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Original Article

Effect of different depth of aspiration on patients without effective cough response

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Abstract: Objective: To investigate the nursing effect of deep or shallow sputum suction in the treatment of patients without cough response. Methods: A total of 144 patients receiving mechanical ventilation without an effective cough reaction were randomly divided into two groups: deep suction group (n=73) and shallow suction group (n=71). Heart rate, breathing, blood pressure, analgesia and sedation score, residual sputum volume, frequency of suction, sputum volume, improvement of phlegm sound, airway bleeding and oxygen before and after intervention were observed. Partial pressure, partial pressure of carbon dioxide and oxygenation index were used to evaluate the effect of two sputum suction methods on patients without an effective cough response. Results: In our study, the fluctuation of vital signs in the deep suction group was significantly higher than that in the shallow suction group. There was a statistical significance between the two groups in the vital signs after nursing intervention ($P < 0.05$), this mainly manifested in the heart rate, breathing, pulse pressure and airway bleeding. On the other hand, there was no statistical significance between the two groups in pulse oxygen, the Behavioral Pain Scale (BPS score) and the Richmond Agitation-Sedation Scale (RASS score) after nursing intervention ($P > 0.05$). The sputum suction effect is obviously improved in the deep sputum suction group compared with the shallow sputum suction group after nursing intervention. The improvement score of phlegm sounds in the shallow sputum suction group was (1.8±0.8) points, and that in the deep sputum suction group was (2.2±0.7) points. The analysis of blood gas was significantly improved in the deep suction group compared with the shallow suction group. There was a statistical significance between two groups in blood gas analysis index, such as oxygenation index, $PaCO_2$ and PaO_2 ($P < 0.05$). Conclusion: Deep sputum suction has a great effect on the vital signs of patients, but there is not a serious effect on the vital signs. Shallow sputum suction does not effectively clean the airway of patients without a cough response; therefore, patients with a weak cough response need deep sputum suction.

keywords: Different depth of aspiration, no effective cough response, mechanical ventilation

Introduction

Most critical patients in the ICU are without a cough response, and they need to have an artificial airway established. Currently, artificial airway treatment accounts for 70% of the care in ICU inpatients, of which 17% of patients have neurological symptoms, leading to no response with cough and an inability to expectorate [1, 2]. The airway secretions of these patients will increase and as will the sputum retention, and sputum suction is an important means of nursing of these patients.

The American Association for respiratory care (AARC) 2012 clinical practice guidelines pointed out that [3] effective sputum suction is an important measure to remove airway secretions, and to help maintain airway patency and prevent pulmonary complications. According to the guidelines, there are two kinds of suction depth, deep suction and shallow suction. There are some disputes about the use of these two kinds of suction depth. Shallow sputum suction cannot achieve effective sputum suction. Deep sputum suction can stimulate the tracheal mucosa, leading to bronchial mucosal edema, inflammation, severe cough, airway spasm, stenosis and even bleeding [4, 5]. Secondly, the development of the guidelines for the best care is based on care given in the respiratory intensive care unit. Therefore, there is still no unified standard for the selection of sputum suction depth for patients in ICU. Studies have shown

that shallow sputum suction can cause less bleeding and damage to the airway mucosa, reduces hemodynamic fluctuations, and reduces the incidence of hypoxemia, so it is recommended to use shallow sputum suction [6-8]. However, some studies have found that the heart rate and blood pressure of patients with shallow suction and deep suction are significantly higher than those before suction, but there is no significant difference between the two groups, and the frequency of sputum suction in the shallow suction group is significantly higher than that in the deep suction group. Moreover, it is suggested to use deep suction to reduce the incidence of complications [9, 10]. Therefore, there is still needs to be a unified standard for the selection of sputum suction depth of ICU critical patients.

How to choose the depth of sputum suction and reduce the incidence of various complications caused by sputum suction is a very urgent research subject in ICU nursing. In this study, 144 patients without a cough reaction were divided into two groups, using different sputum suction depth to explore the appropriate depth of the sputum suction tube insertion. The study aim was to provide a scientific basis for the establishment of a unified and standardized artificial airway sputum suction management mode.

Data and methods

Clinical data

A total of 144 patients without a cough response in our hospital from March 2019 to March 2020 were randomized divided into two groups: the deep sputum suction group (n=73 cases) and the shallow sputum suction group (n=71 cases). The researchers systematically explained the role, purpose and process of the study to their families. Their families voluntarily signed the informed consent form to participate in this study. This study was approved and recognized by the ethics committee of our hospital.

Inclusion and exclusion standard

Inclusive criteria: ① patients were conformant to the diagnostic standard of patients without a cough response [11]: CPF was used as the basis of cough ability evaluation. The CPF threshold was -68l/min, > 68l/min was weak cough ability, and ≤ 68l/min was a strong cough ability; ② The expected time of artificial airway establishment was more than 48 hours; ③ age: ≥18 years; ④ The subjects were willing to cooperate and implement the experiment.

Exclusion criteria: ① Patients with airway injury; ② Severe coagulation dysfunction or thrombocytopenia; ③ Patients with relative contraindications of sputum aspiration: Patients with severe ARDS (PEEP > 12 cmH_2O); ④ Airway bleeding; ⑤ Patients had an acute left heart failure with bloody sputum; ⑥ Patients had a severe airway deformity which affected the insertion of suction tube; ⑦ Being unwilling to participate in our research.

Withdrawal criteria: The subjects had airway obstruction, severe airway bleeding and severe dyspnea during sputum suction.

Methods

The deep sputum suction group: When the sputum suction tube is inserted to meet resistance, it was retreated 1 cm. When the sputum suction begins, the insertion depth of the sputum suction tube for patients with endotracheal intubation must be more than 40 cm, and that for patients with tracheotomy cannula must be more than 15 cm. For deep suction, the tip of the suction tube exceeds the end of the artificial airway and reaches the main bronchus or branch trachea of the patient.

The shallow sputum suction group: For patients with endotracheal intubation, the suction tube was inserted 40 cm; for patients with tracheotomy cannula, the suction tube was inserted 15 cm. The tip of the suction tube is kept in the artificial airway, and the end of the suction tube does not touch the airway of the patient.

All patients in the study were treated with Pacific closed suction tube 14fr. A red marker was used to mark the insertion depth of the closed suction tube at 40 cm or 15 cm. The investigators were composed of researchers themselves and members of the research group. They were trained before the investigation to introduce the background, significance, purpose, data collection methods and precautions of the research, and control the measurement bias. All nurses in the department were trained on the methods of deep and shallow sputum suction, the judgment methods of sputum properties and quantity, and APACHE II

Table 1. Comparison of clinical data between the two groups

	Shallow sputum suction group (n=71)	Deep sputum suction group (n=73)	t/X^2	*P*
Age (years)	67.7±11.6	65.2±10.5	1.811	0.181
Sex			*1.353*	*0.247*
Male (n%)	53 (74.6%)	48 (65.8%)		
Female (n%)	18 (25.4%)	25 (34.2%)		
Nervous system diseases	30 (42.3%)	32 (43.8%)	0.036	0.849
Circulatory diseases	26 (36.6%)	29 (39.7%)	0.145	0.204
Respiratory diseases	32 (45.1%)	32 (43.8%)	0.220	0.883
Liver and kidney diseases	9 (12.7%)	6 (8.2%)	0.760	0.385
Sepsis	58 (81.7%)	54 (74%)	1.234	0.269
PaO_2	127.9±41.7	119.3±44.9	1.415	0.236
$PaCO_2$	44.3±9.4	44.6±14.7	0.021	0.993
Oxygenation index	2.90±1.28	2.85±1.34	0.61	0.805
APACHE II score	23.2±6.2	23.4±5.3	0.017	0.990

Note: Significant difference as P < 0.05.

scoring method, and they passed the examination. The software of the Madiston intensive care system is used for nursing records and data collection. The system automatically collected the monitoring indicators with an interval of 1-120 minutes.

Time of sputum suction: ① V-P curve ring has serrated change and/or large blister sound in auscultation airway; ② Peak airway pressure increases in volume control mode or tidal volume decreases in pressure control mode; ③ Oxygenation and/or deterioration of arterial blood gas values; ④ There are obvious secretions in the airway; ⑤ Acute respiratory distress; ⑥ Suspected aspiration of gastric contents or upper respiratory tract secretions.

Evaluation of the improvement in phlegm sounds

Completely disappeared: Phlegm sounds completely disappeared, and we recorded a score of 3.

Significant improvement: Phlegm sounds had significant improvement, and we recorded a score of 2.

No remission: Phlegm sounds had no remission, and we recorded a score of 1.

Assessment of vital signs

Heart rate, respiration, blood pressure, pulse oxygen, etc. We selected the data recorded by the monitoring system at the closest time point of sputum suction, and collected the data about 5 minutes before and after sputum suction.

Evaluation of residual sputum volume

Deep suction was used to evaluate the amount of residual sputum in the airway 24 hours after the end of the experiment and half an hour after the last suction.

Statistical analysis

All data were analyzed by SPSS software (version 25.0; SPSS Inc). The statistical results are expressed by mean ± standard deviation ($\overline{x}$ ± s), the data comparison was conducted by t-test and the correlation analysis was conducted by Person linear phase, P < 0.05 was the difference set with statistical significance. Analyses were performed using Graph Pad Prism 7 Software (Graph Pad Prism, San Diego, CA).

Results

Clinical data

Table 1 shows the characteristics of the participants. The research included 144 patients after follow-up, this involved 71 patients in the shallow sputum suction group, with a mean age (67.7±11.6) years; while in the deep sputum suction group, there was a mean age (65.2±

Table 2. Comparison of vital signs between the two groups after treatment

group	Number of cases	Heart rate difference	Breathing difference	Pulse pressure difference	Pulse oxygen difference	Airway bleeding	BPS score	RASS score
Shallow sputum suction group	71	3.1±5.8	2.3±0.6	5.4±2.7	2.0±0.1	1 (1.4%)	3.1±0.3	-3.7±0.9
Deep sputum suction group	73	8.0±6.1	3.1±1.0	9.5±2.5	2.2±0.1	8 (11%)	3.0±0.3	-3.6±1.0
T	-	54.325	9.737	231.245	0.175	5.749	0.580	0.540
P	-	0.0003	0.012	0.0002	0.676	0.018	0.810	0.463

Note: Significant difference as $P < 0.05$.

10.5) years. The number of patients who were diagnosed with nervous system diseases in the shallow sputum suction group was 30 (42.3%), and in the deep sputum suction group was 32 (43.8%), there was no statistical significance between the two groups (P=0.849). The number of patients who were diagnosed with circulatory diseases in the shallow sputum suction group was 26 (36.6%), and that in the deep sputum suction group was 29 (39.7%). The number of patients who were diagnosed with respiratory diseases in the shallow sputum suction group was 32 (45.1%), and that in the deep sputum suction group was 32 (43.8%). The number of patients who were diagnosed with sepsis in the shallow sputum suction group was 58 (81.7%), and that in the deep sputum suction group was 54 (74%). The level of PaO_2 in the shallow sputum suction group was (127.9±41.7) mmHg, and in the deep sputum suction group it was (119.3±44.9) mmHg, there was no statistical significance between the two groups (P=0.236). The level of $PaCO_2$ in shallow sputum suction group was (44.3±9.4) mmHg, and the deep sputum suction group was (44.6±14.7) mmHg, there was no statistical significance between the two groups (P=0.993). The level of oxygenation index in shallow sputum suction group was (2.90±1.28), and the deep sputum suction group was (2.85±1.34) there was no statistical significance between the two groups (P=0.805). Moreover, the APACHE II score in the shallow sputum suction group was (23.2±6.2) points, and that in the deep sputum suction group was (23.4±5.3) points, there were no statistical significance between the two groups (P=0.990).

Vital signs

As shown in **Table 2**, the heart rate difference in the shallow sputum suction group was (3.1±5.8), and that in the deep sputum suction group was (8.0±6.1). The pulse pressure difference in the shallow sputum suction group was (5.4±2.7) mmHg, and that in the deep sputum suction group was (9.5±2.5) mmHg. The rate of airway bleeding in the shallow sputum suction group was 1.4% (1/71), and that in the deep sputum suction group was 11% (8/73). The breathing difference in the shallow sputum suction group was (2.3±0.6), and that in the deep sputum suction group was (3.1±1.0), there was statistical significance between the two groups in the heart rate, breathing, pulse pressure and airway bleeding after nursing intervention ($P < 0.05$). However, the pulse oxygen difference in the shallow sputum suction group was (2.0±0.1), and that in the deep sputum suction group was (2.2±0.1). The BPS score in the shallow sputum suction group was (3.1±0.3) points, and that in the deep sputum suction group was (3.0±0.3) points. The Richmond Agitation-Sedation Scale (RASS score) in the shallow sputum suction group was (-3.7±0.9) points, and that in the deep sputum suction group was (-3.6±1.0) points, and there was no statistical significance between the two groups in pulse oxygen, BPS score and RASS score after nursing intervention ($P > 0.05$).

Sputum suction effect

The sputum suction effect had obvious improvement in the deep sputum suction group compared with the shallow sputum suction group after nursing intervention. The frequency of sputum aspirations in the shallow sputum suction group was (14.0±3.0), and that in the deep sputum suction group was (11.9±4.3). The sputum volume in the shallow sputum suction group was (0.3±0.6) L, and that in the deep sputum suction group was (1.5±0.7) L. The improvement in scores of phlegm sounds in the shallow sputum suction group was (1.8±0.8) points, and that in the deep sputum suction group was (2.2±0.7) points. There was statistical significance between the two groups in sputum suction effects after nursing intervention ($P < 0.05$). Furthermore, the PaO_2 in the shallow sputum suction group was (100.5±23.2) mmHg, and that in the deep sputum suction

Table 3. Comparison of Sputum suction effect between the two groups ($\bar{x} \pm s$)

group	Number of cases	Frequency of sputum aspiration	Sputum volume	Improvement score of phlegm sounds (Points)	PaO_2	$PaCO_2$	Oxygenation index	Residual sputum volume
Shallow sputum suction group	71	14.0±3.0	0.3±0.6	1.8±0.8	100.5±23.2	51.8±9.0	2.3±1.0	2.0±0.1
Deep sputum suction group	73	11.9±4.3	1.5±0.7	2.2±0.7	119.3±44.9	44.6±14.7	2.9±1.3	0.2±0.4
T	-	21.3	142.7	10.1	9.9	12.4	7.8	1129.5
P	-	0.0001	0.0005	0.002	0.002	0.001	0.006	0.000

Note: Significant difference as P < 0.05.

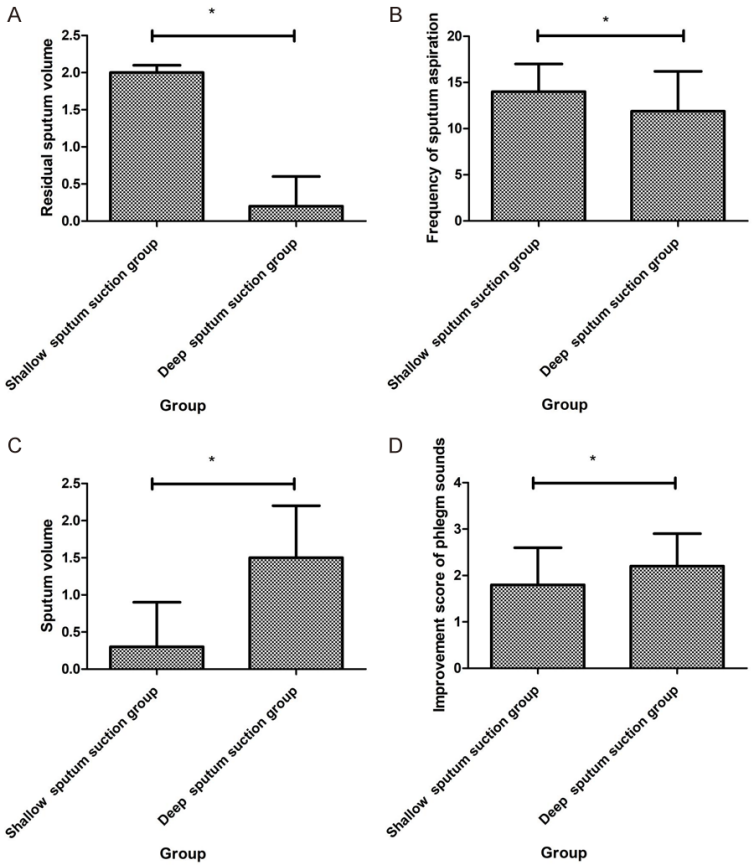

Figure 1. Comparison of Sputum suction effect between the two groups. Note: Compared with deep sputum suction group, *P < 0.05. A*:* Comparison of Residual sputum volume between the two groups. B: Comparison of Frequency of sputum aspiration between the two groups. C: Comparison of Frequency of Sputum volume between the two groups. D: Comparison of improvement score of phlegm sounds between the two groups.

group was (119.3±44.9) mmHg. The $PaCO_2$ in the shallow sputum suction group was (51.8± 9.0) mmHg, and that in the deep sputum suction group was (44.6±14.7) mmHg. The oxygenation index in the shallow sputum suction group was (2.3±1.0), and that in the deep sputum suction group was (2.9±1.3). The residual sputum volume in the shallow sputum suction group was (2.0±0.1) L, and that in the deep sputum suction group was (0.2±0.4) L, and there was statistical significance between two groups in the oxygenation index, $PaCO_2$, PaO_2 and residual sputum volume after nursing intervention (P < 0.05) (**Table 3** and **Figure 1**).

Analysis of blood gas

The PaO_2 in the shallow sputum suction group before and after nursing intervention respectively were (127.9±41.7) and (100.5±23.2) mmHg, and that in the deep sputum suction group respectively were (119.3±44.9) and (121.0± 35.2) mmHg. The $PaCO_2$ in the shallow sputum suction group before and after nursing intervention respectively were (44.6±9.4) and (51.8±9.0) mmHg, and that in the deep sputum suction group respectively were (44.6±14.7) and (45.0±12.3) mmHg. The oxygenation index in the shallow sputum suction group before and after nursing intervention respectively were (2.9±1.3) and (2.3±1.0), and that in the deep sputum suction group respectively were (2.8±1.3) and (2.9±1.3). There was statistical significance between the two groups in oxygenation index, $PaCO_2$ and PaO_2 after nursing intervention (P < 0.05) (**Table 4** and **Figure 2**).

Discussion

As shown in our results, there were significant differences between the two groups in heart

Table 4. Comparison of analysis of blood gas between the two groups before and after intervention ($\bar{x} \pm s$)

	time	Shallow sputum suction group (n=71)	Deep sputum suction group (n=73)	t	*P*
PaO_2 (mmHg)	Before intervention	127.9±41.7	119.3±44.9	5.138	0.0006
	After intervention	100.5±23.2	121.0±35.2	9.523	0.0004
	t	6.510	-0.872	-	-
	P	0.0004	0.386	-	-
$PaCO_2$ (mmHg)	Before treatment	44.6±9.4	44.6±14.7	1.209	0.085
	After treatment	51.8±9.0	45.0±12.3	3.315	0.001
	t	-11.932	-0.646	-	-
	P	0.0003	0.521	-	-
Oxygenation index	Before treatment	2.9±1.3	2.8±1.3	0.623	0.084
	After treatment	2.3±1.0	2.9±1.3	3.678	0.016
	t	6.269	-5.293	-	-
	P	0.0003	0.0002	-	-

Note: Significant difference as P < 0.05.

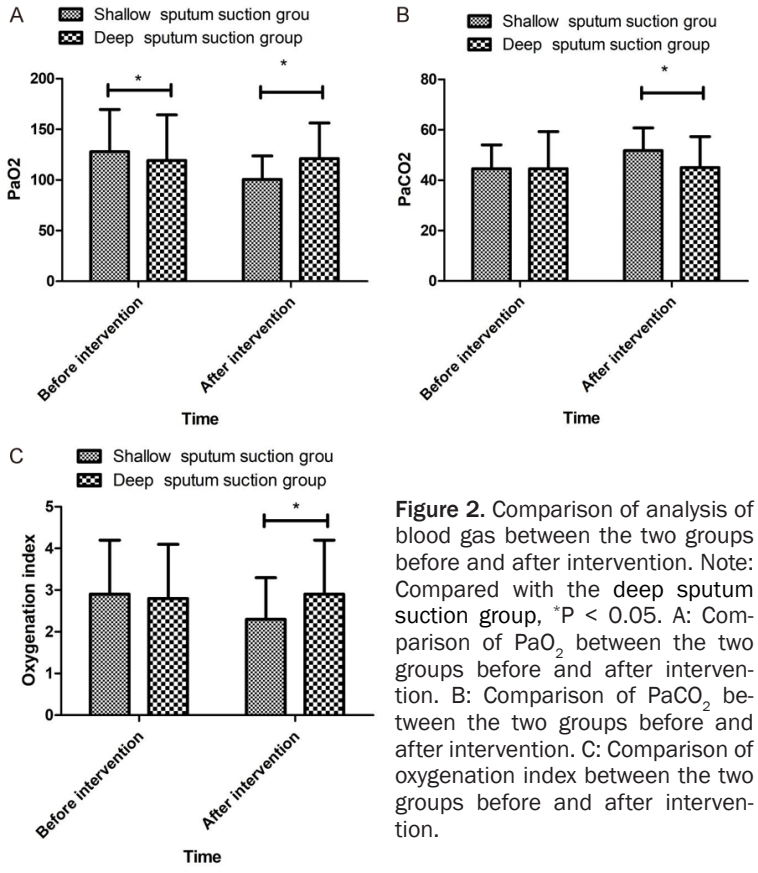

Figure 2. Comparison of analysis of blood gas between the two groups before and after intervention. Note: Compared with the deep sputum suction group, *P < 0.05. A: Comparison of PaO_2 between the two groups before and after intervention. B: Comparison of $PaCO_2$ between the two groups before and after intervention. C: Comparison of oxygenation index between the two groups before and after intervention.

rate difference, breath difference, blood pressure difference, analgesia and sedation score, residual sputum amount, sputum frequency, sputum amount, improvement of phlegm sound, oxygen partial pressure, carbon dioxide partial pressure, oxygenation index and airway bleeding before and after sputum aspiration (P < 0.05). However, there was no statistical difference between the two groups in pulse oxygen difference, analgesia and sedation score during the intervention period Academic significance (P > 0.05).

In our study, the fluctuation of vital signs in the deep suction group was significantly higher than that in the shallow suction group. The main manifestations were increased heart rate and blood pressure. This may be related to the stimulation of the sympathetic nervous system during sputum suction [12]. There was no difference in the influence of pulse oxygen saturation between the two groups. All patients were mechanically ventilated. According to the routine sputum suction process, 100% pure oxygen was infused before sputum suction, which may make up for the influence of sputum suction on pulse oxygen. There was no serious arrhythmia caused by sputum suction in this study, so both shallow

and deep sputum suction were safe. There was no difference in pain and other discomfort stimulation between patients with a poor response to deep and shallow sputum suction. Patients with a poor response to cough may not have an obvious response to sputum suction stimulation, and since their sedation is relatively deep or moderate in severe coma patients, so they may not be sensitive to sputum suction stimulation [13, 14].

The frequency of 24-hour sputum suction in the shallow group was higher than that in the deep group. The amount of sputum suction in the deep group was significantly higher than that in the shallow group. The improvement of sputum sounds in the deep group was more obvious than that in the shallow group. After 24-hours of the study, the amount of deep residual sputum in the shallow group was significantly higher than that in the deep group, which indicated that shallow sputum suction could not effectively remove the deep airway secretion of patients with a weak cough response. There was no difference in the blood gas analysis results between the two groups before enrollment, the oxygen partial pressure and oxygenation index of the deep suction group were higher than those of the shallow suction group, and the carbon dioxide partial pressure was lower than that of the shallow suction group. The blood gas analysis results showed that the oxygen partial pressure and oxygenation index of the shallow sputum suction group were lower than before the intervention, and the carbon dioxide was higher than before the intervention. In the deep suction group, the oxygenation index was significantly improved after the intervention, while the oxygen partial pressure and carbon dioxide partial pressure had no change compared with those before the intervention, which was related to higher pulse oxygen and lower oxygen concentration. Therefore, the cleaning of airway secretion in deep suction group is conducive to oxygen delivery and oxygen and carbon dioxide emission. Deep suction is more likely to damage the airway than shallow suction. In the experiment, 9 patients had airway bleeding, all of which were mild bloody airway secretions or bloodstains in secretions visible to the naked eye. Studies have shown that deep sputum suction can cause different degrees of damage to the tracheal mucosa, the reason is the damage from the suction tube. Blindly and brutally increasing the suction depth will lead to repeated contact and stimulation at the front end of the suction tube and damage to the airway mucosa, especially when the contact at the tracheal carina is more frequent, resulting in mucosal damage, airway mucosal congestion and edema, cilia loss, cell abscission, mucosal fibrosis and even granuloma formation [15-17].

In clinical practice, the length of the trachea is usually different due to the individual differences of patients' age, height and gender. In general, in the process of adult endotracheal intubation, the tip of the endotracheal tube is located in the middle of the bronchus, about 3-5 cm away from the tracheal carina, while the total length of the endotracheal tube is (30±2) cm, (22±2) cm away from the incisor. Due to its special anatomical structure, the trachea has certain requirements on the depth of sputum suction [18]. If the sputum suction tube is inserted too deep, it will stimulate the bulge, cause severe cough, reduce comfort, and cause airway high pressure and damage the airway mucosa [19]. The different depth of sputum suction may be the cause of hypoxemia, mucosal damage and cough. Therefore, safe and effective sputum suction depth can keep the airway unobstructed, which is the key to artificial airway management [20].

Our study had some limitations. Firstly, the number of consecutive patients was small and it was an adult population, which only included the patients without a cough response. Secondly, the duration of time of the study was limited, and we didn't observed the long-term efficacy and recurrence of the consecutive patients. Thirdly, although our results are promising, the explanation is limited by the self-control study design. Therefore, further study of the nursing effect of deep or shallow sputum suction in the treatment of patients without a cough response is still needed.

In conclusion, Deep sputum suction has a great influence on the vital signs of patients, but there was no ill effect on the vital signs. Shallow sputum suction cannot effectively clean the airway of patients without a cough response, therefore, patients with weak cough response need deep sputum suction. This can not only ensure the effectiveness of sputum suction,

but also give consideration to the safety of sputum suction, maintain good ventilation, and reduce the incidence of respiratory mucosal injury, hypoxemia, cough and other related complications.

Disclosure of conflict of interest

None.

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