after tracheotomy, and only had conventional nursing measures, including properly raising of the head of the bed, appropriate maintenance of indoor temperature and humidity, regular open suctioning, close attention to blood oxygen saturation, nursing of the tracheal incision, oral care, dietary intervention, etc. The patients in the study group received continuous airway humidification in addition to the conventional nursing measures. The specific measures were as follows. A Venturi humidification system was used to carry out continuous airway humidification for the patients in the study group, which included a heating humidifier, a Venturi air-oxygen mixing valve, and a heated breathing circuit.

Before intervention, the humidification tank was first installed on the matching humidifier. After sterile distilled water was injected, the humidified gas was mixed with oxygen. The oxygen flow rate was set at 6 L/min and the humidifier temperature was set at 39°C for 7 days of continuous application. The other nursing measures given were the same as the control group.

Outcome measurement and evaluation standards

Comparison of differences in temperature and humidity of inhaled gas at different time points: The temperature and humidity of the inhaled gas of the two groups of patients were measured at 4 different time points on the 1st, 3rd, 5th and the 7th day of intervention by an AZ8708

measuring pen. The test was performed through the side hole of the mask. Each patient was measured 3 times in a row and the average value of temperature and the absolute humidity were taken as the final results.

Comparison of sputum viscosity at different time points: The sputum viscosity was compared at 4 different time points on the 1st, 3rd, 5th and 7th day of intervention. The grading standard of sputum viscosity refers to the American AAR2010 guidelines. Grade I means that the sputum is like rice-water or foam, and sputum will not be retained at the glass joint after suction. Grade II means that a small amount of sputum will be retained at the glass joint after suction, which is easy to be rinsed off. Grade III means that the sputum is obviously thick and yellow, and a large amount of sputum will be retained at the glass joint, which is not easily rinsed off [8].

Comparison of the indicators of respiratory function before and after intervention between the two groups: Monitors and blood gas analyzer were used to monitor the related indicators of respiratory function, which mainly included SpO₂, PaCO₂, and RR. Twenty-four hours of observation time was selected before intervention, and on the 7th day of intervention. The average value was taken as the final result. Normal SpO₂ is between 95% and 100%. The normal PaCO₂ is between 35 mmHg and 45 mmHg, and the normal RR is between 16 times/min and 20 times/min [9].

Dynamic analysis of patients' comfort during intervention: A scale for assessing comfort made by our hospital was used to evaluate the patients' comfort at different time points during intervention, which included five items such as respiratory patency, frequency of cough, and degree of pain, with a maximum score of 10 points. The higher the score was, the better the comforts.

Comparison of the incidence of complications during intervention: The incidence rates of various complications of tracheotomy such as airway bleeding, pulmonary infection, respiratory obstruction, and irritating cough, in the two groups during 7 days of intervention were counted. The evaluation standard for airway bleeding is the occurrence of blood streaks or bloody sputum during suction. The standards for pulmonary infection refer to the "Diagnos-

tic Standards for Hospital Infections" [10]. Relevant clinical symptoms include cough, purulent sputum or sticky sputum, moist rales, body temperature exceeding 37°C, and abnormal increase of white blood cells after 48 hours of hospitalization. The evaluation standard for the formation of sputum callus is that the sputum callus is visible during suction or it can be found during fiberoptic bronchoscopy. The evaluation standard for irritating cough is that the patient has a continuous cough or buckling (Note that coughing during sputum suction is a normal stress response and is not counted).

Comparison of improvement of clinical symptoms between the two groups: The average daily number of sputum suctioning during 7 days of intervention, ICU indwelling time, tracheal extubation time and duration of tracheotomy in the two groups were counted, and the differences between the two groups were compared.

Statistical analysis

SPSS 22.0 statistical software was used to process the data. The measurement data were expressed as ($\bar{x} \pm SD$). The difference between groups was compared by the student's t test. The count data were expressed as n (%). Chi-square test was used to compare count data between groups. Student's t test was also used to compare the difference of continuous variables before and after the intervention, and Graphpad Prism 8.0 was used to plot the experimental results. $P < 0.05$ was considered statistically significant [11].

Results

Comparison of difference in general information between the two groups

There was little difference in general information such as gender, average age, average weight, average BMI, educational level, family monthly income, etc. between two groups ($P > 0.05$) (**Table 1**).

Comparison of differences in temperature and humidity of inhaled gas at different time points between the two groups

After comparison, it was found that at all four time points on the 1st day, 3rd day, 5th day and 7th day of intervention, there was no significant

Table 1. Comparison of difference in general information between the two groups ($\bar{x} \pm s$)/[n (%)]

General information		Study group (n = 40)	Control Group (n=40)	t/X ²	P
Gender	Male	26	23	0.474	0.491
	Female	14	17		
Average age (year)		50.19 \pm 2.32	49.89 \pm 2.66	0.538	0.592
Average weight (kg)		65.19 \pm 3.42	65.32 \pm 2.98	0.181	0.857
Average BMI (kg/m ²)		23.29 \pm 2.32	23.19 \pm 2.44	0.188	0.851
Educational level	College degree or above	11	14	0.343	0.778
	Senior high school	20	18		
	Junior high school or below	9	8		
Family monthly income (yuan)	< 1000	5	6	0.781	0.511
	1000-5000	26	23		
	> 5000	9	11		

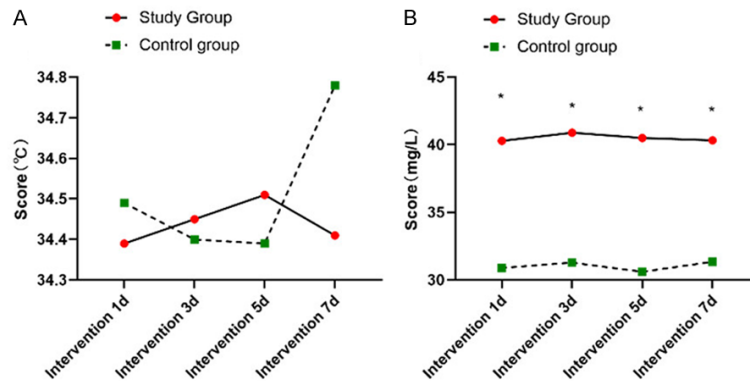


Figure 1. Comparison of difference in temperature and humidity of inhaled gas at different time points between the two groups. The difference in the temperature of inhaled gas between the two groups at four time points of the 1st day, the 3rd day, the 5th day and the 7th day after intervention was not statistically significant ($P > 0.05$) (A). The humidity of inhaled gas of the patients in the study group at 4 time points was significantly higher than that in the control group ($P < 0.05$) (B). * indicates that the difference between the two groups is statistically significant.

difference in the temperature of inhaled gas, showing no statistically significant difference in temperature of inhaled gas between the two groups ($P > 0.05$). The humidity of inhaled gas of the patients in the study group at 4 time points was significantly higher than that in the control group ($P < 0.05$) (**Figure 1**).

Comparison of sputum viscosity between the two groups at different time points after intervention

There was little difference in sputum viscosity between the two groups before intervention ($P > 0.05$). On the 1st day of intervention, there were 9 patients with viscosity III in the study

group and 8 patients with viscosity III in the control group. On the 3rd day, there were 6 cases and 7 cases, respectively. On the 5th day, there were 2 cases and 7 cases, respectively. On the 7th day, there were 0 case and 8 cases, respectively. The difference of sputum viscosity in grade III on the 5th day and the 7th day of intervention between the two groups was statistically significant, and the number of cases of sputum viscosity below degree III in the study group was higher than that in the control group, while the number of cases of sputum viscosity above degree III in the study group was lower than

that in the control group ($P < 0.05$) (**Figure 2**).

Comparison of the indicators of respiratory function before and after intervention between the two groups

There was little difference in RR, SpO₂ and PaCO₂ between the two groups before intervention ($P > 0.05$). On the 7th day of intervention, RR in the study group was lower than that in the control group, and SpO₂ was higher than that in the control group ($P < 0.05$). There was no significant difference in PaCO₂ between the two groups before and after intervention ($P > 0.05$). Intra-group comparison showed that after RR

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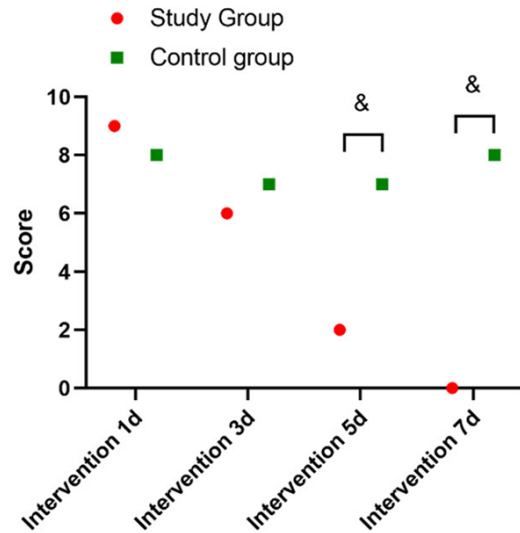


Figure 2. Comparison of sputum viscosity between the two groups at different time points after intervention. On the 1st day of intervention, there were 9 patients with viscosity III in the study group and 8 patients with viscosity III in the control group. On the 3rd day, there were 6 cases and 7 cases, respectively. On the 5th day, there were 2 cases and 7 cases, respectively. On the 7th day, there were 0 case and 8 cases. The difference of sputum viscosity in grade III on the 5th day and the 7th day of intervention between the groups was statistically significant ($P < 0.05$). & indicates that the difference between the two groups is statistically significant.

of the two groups decreased after intervention, SpO_2 increased after intervention compared with before intervention, and there was little change in $PaCO_2$ before and after intervention (Figure 3).

Dynamic analysis of patients' comfort during intervention

The dynamic analysis showed that the scores of patients' comfort in the two groups were not significantly different on the 1st day and the 3rd day of intervention ($P > 0.05$). Over time, the scores of patients' comfort in both groups were significantly lower than those before intervention. The scores on the 5th day and the 7th day of intervention were significantly lower than those on the 1st day of intervention ($P < 0.05$), and the scores of patients' comfort in the study group were higher than those in the control group on the 5th day and the 7th day of intervention ($P < 0.05$) (Figure 4).

Comparison of the incidence of complications during intervention

The incidence rates of various complications such as airway bleeding, pulmonary infection, formation of sputum callus, irritating cough, were counted during the 7 days of intervention. In the study group, there was 1 case of airway bleeding and 1 case of irritating cough, with the total incidence of complications of 5.00%. In the control group, there was 3 cases of airway bleeding, 1 case of pulmonary infection, 1 case of formation of sputum callus and 3 cases of irritating cough, with the total incidence of complications of 20.00%, showing significant difference between the two groups ($P < 0.05$) (Table 2).

Comparison of improvement of clinical symptoms between the two groups

The average daily number of sputum suctioning during the 7 days of intervention, ICU indwelling time, tracheal extubation time and duration of tracheotomy in the study group were significantly lower than those in the control group ($P < 0.05$) (Figure 5).

Discussion

Tracheotomy is one of the effective surgical procedures to relieve respiratory obstruction that is used in clinical practice, and it is also a common means to save the lives of patients with acute and severe diseases. In normal physiological conditions, air will enter the nose and mouth and then enter the airway after being wetted and warmed by the upper respiratory tract. In the state of a tracheotomy, the inhaled gas bypasses the upper respiratory tract and directly enters the midtrachea [12]. Studies have pointed out that the daily water loss of the airway is about 200 ml during normal breathing, while the daily water loss during tracheotomy is as high as 800 ml. Due to excessive dryness of the inhaled air and large amounts of water taken away by exhaled air, most patients will experience dry mucosa and thick secretions, resulting in many complications such as poor sputum excretion, atelectasis, and pulmonary infection. Some patients may even experience secondary brain damage due to hypoxia, affecting their prognosis [13, 14]. In addition, a tracheotomy is an invasive

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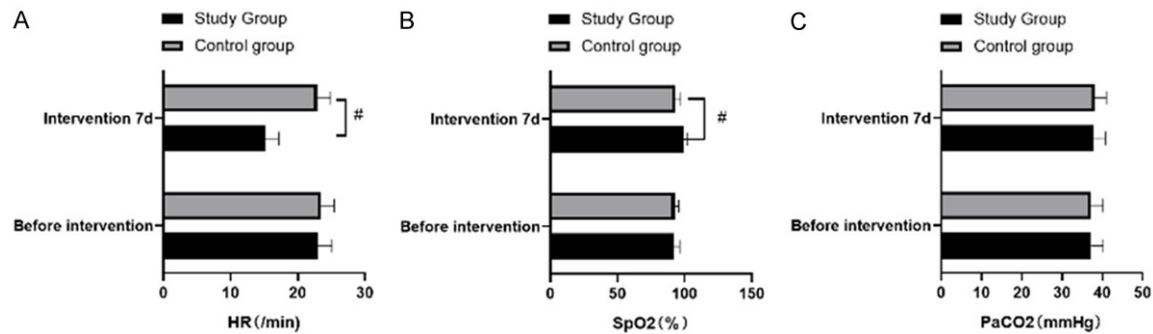


Figure 3. Comparison of the indicators of respiratory function before and after intervention between the two groups. There was little difference in RR between the two groups before intervention ($P > 0.05$). On the 7th day of intervention, RR in the study group was lower than that in the control group ($P < 0.05$) (A). There was little difference in SpO₂ between the two groups before intervention ($P > 0.05$). On the 7th day of intervention, SpO₂ in the study group was significantly higher than that in the control group ($P < 0.05$) (B). There was no statistical difference in PaCO₂ between the two groups before and after intervention ($P > 0.05$) (C). # indicates that the difference between the two groups is statistically significant.

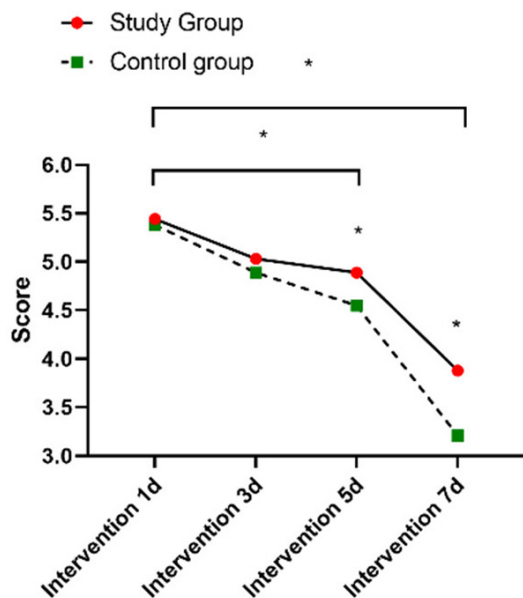


Figure 4. Dynamic analysis of patients' comfort during intervention. The scores of patients' comfort in the two groups were not significantly different on the 1st day and the 3rd day of intervention ($P > 0.05$). The scores on the 5th day and the 7th day of intervention were significantly lower than those on the 1st day of intervention ($P < 0.05$), and the scores of patients' comfort in the study group were higher than those in the control group on the 5th day and the 7th day of intervention ($P < 0.05$). # indicates that the difference between the two groups is statistically significant.

operation, and the inserted tracheal tube and other instruments will cause obvious irritation and damage to the airway mucosa, destroy the integrity of the mucosal structure, and lead to morphological changes of cilia and a decline in

function of ciliary movement and the ability of expectoration, resulting in a significant increase of the chance of pulmonary infection. Data shows that 84% of patients will suffer secondary infections of the lower respiratory tract 3-7 days after tracheotomy [15-17].

Most studies indicate that the main reason for the above phenomena is that the inhaled gas of patients with tracheotomy has not received sufficient humidification. Airway humidification refers to using instruments or an external device to adjust the humidity of the inhaled gas of the patients to be as close as possible to the physiological function of the upper respiratory tract, so as to reduce any related complications [18]. Studies have pointed out that when the inhaled gas by patients with tracheotomy is set at 37°C, relative humidity 100%, and absolute humidity 44 mg/L, the patients will have the lowest risk of various complications such as the formation of sputum callus and airway blockage. Some studies also suggested that an individual's age, living environment, BMI, vital capacity will have a certain impact on the effect of humidification, and a personalized plan for gas humidification should be formulated according to the actual situation of the patient [19, 20].

This study explored the effects of continuous airway humidification on the nursing and complications in patients with tracheotomy by setting up different groups. In terms of the temperature and humidity of inhaled gas, the results showed that the absolute humidity in the

Table 2. Comparison of the incidence of complications during intervention [n (%)]

Group	Case	Airway bleeding	Pulmonary infection	Formation of sputum callus	Irritating cough	Total incidence
Study group	40	1 (2.50)	0 (0.00)	0 (0.00)	1 (2.50)	2 (5.00)
Control group	40	3 (7.50)	1 (2.50)	1 (2.50)	3 (7.50)	8 (20.00)
χ^2	-	-	-	-	-	4.114
P	-	-	-	-	-	0.043

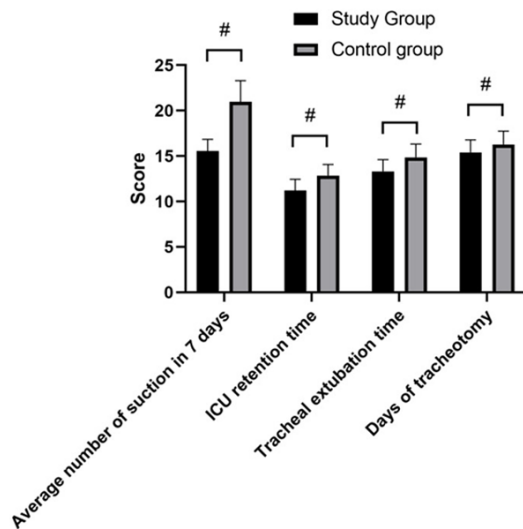


Figure 5. Comparison of improvement of clinical symptoms between the two groups. The average daily times of sputum suction during 7 days of intervention, ICU indwelling time, tracheal extubation time and duration of tracheotomy in the study group were significantly lower than those in the control group ($P < 0.05$). # indicates that the difference between the two groups is statistically significant.

study group was significantly higher than that in the control group. Further analysis showed that the sputum viscosity in the study group decreased significantly after receiving continuous airway humidification, indicating that the airway humidification can not only increase the humidity of the inhaled gas, but also dilute the sputum viscosity and help sputum discharge. A comparative survey of 100 patients with tracheotomy indicated that airway humidification can reduce the proportion of patients with viscosity III from 40% to 11%, which is similar to the results of this article [21]. We speculated that when dry outside air directly enters the airway, it will cause obvious irritation to patients with tracheotomy, as well as take away a lot of water during exhalation, resulting in the increase of sputum retention. Continuous airway humidification can keep the inhaled gas in

a high humidity state, and keep the tracheal cilia in an active state, so as to achieve the purpose of smooth drainage, that's why the sputum viscosity in the study group was significantly lower [22]. The comparative results of the respiratory function-related indicators showed that RR in the study group was lower than that in the control group after intervention, and SpO_2 was higher than that in the control group, indicating that continuous airway humidification can reduce the respiratory rate and improve the oxygenation. A survey of 34 patients with tracheotomy indicated that the PaO_2 of patients with tracheotomy would be significantly lower than normal, which also significantly led to higher respiratory depth and rate than normal [23]. The patients in the study group had a significant decrease in RR after intervention. Continuous airway humidification can promote sputum discharge and avoid blockage of upper respiratory tract, thus reducing airway resistance and increasing oxygenation diffusion. On the other hand, airway humidification will reduce the retention of carbon dioxide in the body through passive breathing, which will help oxygenation functions, as a result the SpO_2 in the study group was significantly higher [24].

The comparison of comfort and clinical symptoms between groups showed that continuous airway humidification was more helpful to improve the subjective experience and prognosis of patients with tracheotomy. The reason might be related to the fact that continuous airway humidification can promote the active discharge of sputum and improve the patient's prognosis, which will improve the comfort of the patient to a certain extent. Regarding the comparison of the incidence of complications between the two groups, there were 2 cases of complications in the study group and 8 cases in the control group within 7 days of intervention. The results of a survey conducted on patients with non-mechanical ventilation of tra-

cheal intubation showed that continuous airway humidification provided by micro-pumps can reduce the rate of pulmonary infection from 12.28% on the 3rd day of intervention to 8.17% on the 5th day of intervention, and the incidence of sputum callus was reduced from 20.00% to 10.00% [25]. Common complications in patients with tracheotomy are irritating cough, airway bleeding, and pulmonary infection, which are also the main factors affecting the prognosis of patients. Airway humidification helps discharge of sputum and bacteria in the airway, thereby reducing the possibility of microbial reproduction in the airway, resulting in lower risk of infection [26].

In summary, continuous airway humidification for patients with tracheotomy is worthy of clinical application. It can help reduce the viscosity of patients' sputum, improve their respiratory function and comfort, and help reduce the incidence of complications and improve prognosis. The innovation of this study was to compare the nursing effects of continuous airway humidification in patients with tracheotomy, which provides a reference for further improving the clinical nursing mechanism in patients with tracheotomy. The limitations of this study lie in two parts; that there is a limited number of study subjects, leading to a lack of comprehensive results, and the study was carried out only in the ICU, therefore other intervention studies in a general ward need to be further demonstrated.

Disclosure of conflict of interest

None.

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References

- [1] Ulkumen B, Eskiizmir G and Celik O. The safety of open surgical tracheotomy performed by otorhinolaryngology residents. *Pak J Med Sci* 2018; 34: 600-605.
- [2] Li H and Mao XH. Effects of nursing intervention on lung infection prevention in patients with tracheotomy. *Medicine (Baltimore)* 2019; 98: e17063.
- [3] Padia R, Miller C, Patak L, Friedman SD, Stone K, Otjen J and Johnson K. Simulation-guided tracheotomy in a patient with fibrodysplasia ossificans progressiva. *Laryngoscope* 2019; 129: 812-817.
- [4] Trouillet JL, Collange O, Belafia F, Blot F, Capellier G, Cesareo E, Constantin JM, Demoule A, Diehl JL, Guinot PG, Jegoux F, L'Her E, Luyt CE, Mahjoub Y, Mayaux J, Quintard H, Ravat F, Vergez S, Amour J and Guillot M. Tracheotomy in the intensive care unit: guidelines from a French expert panel. *Ann Intensive Care* 2018; 8: 37.
- [5] Clum S and Rumbak M. The quality of life after tracheotomy. *Minerva Anestesiol* 2018; 84: 1005-1006.
- [6] Russell CJ, Thurm C, Hall M, Simon TD, Neely MN and Berry JG. Risk factors for hospitalizations due to bacterial respiratory tract infections after tracheotomy. *Pediatr Pulmonol* 2018; 53: 349-357.
- [7] Plotnikow GA, Accoce M, Navarro E and Tiri-belli N. Humidification and heating of inhaled gas in patients with artificial airway. A narrative review. *Rev Bras Ter Intensiva* 2018; 30: 86-97.
- [8] Ferdyn-Grygierek J and Grygierek K. HVAC control methods for drastically improved hygrothermal museum microclimates in warm season. *Build Environ* 2018; 149.
- [9] Donahue S, DiBlasi RM and Thomas K. Humidification of blow-by oxygen during recovery of postoperative pediatric patients: one unit's journey. *J Perianesth Nurs* 2018; 33: 964-971.
- [10] White DE, Bartley J, Campbell AJ and Neill AM. Preliminary evaluation of second-generation n-CPAP machine pilot sleep study data. *Sleep* 2018; 41: A204-A204.
- [11] Minkyung K, Vichaya A, Drew W, Brendon C and Meghna M. 1105 ophthalmic conditions and sleep apnea-hypopnea syndrome: uncharted territory. *Sleep* 2018; A410-A411.
- [12] Li GP and Zhang LZ. Three-dimensional turbulent flow and conjugate heat and mass transfer in a cross-flow hollow fiber membrane bundle for seawater desalination. *International Journal of Heat & Mass Transfer* 2018; 120: 328-341.
- [13] Venugopalan TK, Wong CSY, Suresh S and Sundararajan N. Simultaneous optimization of airway and sector design for air traffic management. *Air Traffic Control Quarterly* 2018; 26: 8-22.
- [14] Dudaryk R, Horn DB and Green JM 3rd. Facial artery pseudoaneurysm: challenges of airway management. *Anesth Prog* 2018; 65: 52-55.
- [15] Abdulfattah O, Lixon A, Kandel S, Rahman EU, Roy S, Dahal S, Alnafoosi Z and Schmidt F. Rare case of *Mycobacterium nebraskense* pre-

- senting as asymptomatic cavitary lung lesion. *J Community Hosp Intern Med Perspect* 2018; 8: 32-34.
- [16] Wagener BM, Hu PJ, Oh JY, Evans CA, Richter JR, Honavar J, Brandon AP, Creighton J, Stephens SW, Morgan C, Dull RO, Marques MB, Kerby JD, Pittet JF and Patel RP. Role of heme in lung bacterial infection after trauma hemorrhage and stored red blood cell transfusion: a preclinical experimental study. *PLoS Med* 2018; 15: e1002522.
- [17] Wang H, Blackall M, Sominsky L, Spencer SJ, Vlahos R, Churchill M and Bozinovski S. Increased hypothalamic microglial activation after viral-induced pneumococcal lung infection is associated with excess serum amyloid A production. *J Neuroinflammation* 2018; 15: 200.
- [18] Cuenca A, Insinna C, Zhao H, John P, Weiss MA, Lu Q, Walia V, Specht S, Manivannan S, Stauffer J, Peden AA and Westlake CJ. The C7orf43/TRAPPC14 component links the TRAPPII complex to Rabin8 for preciliary vesicle tethering at the mother centriole during ciliogenesis. *J Biol Chem* 2019; 294: 15418-15434.
- [19] Gellerfors M, Fevang E, Bäckman A, Krüger A, Mikkelsen S, Nurmi J, Rognås L, Sandström E, Skallsjö G, Svensén C, Gryth D and Lossius HM. Pre-hospital advanced airway management by anaesthetist and nurse anaesthetist critical care teams: a prospective observational study of 2028 pre-hospital tracheal intubations. *Br J Anaesth* 2018; 120: 1103-1109.
- [20] Howard J, Slee AE, Skene S, Inusa B, Kawadler J, Downes M, Gavlak J, Koelbel M, Stotesbury H, Chorozoglou M, Tebbs S, Chakravorty S, Awogbade M, Rees DC, Gupta A, Murphy PB, Hart N, Sahota S, Nwosu C, Gwam M, Saunders D, Muthurangu V, Barber N, Ako E, Thein SL, Marshall M, Reading IC, Cheng MYE, Kirkham FJ and Liossi C. Overnight auto-adjusting continuous airway pressure + standard care compared with standard care alone in the prevention of morbidity in sickle cell disease phase II (POMS2b): study protocol for a randomised controlled trial. *Trials* 2018; 19: 55.
- [21] Shah RT, Makaryus MR, Kumar R, Singas E and Mayo PH. Simulation training for critical care airway management: assessing translation to clinical practice using a small video-recording device. *Chest* 2020; 158: 272-278.
- [22] Reyhler G, Debier E, Contal O and Audag N. Intrapulmonary percussive ventilation as an airway clearance technique in subjects with chronic obstructive airway diseases. *Respir Care* 2018; 63: 620-631.
- [23] Castagna O, Regnard J, Gempp E, Louge P, Brocq FX, Schmid B, Desruelle AV, Crunel V, Maurin A, Chopard R and MacIver DH. The key roles of negative pressure breathing and exercise in the development of interstitial pulmonary edema in professional male SCUBA divers. *Sports Med Open* 2018; 4: 1.
- [24] Bortolotti P, Colling D, Colas V, Voisin B, Dewavrin F, Poissy J, Girardie P, Kyheng M, Saulnier F, Favory R and Preau S. Respiratory changes of the inferior vena cava diameter predict fluid responsiveness in spontaneously breathing patients with cardiac arrhythmias. *Ann Intensive Care* 2018; 8: 79.
- [25] Vianello A, Arcaro G, Molena B, Iovino S, Gallan F, Turato C and Marchese-Ragona R. Effect of a passive exhalation port on tracheostomy ventilation in amyotrophic lateral sclerosis patients: a randomized controlled trial. *J Thorac Dis* 2018; 10: 1007-1014.
- [26] Khazaie H, Negahban S, Ghadami MR, Sadeghi Bahmani D, Holsboer-Trachsler E and Brand S. Among middle-aged adults, snoring predicted hypertension independently of sleep apnoea. *J Int Med Res* 2018; 46: 1187-1196.