The incidence and impact factors of sputum crust obstruction in cannula of patients with artificial airway

Running head: patients with sputum crust obstruction in cannula

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ABSTRACT: Objective This work aims to investigate the incidence rate and possible influencing factors of sputum crust obstruction in cannula of patients with artificial airway. **Methods** 427 patients with different critical illness were established artificial airway by tracheal intubation or tracheotomy. Occurrence and possible influencing factors of sputum crust obstruction in cannula were recorded when all patients were given clinical criteria care for ventilated patients, such as wetting and heating of artificial airway, sputum suction and dilution, turning shot sputum and exhaustive treatment for their primary disease. **Results** Sputum crust obstruction in cannula occurred in 69 patients, the incidence rate was 16.2%, and it was highest in patients with severe traumatic brain injury, reached 20.4%. Sputum crust obstruction in cannula was more likely to happen to patients with lung infection, sticky sputum, long intubated time and no cough reflex. **Conclusions** Even after the adequate prevention and care, sputum crust obstruction in cannula is still a common clinical complication of artificial airway. Especially in patients with gravis type craniocerebral injury, lung infection, sticky sputum, long intubated time and no cough reflex, who need to get close attention. At the same time, new method to prevention sputum crust obstruction in cannula is clinically required.

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1. INTRODUCTION

The establishment and use of artificial airway provide the best treatment conditions for unobstructed airways, ventilator-assisted breathing, respiratory attack, and preventing aspiration [1]. Clinically, the most common methods for establishing artificial airway are endotracheal intubation and tracheotomy. With the advancement in artificial airway technological, many patients without airways still survive with the use of artificial airway. However, artificial airway-related complications are also increasing [2, 3]. Both current research and clinical work indicate that sputum crust obstruction in the cannula is one of the most serious and common complications for patients with artificial airway. The formation of sputum callus in the artificial airway may cause airway obstruction, hypoxemia, increased risk of lower respiratory tract infection, and even death in patients [4, 5]. The incidence rate of sputum crust obstruction in cannula varies in different hospitals and in different sections of the Intensive Care Unit (ICU); however, the specific value still lacks detailed research report [6]. If the incidence rate is known, then we would know who among the patients need special attention to prevent the occurrence of sputum crust obstruction and reduce the incidence rate. Therefore, we hope to discuss the incidence rate of sputum crust obstruction in cannula of patients with different causes and possible related factors, while trying to find the factors that can be improved to reduce the incidence rate. This objective can be done through the study of 427 critically ill patients with artificial airway in the resuscitation room and the Intensive Care Unit of the Emergency Department (EICU) of our hospital, where we cure different kinds of patients who have similar conditions of guardianship and nursing.

2. PATIENTS AND METHODS

2.1. General data

The subjects included 427 critical ill patients (264 males and 163 females) who were established with an artificial airway and who were in the resuscitation room and ICU for more than 24 hours in the Emergency Department of Jinling Hospital, Nanjing, between January 1, 2011 and December 31, 2011. The age of the patients ranged from 21 years to 92 years, with a mean of 52.3 ± 21.5 years. Among these 427 patients, 373 cases had endotracheal intubation having a retention time of 4 to 23 days, with an average of 10.3 ± 5.9 days and 54 cases had tracheotomy having a retention time of 7 to 52 days, with an average of 22.4 ± 8.9 days. Patients who were not established with an artificial airway or did not continue for 24 hours because of transfer, automatic discharge, death, or extubation for other reasons have been excluded. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Jingling Hospital. Written informed consent was obtained from all participants.

2.2. Clinical criteria

When massive sputum formation exists, the most prominent manifestations of patients includes: difficulty of breathing which is progressive with the use of accurate mechanical ventilation, unsynchronised spontaneous breathing and frequency of ventilation, high airway pressure without any obvious incentive, the nasal catheter suction cannot be placed through the distal airway smoothly, and the catheter cannot suck the sputum out, and can only absorb a small amount. Treatment methods include: replacement of the cannula of endotracheal intubation or tracheotomy, use of bronchoscopy to observe and remove the sputum crust, and selection of the individualised treatment according to the patient's condition [7, 8]. The ventilator used was Vela™ from VIASYS Healthcare Company in America. The cannula of endotracheal intubation used was a PVC cannula from Haishen Medical Devices Company, Zhejiang Province of China, while that of tracheotomy was a PVC cannula produced by Mallinckrodt Medical in Ireland.

2.3.Preventive measures used in the clinical setting

Temperature was controlled at 22 ℃ to 24 ℃ and the humidity was about 60% in sick room. The floor was disinfected three times a day, and the entry and exit of personnel was controlled (each patient only have one family visit per day in less than an hour). Airway nurses have gone through unified training for dedicated care for patients with artificial airway. All patients were given standardised airway humidification and warming, with continuous fluid pump composed of 50 ml of saline and 30 mg of ambroxol for 12 hours, and the dosage is increased when necessary. For patients with a ventilator, constant temperature wet process was used to provide humidification at 32 ℃ to 36 ℃. When the patients need to be given aerosol inhalation, the appropriate liquid must be configured according to the specific pathogenic condition. Conventional suction, given once every hour, can increase or decrease the patient's condition, reaction, and treatment needs adequately. Aspiration of sputum with disposable silicone suction catheter (PVC catheter produced by Guangzhao Medical Devices Company, Jiangsu Province, China), with gentle movements for no more than 15 s each time can avoid frequent aspiration. Oxygen saturation, peak airway pressure, and change of breath sounds of each patient were monitored when aspirating the sputum. High concentration of oxygen was provided to maintain oxygen saturation before and after sputum suctioning in patients without ventilator. The percussion was turned over for l to 5 min/h. For critically ill patients who are receiving enteral nutrition, the aspiration of sputum is before the nasogastric. The stomach cannula must be kept unobstructed, and the nutrient solution is then heated to about 37 ℃. The head area of the bed should incline to 45 °to prevent reflux. In the whole process of nasogastric, the patients were observed for nausea, vomiting, and abdominal distension to avoid nutrient solution in the gastric retention. If necessary, gastrointestinal decompression is used. After nasogastric, the patient is kept in a semi-sitting position for 30 min to 40 min, and should avoid turning over and aspiration of sputum [7-13].

2.4.Research methods

We compared the incidence rates of sputum crust obstruction after the establishment of the artificial airway in endotracheal intubation or tracheostomy. We calculated the incidence rates of the sputum crust obstruction of patients with different diseases. We compared the possible risk factors of those mentioned in the literature, such as smoking history, time with the cannula, the presence or absence of lung infection and cough reflex, amount of sputum, sticky degree of sputum between the two groupings in the presence or absence of sputum crust obstruction.

2.5. Judgement standard for risk factors

Standard for sputum amount: Standard sputum suction is needed (for less than 15 seconds, the catheter is slowly rotated while pulling upward). If can suck the sputum in patient's airway completely only for suck once, the amount of sputum is small, if twice, the amount is moderate and if more than twice for a large amount. Standard for properties of sputum: after sputum suction, the suction catheter is rinsed once to wash the catheter clean (this only refers to the suction catheter, and does not include the extension cannula), the sputum is thin, need twice the sputum is slightly sticky, more than twice the sputum is sticky [7]. Combined with the actual situations of the patients with artificial airway, we selected a large number of sputum and sticky sputum to study the possible risk factors. Judgment of the cough reflex: a suction catheter longer than the artificial airway was used to stimulate the tracheal mucosa. If there is no cough action or chest wall movement, then there is no cough reflex. Diagnostic criteria for lung infection: the "Diagnosis and Treatment Guidelines for Hospital-acquired Pneumonia" and "Diagnosis and Treatment Guidelines for Community-acquired Pneumonia" established by Chinese Society of Respiratory Diseases [14, 15] was used in this study.

2.6. Statistical Analysis

All data were analysed using SPSS 16.0. Numerical variables and ordinal variables were presented as mean and standard deviation (SD). T tests were used for the comparison of numerical variables, and the χ^2 test was used for the comparison of the categorical data. A P value less than 0.05 was considered statistically significant.

3. RESULTS

No significant difference has been observed in the incidence rate of sputum crust obstruction between

patients with endotracheal intubation and tracheotomy (**Table 1**).

No significant difference has been observed in the incidence rate of sputum crust obstruction between different diseases, as shown in **Table 2**. In addition, the difference in the incidence rate of sputum crust obstruction between chronic obstructive pulmonary disease (COPD) group and cardio-pulmonary resuscitation (CPR) group was significant ($\chi^2 = 3.8741$, $P < 0.05$). A significant difference ($\chi^2 = 4.2230$, $P < 0.05$) was observed between the COPD group and composite trauma group. The difference among other groups was insignificant.

A significant difference in distribution of lung infection, sticky sputum, long intubated time, and no cough reflex between the two groupings in the presence or absence of sputum crust obstruction (**Table 3**).

Table 1 Sputum crust obstruction information about patients with endotracheal intubation or tracheotomy

Method of artificial airway	Number of patients	Number of patients with sputum crust obstruction	Incidence rate	χ^2 value	p value
Endotracheal intubation	373	57	15.3%	1.6773	p>0.05
Tracheotomy	54	12	22.3%		

Table 2 Sputum crust obstruction information about patients with different disease

Disease	Number of patients	Number of patients with sputum crust obstruction	Incidence rate	χ^2 value between other groups and gravis type craniocerebral injury group	p value between other groups and gravis type craniocerebral injury group
Gravis type craniocerebral injury	161	33	20.4%		
Compound trauma	37	2	5.4%	4.7087	p<0.05
CPR postoperative	48	3	6.25%	5.2639	p<0.05
COPD	122	23	18.9%	0.1182	p>0.05
ARDS	59	8	14.8%	1.3705	p>0.05

Table 3 Comparison of possible risk factors between the two groups of patients with or without sputum crust obstruction

Possible risk factors	Patients with sputum crust obstruction	Patients without sputum crust obstruction	t value or χ^2 value	p value
Time with the cannula (endotracheal intubation)	13.4 ±3.5	9.74 ±6.3	4.2658	p<0.001
Time with the cannula (tracheotomy)	27.1 ±6.7	21.1 ±9.53	2.0354	p<0.05
With lung infection	48/69	173/358	10.0473	p<0.01
Large amount	27/69	112/358	1.6218	p>0.05
Sticky sputum	32/69	97/358	10.2012	p<0.01
Without cough reflex	53/69	201/358	10.2520	p<0.01
Smoking history	21/69	113/358	0.0343	p>0.05

4. DISCUSSION

With the development of modern first aid techniques, a growing number of critically ill patients can enter the hospital for treatment. In addition, many of these patients eventually became healthy, with the help of the proper endotracheal intubation or tracheotomy. However, following the increased use of tracheal intubation and tracheotomy, the extension of application time, and the sputum crust formed in the artificial airway has gradually become questionable and cannot be ignored by clinicians [16, 17]. Patients with artificial airway had sputum crust obstruction even after adequate suctioning, and airway cleaning in different subjects of ICU in our hospital caused airway obstruction, hypoxaemia, increased risk of lower respiratory tract infection, and even death in patients. Sometimes even the timely replacement of cannula would still have a serious impact to clinical work and patient safety [18, 19].

Scholars have conducted many studies on the formation of sputum crust and have revealed that the causes are as follows: 1) Artificial airway damages he body's natural defence mechanism by forming a short-circuit channel that easily leads to sputum production and, eventually, bacterial deposition in the artificial airway; 2) After tracheotomy, airway is directly exposed to the outside environment, which damages the sputum suction and expectoration mechanism; 3) Repeated use of catheter suctioning can cause tracheobronchial mucosal injury. The damage

caused by tracheal intubation often causes local mucosal bleeding and blood scab formation. In addition, the sputum crust gradually expanded to form bloody sputum scab as blood scab being the centre; 4) Respiratory secretions of patients with pulmonary infection are plenty and thick; 5) Long duration of the samples in the cannula.

In the current study, the patients with established with artificial airway due to gravis type craniocerebral injury have the highest probability of sputum crust obstruction, which was about 20.4%. Based on previous review of the literature, we believe that the highest probability is related to the high proportion of patients with disturbance of consciousness, without cough reflex, and independently expectoration disability. Patients with COPD or with acute respiratory distress syndrome (ARDS) have a high possibility just under the patients with gravis type craniocerebral injury as 18.9% and 14.8%. We suggest that this result may be related with the poor baseline pulmonary function, vulnerability to pulmonary infection, and sticky sputum. However, we cannot obtain the true incidence rate of sputum crust obstruction generally applicable to all diseases because of the difficulty in acquiring enough sample size and control sample homogeneity. This process only prompt clinicians to pay more close attention in monitoring patients with gravis type craniocerebral injury, COPD, and ARDS, to prevent sputum crust obstruction.

The comparison between the two groupings in the presence or absence of sputum crust obstruction indicates that the difference in lung infection, sticky sputum, long intubated time, and without cough reflex was significant ($P < 0.05$). This result prompts clinicians to be more vigilant and provide more meticulous care to patients with the aforementioned risk factors. No significant difference in smoking history and the large amount of sputum was observed between the two groups ($P > 0.05$), because rigorous standardisation care and treatment reduced their influence.

No specific report about the incidence rate of sputum crust obstruction worldwide can be found, and it varies in different hospitals and in different sections of the ICU. This phenomenon is related to the units that have different custody and care conditions; however, it is related to different diseases and the possible common risk factors still lack detailed research report. Therefore, this study focused on the preliminary study of these issues, and the results indicate that the patients with disease that has a higher possibility to yield sputum crust obstruction or those with possible common risk factors need more attention for prevention. In addition, under the current clinical conditions, even after the adequate expectoration, suction, and other related treatment and care, the incidence of sputum crust obstruction is still unavoidable.

However, this study does not fully explain the connection between the factors of the study and sputum crust obstruction occurrence. In addition, we cannot formulate a regression equation because of the insufficient sample size and the actual situation of patients with artificial airway. Numerous diseases can force patients to resort to the artificial airway, if necessary. At the same time, every patient can have different risk factors, thus a huge sample size is needed to find all relevant factors and establish the correlation between these factors and the formation of sputum crust, which may be difficult to achieve.

In accordance to the other clinical workers, we believe that the key to resolve sputum crust obstruction is not only the need of a more meticulously treatment and care, but also looking for a new application to change the performance of the artificial airway to prevent the formation of sputum crust. Many researchers have conducted related research and improvement of cannula; however, their achievement results to problems, such as poor effect, inherent structure change, security verification difficulty, and promotion difficulty [20, 21]. We collaborated with the Southeast University to use safe and reliable nanomaterials to transform the inner and outer surfaces of the cannula and made no changes to the inherent structure and operating steps. In addition, it increased the water repellency of the cannula and reduced the sputum crust formed. The new cannula achieved good results in the in vitro experiments and was applied for two patents. Our future research will include cannula of new materials, and we hope that it can help reduce the incidence rate of sputum crust obstruction in the clinic.

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