

The effect of sputum suction at different decubitus of low muscle strength patients with ventilators

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Research

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Abstract

BACKGROUND

Sputum suction with ventilators is a method to save the life of respiratory failure patients. However, the effect of different decubitus in the process of sputum suction on low muscle strength patients is not understood.

METHODS

The low muscle strength patients received the sputum suction using orotracheal intubation were randomly divided into 0°decubitus group and 30°decubitus group. The clinical indicators and blood gas analysis were used to compare the advantages of the two groups. In addition, 11 main complications and incidents were selected to evaluate the safety of the 0°decubitus group and 30°decubitus group.

RESULTS

There was no significant difference between 0°decubitus group and 30°decubitus group in baseline characteristics and safety assessments. For clinical indicators, the 0°decubitus group displayed the earlier appearance of pulmonary infection control (PIC) window, shorter time of invasive ventilation and hospital stay, shorter total time of ventilation, lower reintubation rate and ventilator-associated pneumonia (VAP) rate, and higher weaning success rate compared with the 30°decubitus group. In addition, the blood gas analysis showed that the concentrations of O₂ (PaO₂) and oxygen saturation (SaO₂) were higher in 0°decubitus group than in 30°decubitus group, while the concentrations of CO₂ (PaCO₂) was lower in 0°decubitus group than that in 30°decubitus group.

CONCLUSIONS

The sputum suction at 0°decubitus had more advantages than at 30°decubitus for the low muscle strength patients with ventilators.

Background

Respiratory failure, a serious complication, is often seen in the intensive care unit (ICU) patients (1). Based on the statistics from the United States, respiratory failure led to 36 deaths during the initial hospitalization and had become the third leading cause of mortality (2). Therefore, looking for effective treatment of respiratory failure is crucial to improve the survival rate of ICU patients.

Mechanical ventilation as a life-saving intervention is widely used all over the world (3). Although ICU patients with ventilation could recover from respiratory failure, several patients were still required

prolonged weaning (4). Obviously, prolonged mechanical ventilation increased the risk of death and healthcare cost. Sputum suction with ventilation is a common treatment method in nursing to keep the respiratory tract unobstructed. Several nurses in China found that sputum suction at 30° to 45° decubitus could promote the increase of thoracic pressure after the contraction of abdominal muscle and diaphragm muscle, so that it had advantage to freely cough up sputum for the respiratory failure patients. Besides, sputum suction 30° to 45° decubitus also could relieve the pain of respiratory failure patients. However, the effect of decubitus on sputum suction for the respiratory failure patients with low muscle strength is not fully understood.

The aim of this study was to explore the role of different decubitus in sputum suction for low muscle strength through assessing the major clinical indicators and blood gas analysis. In addition, we also selected 11 main complications and incidents to evaluate the safety of different decubitus for sputum suction.

Materials And Methods

Study design and subjects

This study was approved by the institutional review board of Union Hospital of Tongji Medical College of Huazhong University of Science and Technology. 110 respiratory failure patients in the ICU of Union Hospital received the treatment of sputum suction between August 2018 and August 2019. The patients were selected based on the inclusion criteria and randomly divided to the sputum suction at 0°decubitus group and the sputum suction at 30°decubitus group. Patients received orotracheal intubation according to the criterion of invasive mechanical ventilation (5). The low muscle strength was defined as the muscle strength less than 3 based on Lovett's scale (Table 1). We included the low muscle strength patients, aged more than 25 years, muscle strength less than 3, without the contraindications for 0°decubitus and 30°decubitus, and treated with orotracheal intubation mechanical ventilation. This study excluded the diagnosis of pulmonary diseases, patients with active hemoptysis, patients with aphthous ulcer, and patients without facial injury. The pulmonary infection control (PIC) window was defined as: consciousness; significant reduction of the bronchial-pulmonary infection shadow on the chest, no obvious fusion patch; significant decrease of sputum that turned lighter, and the viscosity declined to below degree II (6). Besides, the PIC window also accompanied by at least one of the following indications: white blood cells (WBC) was less than $10 \times 10^9/L$ or reduced more than $2 \times 10^9/L$ in peripheral blood; and the body temperature less than 38°C.

Grouping and procedure

Patients were randomly divided into 0°decubitus group and 30°decubitus group. A total of 16 low muscle strength patients in 0°decubitus group received the treatment of sputum suction at 0°decubitus (Fig. 1), while 14 low muscle strength patients in 30°decubitus group received the treatment of sputum suction at 30°decubitus. All the selected patients were invited to participate in orotracheal intubation.

All the nurses who participated in the sputum suction were above nursing level and passed sputum suction training. The sputum suction of orotracheal intubation was performed using a disposable sputum suction tube. After clearing the sputum from the patients' mouth and nasopharynx, the nurses removed the pillow, gently uplifted the patients' neck. The nurse held the rotatable joint when prepared to perform sputum suction. At the same time, the sputum suction tube was inserted through weasand into the pulmonary central airway. Then, the nurse pressed the control button on the ventilator. The orotracheal intubation was performed according to the guidelines (7). After completing sputum suction, the sputum suction tube was softly taking off the pulmonary central airway until saw the black indicatrix of tube. Each time for sputum suction should not exceed 15 s, followed by oxygen inhalation for 1 min. To compare the advantages of 0°decubitus group and 30°decubitus group, the blood gas such as pH, concentrations of O₂ and CO₂, and oxygen saturation (SaO₂) were measured before and after the sputum suction by orotracheal intubation.

Observation of clinical indicators

The time of the PIC window appearance was recorded as the primary endpoint. The total time of ventilation, hospital stay, weaning success rate, reintubation rate, ventilator-associated pneumonia (VAP) incidence, and fatality rate were counted as the secondary endpoint. VAP was defined as pneumonia occurring more than 48 h after sputum suction. Besides, the safety was assessed by evaluating the 11 complications and incidents: reflexive respiratory/cardiac arrest, upper respiratory tract injury, bleeding in airway, asphyxia, arrhythmia, blood pressure fluctuation, cerebrovascular accident, shock, pneumothorax/blood pneumothorax, mediastinal/subcutaneous emphysema, and vomiting.

Statistical analysis

The SPSS 19.0 as the statistical analysis software was used to perform the statistical analysis. The data were presented as mean ± standard deviation (SD) or median. The data conforming to the normal distribution were analyzed using Student *t*-test, while the data conforming to the abnormal distribution were analyzed using the nonparametric test. The categorical data were analyzed using the Chi-squared test. *P* < 0.05 was considered statistically significant.

Results

The comparison of baseline characteristics on the low muscle strength patients

The baseline characteristics on the low muscle strength patients included age, gender, body mass index (BMI), heart rate (HR), *etc.* As shown in Table 2, 16 patients going through sputum suction at 0°decubitus and 14 patients going through sputum suction at 30°decubitus were analyzed. The baseline characteristics including age, gender, BMI, HR, respiratory rate (RR), systolic blood pressure (SBP), mean arterial pressure (MAP), and oxygenation index (PaO₂/FiO₂) did not show any differences between

0°decubitus and 30°decubitus. Besides, no significant differences in the comorbidities such as paraplegic, severe pancreatitis, myasthenia gravis, *etc.* were observed between the two groups.

The comparison of clinical indicators after sputum suction

The clinical indicators such as the time of PIC window appearance, time of invasion ventilation and hospital stay, total time of ventilation, *etc.* were recorded after the low muscle strength patients went through the sputum suction at 0°decubitus or 30°decubitus. Compared with 30° decubitus, the time of PIC window appearance was shortened by 3.6 days after sputum suction with 0°decubitus (Table 3). The time of invasive ventilation in 0°decubitus group was shortened by 2.2 days compared with that in 30° decubitus. The total time of ventilation and hospital stay in 0°decubitus group was also shorter than in 30°decubitus group. Meanwhile, the sputum suction with 0°decubitus reduced reintubation rate and VAP incidence, while it increased the weaning success rate. However, no significant difference in fatality rate between 0°decubitus group and 30°decubitus group. The data on clinical indicators suggested that sputum suction with 0°decubitus had more advantages than that at 30°decubitus for the low muscle strength patients.

The comparison of blood gas analysis between two groups

The blood gas was analyzed before and after sputum suction with 0°decubitus or 30°decubitus. For pH, no significant differences were observed between 0° decubitus group and 30°decubitus group before and after the sputum suction (Fig. 2). However, the concentration of O₂ (PaO₂) after the low muscle strength patients went through sputum suction at 30°decubitus significantly decreased compared with at 0°decubitus. The result on SaO₂ was similar to PaO₂ (decreased by 3% at 30°decubitus). The concentration of CO₂ (PaCO₂) in 30 °decubitus group increased by 1.11-fold compared with 0 °decubitus group. Taken together, the result of the blood gas analysis was better in 0 °decubitus group compared with 30°decubitus group.

The comparison of safety assessments between two groups

The safety parameters including reflexive respiratory or cardiac arrest, upper respiratory tract injury, bleeding in airway *etc* were evaluated. The details on the safety assessments for the patients suffering sputum suction with 0°decubitus or 30°decubitus were displayed in Table 4. The reflexive respiratory or cardiac arrest (4 in 0°decubitus group and 5 in 30°decubitus group), bleeding in airway (1 in 0°decubitus group and 2 in 30°decubitus group), asphyxia (3 in 0°decubitus group and 4 in 30°decubitus group), arrhythmia (2 in 0°decubitus group and 1 in 30°decubitus group), blood pressure fluctuation (5 in 0°decubitus group and 6 in 30°decubitus group), and vomiting (1 in 0°decubitus group and 1 in 30°decubitus group) were not observed any significant differences between two groups. Besides, no patients in two groups showed upper respiratory tract injury, cerebrovascular accident, shock, pneumothorax/blood pneumothorax, and mediastinal/subcutaneous emphysema.

Discussion

In this study, we observed that the low muscle strength patients suffering the sputum suction with 0°decubitus appeared PIC window earlier compared with that with 30°decubitus. The time of invasive ventilation and hospital stay, and the total time of ventilation in 0°decubitus group were shorter than that in 30°decubitus group. The patients suffering the sputum suction with 0°decubitus displayed the lower rate of reintubation, VAP incidence, and fatality. The weaning success rate was elevated in 0°decubitus group. Besides, the analysis for blood gas suggested that the sputum suction with 0°decubitus was better than 30°decubitus. Our findings proved that the sputum suction with 0°decubitus had more advantages than 30°decubitus.

Prolonged invasive ventilation might cause respiratory muscle fatigue for the patients (8). The PIC window was put forward to assist the nurse to find out the optimal timing of avoiding weaning failure when the invasive ventilation had to be prolonged (9). In our study, we found the PIC window in 0°decubitus group appeared earlier than that in 30°decubitus group. Compared with 30°decubitus group, the time of invasive ventilation and hospital stay, the total time of ventilation, reintubation rate, and VAP incidence were lower in 0°decubitus group. Besides, the 0°decubitus group had a higher weaning success rate than 30°decubitus group.

Blood gas analysis is a crucial test to identify the pH of blood, the amount of oxygen and carbon dioxide, and oxygen saturation in the blood. The results of the blood gas analysis are useful to determine how well treatments were working. PaO₂ and PaCO₂ are the basic indicators to assess the pulmonary function. In general, the increase of PaO₂ and decrease of PaCO₂ represent improving the pulmonary function. In this study, we observed that PaO₂ and SaO₂ were higher in 0°decubitus group than that in 30°decubitus group. Compared with 30°decubitus group, the PaCO₂ with the lower level in 0°decubitus group was observed.

For the patients with the low muscle strength, they could not overcome the gravity of sputum to cough up the sputum into the central airway to extract it when they received the treatment of sputum suction at 30°decubitus. In addition, the sputum that was coughed up into the central airway was distributed in the bottom of the airway using sputum suction at 0°decubitus. Hence, the top of airway had a larger space to provide airflow, which impaired the ability of the sputum moving.

Conclusion

In summary, the comparison of clinical indicators and blood gas analysis between 0°decubitus group and 30°decubitus group, the sputum suction at 0°decubitus group had more advantages than that at 30°decubitus group for the patients with the low strength. Hence, the sputum suction at 0°decubitus may be worth of practice for the patients with low muscle strength. However, the limitations on the sputum suction at 0°decubitus remain to be further investigated.

Declarations

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology (Wuhan, China). All patients signed written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that there is no conflict of interests.

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No funding was received.

Author contributions

JTH designed the study. YL and JW performed most of the experiments. LJF and SSL collected the data and wrote the paper. All authors read and approved the final manuscript.

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Tables

Table 1 Lovett's scale of muscle strength

MUSCLE FUNCTION LEVEL	SCALES		
	GRADE	%	LOVETT SCALE
No evidence of contractility	0	0	0 (zero)
Slight contractility, no movement	1	10	T (trace)
Full range of motion, gravity eliminated*	2	25	P (poor)
Full range of motion with gravity	3	50	F (fair)
Full range of motion against gravity, some resistance	4	75	G (good)
Full range of motion against gravity, full resistance	5	100	N (normal)

*Passive movement.

Table 2 General data of 0°decubitus group and 30°decubitus

	0°decubitus (n=16)	30°decubitus (n=14)	P value
Age	44.3±9.5	47.2±9.8	0.408*
Gender	10/6	8/6	0.765 [#]
BMI	29.2±2.2	29.1±2.2	0.890*
HR, beats/min	83.8±9.1	85±13.1	0.766*
RR, beats/min	26.9±2.9	26.2±3.3	0.583*
SBP, mm Hg	116.7±13.3	118.5±13.1	0.569*
MAP, mm Hg	90±7.3	91.2±7.7	0.676*
PaO ₂ /FiO ₂	221.1±11.1	219.7±8.3	0.714*
Comorbidities			0.975 [#]
Paraplegic	2	2	
Severe pancreatitis	2	1	
Myasthenia gravis	3	2	
Sepsis	1	1	
Heart failure	2	2	
Cerebrovascular accident	1	2	
Organophosphorus poisoning	1	0	

HR, RR, SBP, MAP, and R/F ratio were measured at intensive care unit admission. BMI = body mass index, FEV₁ = forced expiration volume in the first second, HR = heart rate, MAP = mean arterial pressure, PaO₂/FiO₂ = oxygenation index, RR = respiratory rate, SBP = systolic blood pressure. * *t* test. [#] Chi-squared test.

Table 3 Clinical indicators between 0°decubitus group and 30°decubitus group after sputum suction

	0°decubitus	30°decubitus	P value
Appearance of PIC window, d	2.8±0.7	6.4±1.7	0.001*
Time of invasive ventilation, d	3.9±1.3	6.1±1.3	0.001*
Total time of ventilation, d	9.4±1.9	13.1±2.1	0.001*
Hospital stay, d	14.2±1.8	17.6±2.1	0.001*
Weaning success rate, %	97.12	81.26	0.001 [#]
Reintubation rate, %	2.26	8.67	0.046 [#]
VAP incidence, %	2.28	10.41	0.018 [#]
Fatality rate, %	3.71	4.35	0.818 [#]

**t*-test. [#] Chi-squared test. PIC = pulmonary infection control, VAP = ventilator-associated pneumonia.

Table 4 Analysis of safety assessments

	0°decubitus	30°decubitus	P value
Reflexive respiratory/cardiac arrest	4	5	0.05*
Upper respiratory tract injury (pain, hemorrhage, infection, etc)	0	0	
Bleeding in airway	1	2	0.05*
Asphyxia	3	4	0.05*
Arrhythmia	2	1	0.05*
Blood pressure fluctuation	5	6	0.05*
Cerebrovascular accident	0	0	
Shock	0	0	
Pneumothorax/blood pneumothorax	0	0	
Mediastinal/subcutaneous emphysema	0	0	
Vomiting	1	1	0.05*

*t-test.

Figures

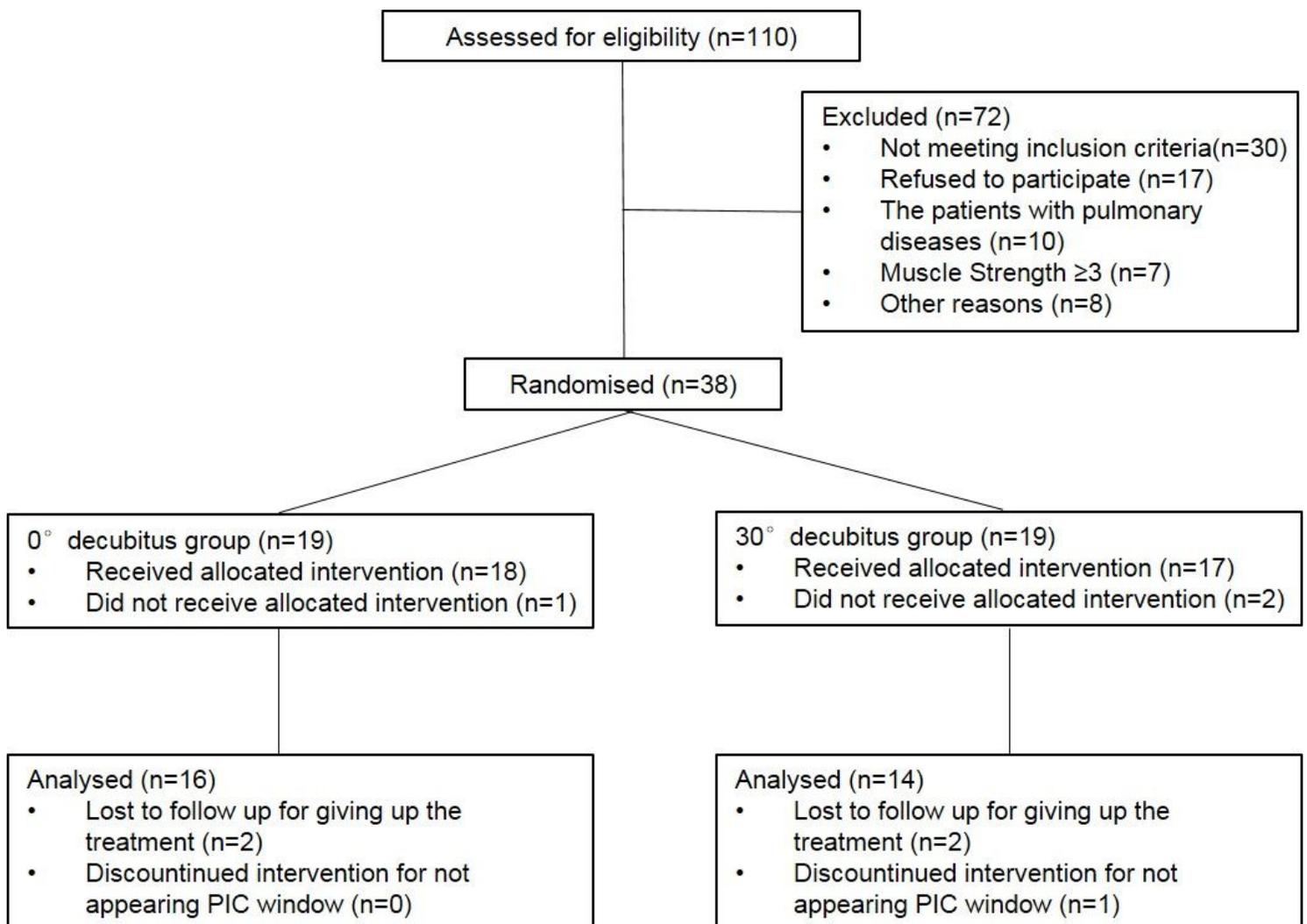


Figure 1

The flow chart of the grouping process. PIC, pulmonary infection control.

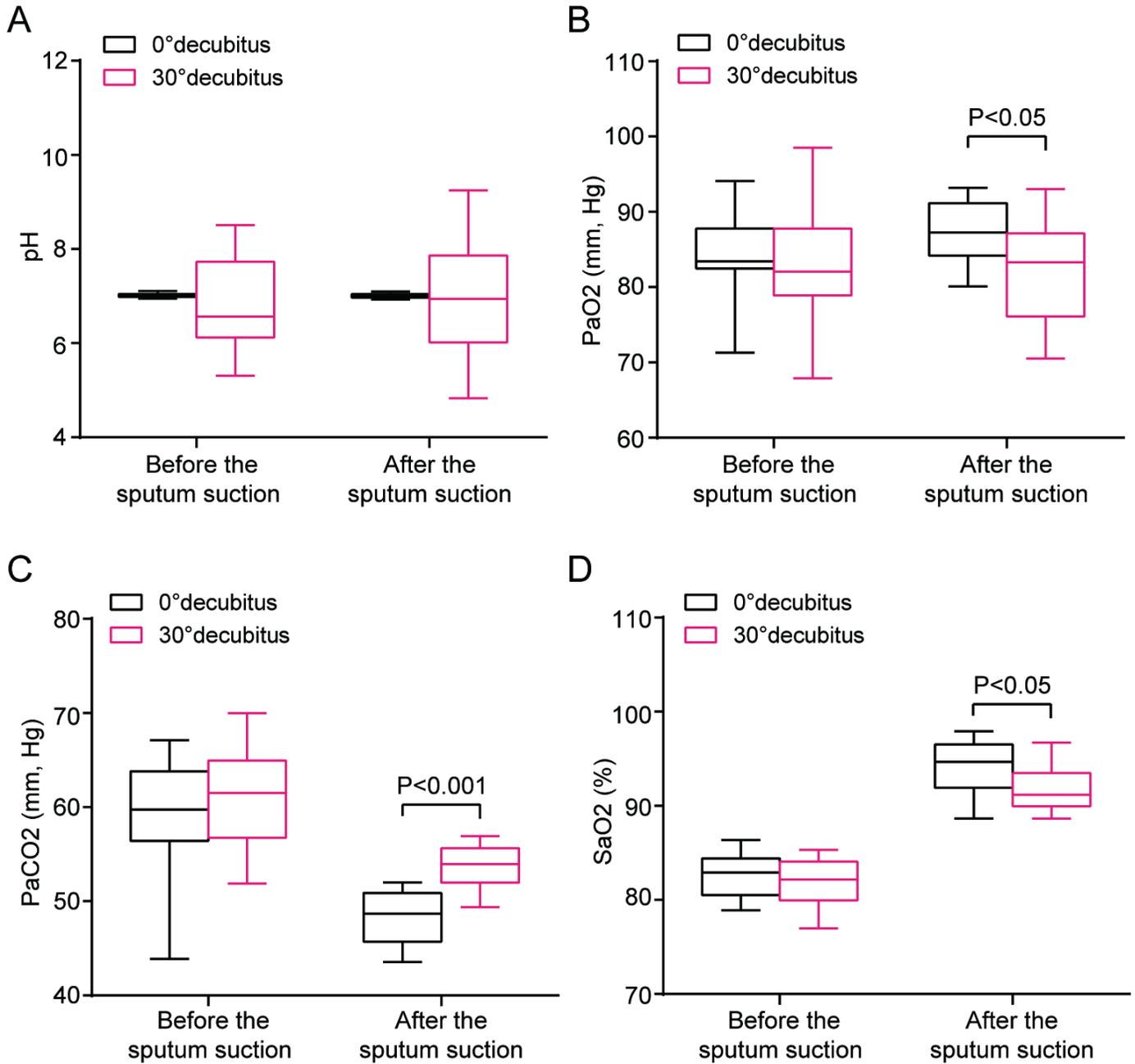


Figure 2

The blood gas analysis before and after sputum suction with 0° decubitus or 30° decubitus. (A) The change of pH in blood before and after sputum suction with different decubitus. (B) The difference in the concentration of O₂ (PaO₂) in blood between before and after sputum suction with different decubitus. (C) The change of the concentration of CO₂ (PaCO₂) in blood before and after sputum suction with different decubitus. (D) The difference of oxygen saturation (SaO₂) in blood between before and after sputum suction with different decubitus. A total of 16 patients received the sputum suction with 0° decubitus. A total of 14 patients received the sputum suction with 30° decubitus.