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Analysing the therapeutical action of lung recruitment maneuver on patients with acute respiratory distress syndrome by comparing different ventilation strategies.

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Abstract

Introduction: This study is to analyse the therapeutical action of Lung Recruitment Maneuver (LRM) on patients with Acute Respiratory Distress Syndrome (ARDS) by comparing different ventilation strategies.

Methods: In control group, patients' Positive End-Expiratory Pressure (PEEP), in Synchronized Intermittent Mandatory Ventilation (SIMV) plus PEEP model, were increased successively with the levels of 5 cm H_2O, 10 cm H_2O and 15 cm H_2O, and 60 min duration ventilation in every level. On the basis of control group, in test group excepting for LRM in the beginning of each level, SIMV plus PEEP model was taken, and patients' PEEP also increased successively with the levels of 5 cm H_2O, 10 cm H_2O and 15 cm H_2O, and 60 min duration ventilation in every level. Blood gas analysis was performed for patients. Oxygenation index (PaO_2/FiO_2), partial pressure of arterial carbon dioxide ($PaCO_2$), blood oxygen pressure (PaO_2), QS pulmonary shunt (Qs/Qt) and saturation of blood oxygen (SpO_2) were taken statistically and calculated.

Results: In test group, after lung recruitment maneuver, patients' SpO_2, PaO_2, PaO_2/FiO_2 and Qs/Qt were improved significantly ($P<0.05$). $PaCO_2$ of patients in two groups had significant difference only when PEEP was 10 cm H_2O, while in other levels the differences did not have significant difference ($P>0.05$).

Conclusion: LRM has remarkable curative effect on maintaining alveolar dilatation and improving pulmonary ventilation.

Keywords: Lung recruitment maneuver, Acute respiratory distress syndrome, Positive end expiratory pressure, Saturation of blood oxygen.

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Introduction

Acute Respiratory Distress Syndrome (ARDS) is a life-threatening respiratory system disease caused by various intrapulmonary and extra pulmonary pathogenic factors [1]. Hypoxemia, non-cardiogenic pulmonary oedema, pulmonary inflammation and lower of pulmonary compliance are its clinical characters [2]. Around the world, the mortality of ARDS was over 40% [3]. At present, the therapeutic methods for ARDS were mainly respiratory support and haemodynamic support assisted anti-inflammation, anti-shock, vascular dilation, free radical scavenging and so on [4]. Recently, different ventilation strategies emerged in endlessly, such as preset pressure ventilation and inverse ratio ventilation, prone position ventilation, and Synchronized Intermittent Mandatory Ventilation (SIMV). Lung Recruitment Maneuver (LRM) and Positive End-Expiratory Pressure (PEEP) combined with these ventilation strategies could open the collapsed pulmonary region and keep extension state in incomplete dilation region, which could reduce the risk of hypoxemia [5].

Participants and Methods

Participants

Inclusion criteria are: 1) Patients entered into ICU of Henan Provincial People's Hospital in 72 hours after suffering ARDS; 2) patients were in 20-65 years old; 3) patients with $PaO_2/FiO_2 \leq 250$ mmHg, who needed mechanical ventilation; 4) patients were treated with PEEP and LRM. Patients met the following criteria were excluded. (1) Patients suffered from pneumothorax, subcutaneous emphysema or pulmonary bullae, and severe chronic respiratory diseases. (2) Patients had intracranial hypertension or took craniocerebral operation recently. (3) Patients relied on breathing machine for a long time. (4) Patients suffered from neuromuscular disease. (5) Women were in pregnancy or in lactation. (6) Patients had contraindications to use pacemakers and automatic implantable cardioverter defibrillator and so on. This study was approved by the ethics committee of Henan Provincial People's Hospital.

Grouping

Patients were divided into control group and test group according to whether they treated with LRM. The control group was treated with SIMV plus PEEP. The test group was treated with SIMV plus LRM plus PEEP. In Table 1, the data showed that there was 60 patients in test group, with average age 46.3 years old and gender ratio (male/female) 36/24, and there was 60 patients in control group, with average age 48.6 years old and gender ratio (male/female) 31/29. The difference was not statistically significant.

Methods

Therapeutic method

After admission, unobstructed respiratory tract was kept. Electrocardiogram, heart rate, respiration and saturation of blood oxygen were routinely monitored. Arterial blood pressure and central venous pressure were dynamically monitored. Anti-shock was actively taken. Sufficient oxygen was inhaled without delay. Hormone and antibiotic were taken to resist inflammatory. Analgesic was taken to relieve pain. Patients were put trachea cannula to assist respiration according to their blood gas analysis results.

Bi-level positive airway pressure ventilation therapy apparatus were applied on patients to make SIMV plus PEEP. Parameter setting: Tidal Volume (VT) with 8-10 ml/kg, Respiratory Rate (RR) with 12-20/min, 60% concentration of oxygen inhalation (FiO_2), 1: 1.0-1.5 on Inspiration/Expiration (I/E). After getting 0 cm H_2O PEEP and 8 hours ventilation, patients could be in stable condition, and then the following study could continue.

In control group, patients' PEEP, in SIMV plus PEEP model, were increased successively with the levels of 5 cm H_2O, 10 cm H_2O and 15 cm H_2O, and 60 min duration ventilation in every level. On the basis of control group, LRM was taken in the beginning of each level in test group. At the moment, FiO_2 increased to 100%, and PEEP was 20 cm H_2O. After 2 min LRM, in SIMV plus PEEP model, PEEP also increased successively with the levels of 5 cm H_2O, 10 cm H_2O and 15 cm H_2O, and 60 min duration ventilation in every level. After the end of ventilation in each PEEP level, it returned to SIMV plus PEEP (0 cm H_2O) model. Through 2 hours ventilation, it could remove the effect of previous model on the following study.

During LRM, patients' circulatory system needed to be closely monitored. LRM would be terminated when appeared the following situations: arterial systolic blood pressure (SBP) was less than 90 mmHg; heart rate was no less than 140/min or added 20/min after LRM; arrhythmia led to fall of blood pressure; SpO_2 was less than 90% or reduced more than 5% after LRM.

Monitoring index

In the end of ventilation of SIMV plus PEEP (0 cm H_2O) model, patients' SpO_2 were detected. Mixed venous blood from pulmonary artery and femoral artery blood were drawn to take blood gas analysis. Patients' PaO_2/FiO_2, $PaCO_2$, PaO_2 and Qs/Qt were calculated.

In control group, after 50 min in each PEEP level, patients' blood were taken blood gas analysis, and patients' PaO2/FiO_2, $PaCO_2$, PaO_2, SpO_2 and Qs/Qt were taken statistically and calculated. In test group, except for the indexes mentioned above, patients' SpO_2 were detected in the end of LRM.

Statistical analysis

SPSS 21.0, a type of statistical analysis software, was used to analyse the data. Measurement data were showed as mean ± standard deviation. Enumeration data were showed as frequency. Chi-square test was applied to compare enumeration data between the two groups. T-test was applied to compare measurement data between the two groups. Differences of patients' PaO_2/FiO_2, $PaCO_2$, PaO_2, SpO_2 and Qs/Qt between two groups were analysed in the three levels of PEEP. When P was less than 0.05, the differences had statistical significance.

Results

General information

The 120 participants, treated in Henan Provincial People's Hospital from May, 2013 to December, 2015, were equally divided into the teat group and the control group. Patients in two groups had no significant differences in gender, age, blood pressure, heart rate, $PaCO_2$, PaO_2, PEEP and APACHE II on admission (P>0.05) (Table 1).

The therapeutical effect of LRM on ARDS

In test group, patients were taken LRM before the beginning of each PEEP level. Thus, compared with patients in control group, after LRM, SpO_2, PaO_2, PaO_2/FiO_2 and intrapulmonary shunt of patients in test group were improved significantly (Table 2). Especially, the differences of SpO_2 and oxygenation index in different PEEP level between two groups had statistical significance (P<0.05). The oxygenation index and saturation of blood oxygen of patients in test group were significantly higher than those in control group. $PaCO_2$ of patients in two groups had significant difference only when PEEP was 10 cm H_2O. While PEEP was in other levels, the differences had no statistical significance (P>0.05) (Table 3).

Table 1. General information.

Characteristic		Test group (n=60)	Control group (n=60)	P
Age, mean (year)*		46.3 ± 10.2	48.6 ± 9.7	0.208
Gender#	Male	36	31	0.358
	Female	24	29	
Heart rate*		70.6 ± 15.3	72.1 ± 17.8	0.622
Mean arterial pressure*		71.3 ± 20.1	73.2 ± 18.9	0.595

APACHE II*	20.3 ± 5.7	19.6 ± 6.0	0.514
$PaCO_2$*	43.3 ± 7.3	42.6 ± 8.2	0.622
PaO_2*	69.8 ± 12.6	68.3 ± 11.9	0.504
PEEP*	9.7 ± 3.9	10.6 ± 4.3	0.232
Note: *T-test was applied. #Chi-square test was applied.			

Table 2. *After LRM, patients' SpO_2 in test group.*

Index	PEEP (5 cm H_2O)	PEEP (10 cm H_2O)	PEEP (15 cm H_2O)
SpO_2	0.913 ± 0.026	0.931 ± 0.033	0.941 ± 0.030

Table 3. *Respiratory mechanical index of patients in two groups in different PEEP level.*

Characteristic	PEEP	Test Group (n=60)	Control Group (n=60)	P
$PaCO_2$	5 cm H_2O	35.6 ± 10.3	37.2 ± 11.2	0.417
	10 cm H_2O	34.2 ± 6.5	36.8 ± 7.2	0.040
	15 cm H_2O	34.8 ± 6.9	35.8 ± 8.1	0.468
PaO_2	5 cm H_2O	76.3 ± 15.5	71.4 ± 11.1	0.049
	10 cm H_2O	89.8 ± 23.6	81.1 ± 21.3	0.020
	15 cm H_2O	94.5 ± 30.9	87.6 ± 22.4	0.164
PaO_2/FiO_2	5 cm H_2O	139.6 ± 22.8	130.7 ± 24.9	0.043
	10 cm H_2O	186.8 ± 44.6	170.3 ± 35.1	0.026
	15 cm H_2O	209.3 ± 42.6	191.6 ± 49.8	0.039
SpO_2	5 cm H_2O	0.932 ± 0.031	0.921 ± 0.023	0.029
	10 cm H_2O	0.954 ± 0.030	0.934 ± 0.031	0.005
	15 cm H_2O	0.968 ± 0.043	0.951 ± 0.036	0.021
Qs/Qt	5 cm H_2O	28.9 ± 7.7	32.6 ± 11.2	0.037
	10 cm H_2O	24.3 ± 6.2	26.7 ± 8.6	0.082
	15 cm H_2O	21.2 ± 5.9	23.6 ± 6.8	0.041
Note: T test was applied.				

Discussion

The pathological characteristics of ARDS was that reduced alveolar surfactant could expand alveolar surface tension and make alveolar collapse, which further caused patients with insufficient blood oxygen and dysfunctional systems [6]. A research showed that in pathophysiological process of ARDS alveolar collapse was connected with oedema caused by inflammatory response [7]. And for patients with damage of pulmonary function after cardiovascular surgery, LRM combined with PEEP could effectively improve oxygenation, broaden EELV, reduce damage of lung and increase the cure rate [8]. In LRM, resistance from thoracic wall should be overcome to form transpulmonary pressure to open collapsed alveolus. Once alveolus was opened, low pressure should be maintained to avoid alveolus collapsing again [9]. After LRM, pulmonary volume could significantly broaden, which increased ventilation volume of patients. The majority of LRM happened in the first several minutes during the continual inflation [10], while the treatment time was of vital importance to the change of patients' haemodynamic.

Our research showed that for patients taken LRM, the partial pressure of blood oxygen, oxygenation index and saturation of blood oxygen obviously increased. The reason was that PEEP combined with LRM could better open collapsed alveolus to broaden contact area of gas and blood, which greatly helped oxygen diffuse into blood through alveolar membrane. However, there were no changes in $PaCO_2$. The reason was that Pa-ET CO_2 in artery and mixed vena was significantly lower than Pa-ET O_2, and CO_2 dissociation curve was a straight line, which helped compensation to avoid CO_2 retention. Long-time dysfunction ventilation could lead to CO_2 retention, reduced oxygenation, and minished ventilation perfusion ratio [11]. Due to the increased oxygen diffused into blood from lung, intrapulmonary shunt of patients in test group was significantly lower than that in control group.

A large number of experimental studies showed that LRM could not only improve pulmonary ventilation through continuous ventilation but also have fewer adverse reactions and decreased incidence rate of pneumothorax and so on [12]. Simultaneously, LRM could improve the function of heart, especially the ventriculus dexter [13]. In clinical practices, LRM is simple to operate and easy to implement, so it is worth using widely according to patients' conditions.

Conclusion

The results showed that after treated with LRM, SpO_2, PaO_2, PaO_2/FiO_2 and Qs/Qt of patients in test group were obviously improved compared with those in control group ($P<0.05$). Especially, in different PEEP levels, patients' PaO_2/FiO_2 and SpO_2 in test group were obviously higher than those in control group. And only when PEEP was 10 cm H_2O, $PaCO_2$ in the two groups were significantly different. There was no statistically significant in other PEEP level. The results indicate that LRM has a significant effect on maintaining alveolar ectasia and improving pulmonary ventilation.

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