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Original Article

Effects of prone position on lung function of patients undergoing mechanical ventilation under total intravenous anesthesia

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Abstract: Lung function of patients is one of the most important issues for anesthesiologists during the perioperative period. This study aimed to evaluate the effects of prone position on lung function of patients undergoing mechanical ventilation under total intravenous anesthesia. Sixty patients undergoing elective surgery were randomly divided into 2 groups: supine group (receiving operation in supine position requiring mechanical ventilation under total intravenous anesthesia) and prone group (receiving operation in prone position requiring mechanical ventilation under total intravenous anesthesia). Arterial partial pressure of oxygen (PaO_2), alveolar-arterial oxygen difference (A-aDO_2), peak airway pressure and peak mean pressure were measured at the same time. The results showed that there were no significant difference in peak airway pressure and peak mean pressure between two groups at the different time points (95% CI: 6.3-6.9 cmH_2O VS. 6.4-7.2 cmH_2O, P=0.57; 17.0-18.1 cmH_2O VS. 16.1-17.7 cmH_2O, P=0.49). Compared with supine group, PaO_2 was significantly increased, and A-aDO_2 was significantly decreased in prone position (95% CI: 301.2-493.0 mmHg VS. 244.1-272.6 mmHg, P<0.004; 186.1-265.0 mmHg VS. 396.1-422.4 mmHg, P<0.001). In conclusion this article suggests that mechanical ventilation under total intravenous anesthesia do not negatively affect the lung function when patients are in either prone or supine position, and the pulmonary ventilation function is better than that in supine position.

Keywords: Supine position, prone position, lung volume measurements, respiratory function tests

Introduction

With the recent developments in surgical maneuvers and monitoring devices, there have been a growing number of operative positions applied clinically such as supine position, prone position, lateral position and so on. Supine and prone positions are the two most commonly used. Now, the continuing debate over the merits of the supine versus prone position still arouses substantial interest, particularly in the respiratory diseases.

People subjectively think prone position belongs to non-physical postures, reduces lung compliance and pulmonary oxygenation function and increases the alveolar walls of atelectasis compared with supine position. However, the prone position rather than the supine position has been reported to improve the respiratory dynamic changes. Respiratory benefits of the prone position in the adult respiratory distress syndrome (ARDS) have been demonstrated both in patients and in an animal model (Cornejo et al., 2013) [1, 2].

Pulmonary atelectasis develops in the most dependent part of the lungs during general anesthesia in 90% of humans with normal lung function, and was considered the major cause of impairment of gas exchange and lung compliance [3]. Body position has also been shown to have an effect on arterial oxygenation [4] and functional residual capacity [5]. Previous studies suggested that prone positioning of chronic obstructed pulmonary disease patients requiring mechanical ventilation improves oxygenation and lung mechanics during sigh versus semirecumbent positioning [6]. However, no study has been conducted to investigate the pulmonary ventilation function of patients undergoing mechanical ventilation under the general anesthesia. The aim of this study was to evaluate the effects of the prone position on the lung function of patients undergoing mechanical ventilation under total intravenous anesthesia.

Materials and methods

Ethnics

The present study has been performed with the approval of the ethics committee of The Third Hospital of Hebei Medical University and is in compliance with the Helsinki Declaration. The informed consents of the study were collected from all the candidate subjects.

Subjects

This study involved 60 patients from February 1, 2016, to August 31, 2016. 30 patients underwent lower extremity surgery in prone position; the other 30 patients received spinal surgery in supine position. American Society of Anesthesiologists' physical status class I & II. Exclusion criteria included known smoking habits, disease of respiratory system or a history of bronchiolitis, respiratory tract infection within the past four weeks. The characteristics of participants were shown in **Table 1**.

Anesthesia

Monitoring equipments for electrocardiogram, pulse oximetry and invasive blood pressure were applied. Fractions of inhaled oxygen, end-tidal concentrations of carbon dioxide, minute ventilation, respiratory rate, and peripheral arterial oxygen saturation were all recorded.

An intravenous cannula was inserted for intravenous administration of fluids and drugs. Following negative Allen's test, a radial artery catheter was inserted under local anesthesia for measurement of arterial blood gases tension and evaluation of acid base status. Baseline measurements of heart rate, mean arterial blood pressure and arterial blood gases were measured before induction of anesthesia. After preoxygenation (with 100% O_2 for 3 min), anesthesia was induced using fresh gas flow at a rate of 6-8 L/min. Anesthesia was induced by intravenous injection of midazolam 0.05-0.2 mg/kg, 1-2.5 mg/kg propofol and 0.1-2 μg/kg sulfentanil. Tracheal intubation was performed after establishing muscle relaxation by intravenous injection of 0.3-0.6 mg/kg benzene sulfonic acidcis atracurium. Following manual ventilation of the lungs, the trachea was intubated orally with a cuffed tracheal tube of a diameter which allowed an air leak (female patient was intubated with an endotracheal tube 7.5 mm in inner diameter, and male was intubated with an endotracheal tube 8 mm in inner diameter) under direct laryngoscope. The subjects were then connected to a Fabius Tiro ventilator (Dräger, Germany) set in a volume-controlled mode. Patients were mechanically ventilated using closed circuit anesthesia. The ventilatory setting consisted of a ventilatory rate of 8-12/min or the rate which maintained $PaCO_2$ within the physiologic limits (35-45 mmHg) as detected by $ETCO_2$ concentrations, a tidal volume of approximately 8-10 ml/kg, an inspiration to expiration ratio of 1:2 were used, and fraction of inhaled oxygen was set at 100% at a fresh gas flow of 1-2 L/min with PEEP (5 cmH_2O). Anesthesia was maintained with continuous infusion of propofol at a rate of 4-12 mg/kg/h and remifentanil at a rate 0.25-2 μg/kg/min. After surgery, muscle relaxation was reversed, trachea was extubated, and the subject was transferred to the recovery room. All haemodynamic parameters such as heart rate, blood pressure and ECG were within normal values.

Vital capacity manoeuvre

Alveolar recruitment was achieved by applying steps (1-6) sequentially between T_1 and T_2, T_3 and T_4. The VC manoeuvre was performed as follows: (1) The ventilator was switched to pressure-controlled mode, using an inspiratory hold button, inspiratory pressure was changed immediately to 40 cmH_2O. (2) PEEP was increased in steps of 5 cmH_2O up to a maximum of 15 cmH_2O to obtain information on the haemodynamic state of the patients. If a patient's mean arterial pressure or heart rate changed by more than 20% compared with baseline, the intervention was stopped and normal saline 500 ml was given before the next recruitment. (3) The longest possible inspiratory time was selected by changing ventilatory frequency to 6 bpm. (4) Tidel volume was increased until either a tidal volume of 18 ml/kg or a peak inspiratory pressure of 40 cmH_2O was reached and an inspiratory hold was kept for 8 s. (5) Tidal volume was then reduced to

Table 1. Characteristics of participants

Groups	N	Sex ratio (Male/Female)	Age (years)	BMI (kg/m^2)	Tidal volume (ml)	RR (min)	FiO_2 (%)	PEEP (cmH_2O)
Supine	30	17/13	45±14	20.8±3.1	530±90	11±1	98.2±0.9	4
Prone	30	14/16	42±13	21.5±4.3	545±96	10±2	98.2±0.8	4
P			0.782	0.137	0.576	0.230	0.152	

Table 2. Ppeak and Pmean in supine and prone at different time point

	Group	T_1	T_2	T_3	T_4	T_5
Ppeak (cmH_2O)	Supine	16.9±1.0	17.4±2.0	17.4±2.0	18.1±2.1	18.5±2.2
	Prone	16.6±3.5	16.9±2.1	17.7±2.2	17.8±2.4	18.8±2.3
	P	0.421	0.339	0.541	0.237	0.674
Pmean (cmH_2O)	Supine	6.0±1.1	7.2±1.0	7.1±1.0	6.9±1.1	7.0±1.0
	Prone	6.6±1.0	6.1±0.8	7.2±1.2	6.3±1.0	6.4±1.1
	P	0.129	0.158	0.524	0.212	0.189

Table 3. The parameters in supine and prone position

	Supine	Prone	*P*
PH	7.37 (7.32-7.41)	7.39 (7.34-7.38)	0.377
$PaCO_2$ (mmHg)	37.4 (34.1-44.7)	36.9 (35.7-43.6)	0.423
Pmean (cmH_2O)	6.5 (6.3-6.9)	6.8 (6.4-7.2)	0.512
Ppeak (cmH_2O)	17.8 (17.0-18.1)	17.4 (16.1-17.7)	0.315
PaO_2 (mmHg)	267.4 (244.1-272.6)$^{\#}$	452.5 (301.2-493.0)	<0.005
A-aO_2 (mmHg)	402.7 (396.1-422.4)$^{\#}$	213.3 (186.1-265.0)	<0.001

baseline values. (6) PEEP was decreased twice to obtain PEEP 5 cmH_2O. Thereafter, the ventilator was switched back to volume-controlled mode, as used before the VC manoeuvre.

Time design

10 min (S/PT_0) before induction of general anesthesia, 5 min (ST_1), 30 min (ST_2), 90 min (ST_3) after tracheal intubation, at the end of surgery (ST_4) and 5 min (ST_5) before tracheal extubation, 10 min (ST_6) after tracheal extubation while patients were in supine position. The moment turning supine to prone PT_1 (equating to the time ST_1), 30 min (PT_2), 90 min (PT_3) after tracheal intubation, at the end of surgery (PT_4) and the monment turning prone to supine PT_5 (equating to the time ST_5), 10 min (ST_6) after tracheal extubation while patients were in prone position.

Operative position

The patients were moved to a prone position involved supporting the upper chest and abdomen by a roll and allowing for free movement of the abdomen who had prone surgery at the time PT_1. The head was kept in the neutral position by placing it on a horse-shoe shaped head rest. After confirming that the fixed position of the tubes of the patient in the prone position did not change, the breath sounds of both lungs were confirmed by auscultation to be the same. That was adjusted to the patient's configuration for achieving best position as possible with airway pressure guidance. The patients in supine position did not need to change.

Parameters

A-aDO_2 was computed according to the following formula: A-aDO_2=PAO_2-PaO_2, PAO_2=(PB-47)× FiO_2-$PaCO_2$/R.

PB: atmospheric pressure, FiO_2: inhaled oxygen concentration, 47: the saturation water vapor pressure at 37°C, R: respiratory quotient (average 0.8).

Peak airway pressure and peak mean pressure were measured at the different time points.

Analyzing of blood gases

A sample of blood was obtained from the radial artery and analyzed with a blood-gas analyser (Radiometer ABL800, Denmark).

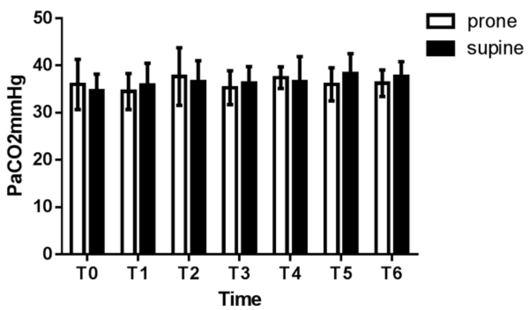

Figure 1. Comparison of $PaCO_2$ between supine and prone positions. And there was no significant difference in two groups.

Figure 2. Comparison of PH between supine and prone positions. And there was no significant difference in two groups.

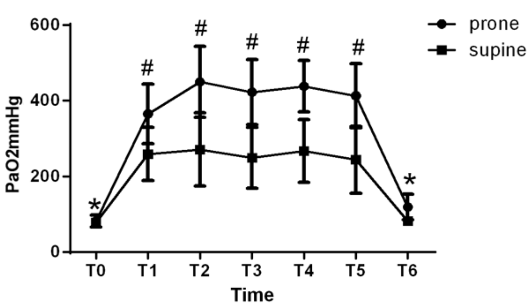

Figure 3. Comparison of PaO_2 between supine and prone positions. *; $P>0.05$, #; $P<0.05$.

Statistical analysis

For all statistic analyses except that (**Table 3**, data were analyzed using all measurements) are reported as the mean ± SD. Data analysis was performed by SPSS (version 13.0 for Windows, SPSS Inc, Chicago, IL, USA). Differences between positions were reported with 95% confidence interval. One-way analysis of variance was used for analysis of differences between groups at each time point. Data were submitted to repeated-measures ANOVA within group. A two-tailed probability value of $P<0.05$ was considered as statistically significant.

Results

Characteristics of participants were shown in **Table 1**. The two groups were similar with age, BMI, tidal volume and RR. The average surgical time was ranged between 1.5-2 h (mean 1.7±0.3).

Peak airway pressure (Ppeak) and peak mean pressure (Pmean) had no significant changes in the two positions (95% CI: 6.3-6.9 cmH_2O *VS.* 6.4-7.2 cmH_2O, $P=0.57$. 17.0-18.1 cmH_2O *VS.* 16.1-17.7 cmH_2O, $P=0.49$), and have no significantly statistical difference at the different time points in the same position ($P=0.42$), the results were listed in the **Tables 2** and **3**.

As shown in **Figures 1** and **2**, there was no significant difference in $PaCO_2$, PH in two positions (95% CI: 34.1-44.7 mmHg *VS.* 35.7-43.6 mmHg, $P=0.59$. 7.32-7.41 *VS.* 7.34-7.38, $P=0.78$), and no significant difference at the different time points in the same position, either.

PaO_2 and $A\text{-}aDO_2$ were significantly lower at T_0 (PT_0: PaO_2=82.44±15.92 mmHg, $A\text{-}aDO_2$=18.49±10.1 mmHg. ST_0: PaO_2=79.10±8.62, $A\text{-}aDO_2$=27.36±7.3), T_6 (PT_6: PaO_2=119.0±33.78 mmHg, $A\text{-}aDO_2$=38.8±26.0 mmHg. ST_6: PaO_2=82.15±8.01, $A\text{-}aDO_2$=30.53±6.2 mmHg). PaO_2 was markedly improved in prone position (95% CI 301.2-493.0 mmHg *VS.* 244.1-272.6 mmHg, $P<0.004$), but $A\text{-}aDO_2$ were markedly decreased (95% CI 186.1-265.0 mmHg *VS.* 396.1-422.4 mmHg, $P<0.001$), except the points T_0, T_6 (**Figures 3** and **4**).

Discussion

This study was undertaken to investigate the effects of prone position on lung function of patients undergoing mechanical ventilation under total intravenous anesthesia. Our results further showed patients undergoing mechanical ventilation under total intravenous anesthesia did not negatively affect the lung function in prone position, and the pulmonary ventilation function is better than in supine position.

We positioned our patients as described by Smith [7], assuring free abdominal movements, with upper chest and pelvic supports. This kind

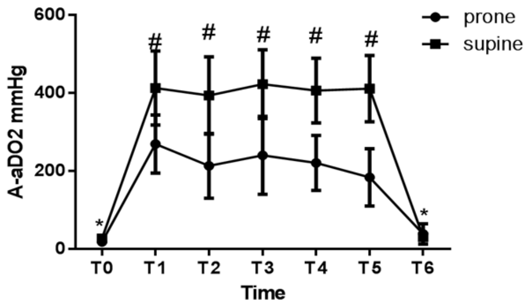

Figure 4. Comparison of A-aDO_2 between supine and prone positions. *; *P*>0.05, #; *P*<0.05.

of prone position could reduce the oppression of the chest and abdomen and increase the compliance of the lung compared with other kinds of prone position.

General anesthesia decreases functional residual capacity and compliance of the respiratory system, both of which are closely related to atelectasis [8]. Atelectasis alters surfactant function, stimulating alveolar macrophages, increasing pro-inflammatory cytokines, altering the permeability of the alveolar capillary membrane, and potentially predisposing the patient to ventilator-induced lung injury. However, atelectasis can be prevented and treated during the perioperative period through the open lung approach, which involves recruitment manoeuvres [9] and the application of PEEP [10]. There were many reports showing benefits of the use of PEEP in terms of oxygenation. Several studies showed that low levels of PEEP (5 cmH_2O) during one lung ventilation (OLV) improved oxygenation, but the higher levels were not better or were even worse because of over distension [11, 12]. Several reviews also have advocated for using low levels of PEEP (5 cmH_2O) during OLV [13, 14]. Therefore, our study applied low levels of PEEP (5 cmH_2O) in two groups.

With the development of modern anesthetic monitoring devices, the peak inspiratory pressure and peak mean pressure can be measured. By this, the respiratory dynamics can be monitored indirectly. When the amount of gas that expanded the lungs was constant, the increase in peak airway pressure was considered to be the state when the airway resistance increased, pulmonary compliance decreased, or both occurred simultaneously [15]. In this study, our results demonstrated that there is no difference between two groups in $PaCO_2$, and the influence of high carbonic acid on lung function can be excluded. Furthermore, no significant change was found in the peak airway pressure and the peak mean pressure at the same time potions in the prone position compared with the supine position. It implied that pulmonary compliance was not significantly different between two groups through the operation.

A-aDO_2 is the difference of oxygen partial pressure between alveolar gas and arterial blood [16]. It is an important index to judge the ability of oxygen diffusion in the lung. During the general anesthesia, the value of A-aDO_2 is closely related to alveolar oxygen partial pressure. With the alveolar oxygen partial pressure improving, A-aDO_2 decreases and pulmonary ventilation function improves. In the present study, PaO_2 and A-aDO_2 was significantly decreased at T_0, T_6 in the two positions. One explanation was that patients inhaled the air at T_0 and T_6. PaO_2 was significantly improved. Results confirmed that prone position could provide patients a more uniform lung perfusion, a more distributed V/Q matching and an increase in functional residual capacity compared with supine position under total intravenous anesthesia.

These experiments were repeated several times, and were carried out under double blind conditions in experiments. All results were in good agreement, indicating the results are valid and repeatable.

Taken together, our results indicated that mechanical ventilation under total intravenous anesthesia do not negatively affect the lung function when patients are in either prone or supine position, and the pulmonary ventilation function is better than that in supine position.

Disclosure of conflict of interest

None.

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