Original Article

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TANAFFOS

Comparing the Effect of Respiratory Physiotherapy and Positive End-Expiratory Pressure Changes on Capnography Results in Intensive Care Unit Patients with Ventilator-Associated Pneumonia

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Background: While critically ill patients experience a life-threatening illness, they commonly develop ventilator-associated pneumonia (VAP) which can increase morbidity, mortality, and healthcare costs. The present study aimed to compare the effect of respiratory physiotherapy and increased positive end-expiratory pressure (PEEP) on capnography results.

Materials and Methods: This randomized control clinical trial was performed on 80 adult patients with VAP in the intensive care unit (ICU). The patients were randomized to receive either PEEP at 5 cm H_2O, followed by a moderate increase in PEEP to 10 cm H_2O, or PEEP at 5 cm H_2O with respiratory physiotherapy for 15 min. The numerical values were recorded on the capnograph at minutes 1, 5, 10, 15, and 30 in both methods. Data collection instruments included a checklist and MASIMO capnograph.

Results: As evidenced by the obtained results, the two methods significantly differed in the excreted pCO_2 (partial pressure of carbon dioxide) ($P<0.0001$). However, the average amount of excreted pCO_2 was higher in the respiratory physiotherapy and PEEP intervention (38.151mmHg) in comparison with increasing PEEP alone method (36.184mmHg). Also, PEEP elevation method prolonged the time of the first phase (inhalation time) and the second phase while shortening the third phase (exhalation time) in capnography waves.

Conclusion: CO_2 excretion in patients with VAP increased after respiratory physiotherapy. Further, physiotherapy demonstrated more acceptable results in CO_2 excretion compared with PEEP changes in mechanically ventilated patients.

Keywords: Respiratory Physiotherapy; Positive End-Expiratory Pressure Changes; Capnography; Ventilator-Associated Pneumonia

INTRODUCTION

Ventilator-associated pneumonia (VAP) is a pneumonia that occurs 48-72 hours after endotracheal intubation. It complicates the course of 8 to 28% of patients receiving mechanical ventilation (MV) (1). In contrast to infections of more frequently involved organs (e.g., urinary tract and skin), for which mortality is low (ranging from 1 to 4%), the mortality rate for VAP ranges from 24 to 50%. It can reach as high as 76% in some specific settings or when high-risk pathogens cause lung infection (1-4). Beyond mortality, the economic burden of VAP includes increased ICU lengths of stay (LOS) (from 4 to 13 days) and incremental costs associated with VAP which is estimated at between $5,000 and $20,000 per diagnosis (5).

Identifying the causative organism and local resistance patterns in the ICU is crucial in selecting the appropriate method of drug therapy. However, it's worth noting that VAP (Ventilator-Associated Pneumonia) can have adverse effects on arterial oxygen tension and carbon dioxide removal efficiency due to factors such as increased whole-body oxygen uptake, intrapulmonary shunt, ventilation-perfusion mismatching, and limited alveolar-end capillary oxygen diffusion. (6, 7). As a result, improving the oxygenation status and increasing CO_2 excretion can be considered as primary supportive treatment.

Positive end-expiratory pressure (PEEP) can be one of the reasonable options to enhance oxygenation. This increases the solubility of oxygen as well as its ability to cross the alveolocapillary membrane and boosts the oxygen content in the blood. Also, increasing PEEP can be used to improve ventilation-perfusion (V/Q) mismatches (8). The application of positive pressure inside the airways can open or "splint" airways that may otherwise be collapsed, decrease atelectasis, improve alveolar ventilation, and, in turn, reduce V/Q mismatch which occurs due to VAP (9-11). However, this can have some drawbacks. Indeed, high PEEP can lead to barotrauma, hemodynamic disturbances, pneumothorax, bronchopleural fistula, hypovolemia, intracardiac shunting, subcutaneous emphysema, and increased intracranial pressure (8). In other words, the positive effects of PEEP depend on the ability of the lung tissue to regenerate in different patients.

On the other hand, retention of airway secretions is a common and severe problem in ventilated patients. The possible solutions include treating or preventing secretion retention through mucus thinning, patient positioning, airway suctioning, and chest or airway vibration/percussion. Recent studies have suggested that early mobilization is effective for respiratory infections. However, respiratory care may be necessary for airway clearance during the inflammatory phase of pneumonia. Respiratory physiotherapy is highly recommended to improve the ventilation of patients with VAP (12). This study aimed to compare the effect of respiratory physiotherapy and PEEP changes on capnography results in patients with VAP to determine a safe and effective measure to reduce the V/Q mismatch and promote carbon dioxide removal.

MATERIALS AND METHODS

This randomized controlled study was performed in a 10-bed adult intensive care unit (ICU) during April 2019 and November 2019. This study was approved by the Ethics Committee of the School of Nursing and Midwifery of Sabzevar University of Medical Sciences (Code of ethics: IR.MEDSAB.REC.1397.050) and registered in the Iranian registry for clinical trials with IRCT number: IRCT20181105041567N1. Consent was obtained from at least one parent or legal guardian before enrollment. Overall, 80 patients aged 18 to 80 years undergoing mechanical ventilation with the diagnosis of ventilator-related pneumonia with positive trachea culture were included in the study.

The allocation sequence was generated by a computerized random generation program stratified by two groups: receiving either respiratory physiotherapy or high PEEP in the ICU.

The inclusion criteria were as follows: patients aged between 18 and 80 years with a tracheal tube undergoing mechanical ventilation with PEEP, VAP-positive tracheal culture, absence of any previous infections, eligible patients to receive PEEP, malnutrition, and moderate to severe anemia (for men Hb<12, for women, Hb<10).

The exclusion criteria consisted of systolic blood pressure less than 90 mm Hg, symptoms of increased intracranial pressure, rib fractures, chest tubes, pressure ulcers in the scapular region, fractured cervical and lumbar vertebral and immobilization, as well as abdominal and chest surgeries. Exclusion criteria during the study were considered patients with peak inspiratory pressure (P-mean) less than 10 cm H_2O on the ventilator, removal of the endotracheal tube, and cardiopulmonary resuscitation during the study.

Patients were randomized to receive positive end-expiratory pressure at 5 cm H_2O, followed by a moderate increase in PEEP to 10 cm H_2O for 30 min (13-15), or PEEP at 5 cm H_2O with two cycles of respiratory physiotherapy which involved percussion clapping of the chest with a cupped hand of the anterior and posterior thorax performed by a nurse at the first 5 min. Thereafter, they received thoracic vibration (anterior and posterior) via a vibrator with a frequency of 5 Hz and a mean maximum force of 272N directly on the chest (16) by a nurse for 10 min (17, 18). Throughout the intervention, all procedures were performed under the supervision of an ICU resident anesthesiologist. The numerical values that were displayed on the capnograph at minutes 1, 5, 10, 15, and 30 were recorded on the chart in both methods.

All data were analyzed using IBM SPSS 22.0 (IBM, Armonk, NY, USA). Descriptive statistics have been presented as mean ± SD for continuous variables and as numbers and percentages for categorical variables. Since the distribution of continuous variables was not normal according to the Shapiro–Wilk test, they were analyzed using Mann–Whitney U test for between-group comparisons and Freidman's test for repeated measures. Differences were considered significant when the P value was less than 0.05.

RESULTS

In this study, 80 patients (66 men and 14 women) with a mean age of 47.43±9.98 years were studied. The mean Glasgow coma score (GCS) of the patients was 6.46±2.64. All patients had been hospitalized due to cerebral hemorrhage. Acinetobacter was the most common pathogen resulting from tracheal culture (32.5%) followed by *Staphylococcus aureus* (22.5%). Tracheal suctioning was performed three times a day on average.

There was no significant difference in baseline characteristics between the two groups (Table 1). Both chest physiotherapy at 5 cm H_2O PEEP (CPS-5) and PEEP-5-to-10 cm H_2O were associated with a significant increase in $ETCO_2$ (Table 2). On the other hand, except for pre-intervention, at all other time points, $ETCO_2$ was higher in the CPS-5 group than in the PEEP 5-to-10 cm H_2O group, indicating its better performance (Table 2).

Finally, Table 3 reports the average time of each phase of the capnograph. As seen, PEEP-5-to-10 cm H_2O was associated with significant changes in the capnograph phases which were more significant in the second phase. However, the changes in the CPS-5 group were not significant.

Table 1. Baseline characteristics of the patients

Group / Variable	CPS-5 (n=40)	PEEP-5-to-10 (n=40)	P.value
Age (years)	47.51±11.58	47.35±8.29	0.617
BMI (Kg/m²)	26.70±6.27	27.47±5.62	0.546
GCS	6.92±2.55	6.02±2.67	0.151
Male (%)	35 (87.5%)	31 (77.5%)	0.239

PEEP-5-to-8; increasing PEEP from 5 cmH_2O to 10 cmH_2O. CPS-5; chest physiotherapy at 5 cmH_2O PEEP

Table 2. Comparison of $ETCO^2$ based on the intervention

Group / Time point	CPS-5 (n=40)	PEEP-5-to-10 (n=40)	P.value*
0th min	35.817±4.840	35.312±5.521	0.725
1th min	36.187±5.688	35.550±5.654	<0.001
5th min	37.237±5.796	35.825±5.557	<0.001
10th min	38.312±5.703	36.337±5.736	<0.001
15th min	39.175±5.980	36.525±5.802	<0.001
30th min	39.862±6.077	36.700±5.704	<0.001
P-value**	<0.001	<0.001	

*: independent samples

**: repeated measures

PEEP-5-to-10; increasing PEEP from 5 cmH2O to 10 cmH2O. CPS-5; chest physiotherapy at 5 cmH2O PEEP

Table 3. Comparison of duration of capnography phases based on the intervention

Phase	Group	CPS-5 (n=40)	PEEP-5-to-10 (n=40)	P.value*
	0th min	1.739±0.134	1.731±0.421	0.847
	1th min	1.741±0.184	1.736±0.184	<0.001
	5th min	1.739±0.18185	1.739±0.184	0.750
Phase 1	10th min	1.741±0.184	1.740±0.185	0.306
	15th min	1.741±0.185	1.740±0.184	0.102
	30th min	1.740±0.183	1.740±0.184	0.714
	P-Value**	0.230	<0.001	
	0th min	0.138.4±0.024	0.121±0.004	<0.001
	1th min	0.145±0.005	0.10±0.002	<0.001
	5th min	0.134±0.004	0.128±0.004	0.384
Phase 2	10th min	0.128±0.004	0.144±0.004	0.028
	15th min	0.134±0.004	0.135±0.004	0.853
	30th min	0.134±0.004	0.142±0.004	0.052
	P-Value**	0.119	<0.001	
	0th min	2.934±0.512	2.933±0.521	0.078
	1th min	2.935±0.524	2.939±0.524	0.002
	5th min	2.935±0.523	2.948±0.521	0.793
Phase 3	10th min	2.936±0.525	2.936±0.523	0.521
	15th min	2.937±0.523	2.935±0.5225	0.220
	30th min	2.936±0.523	2.936±0.523	0.481
	P-Value**	0.351	0.011	

*: independent samples

**: repeated measures

PEEP-5-to-10; increasing PEEP from 5 cmH2O to 10 cmH2O. CPS-5; chest physiotherapy at 5 cmH2O PEEP

DISCUSSION

We compared the capnography results between increasing PEEP from 5 to 10 cm H_2O (PEEP-5-to-10) with chest physiotherapy at 5 cm H_2O PEEP (CPS-5) in 80 patients with VAP. Overall, the results revealed that both the PEEP-5-to-10 and the CPS-5 are associated with an increase in $ETCO_2$, suggesting improved ventilation. In addition, the rise of $ETCO_2$ was more significant following the CPS-5, meaning the better performance of CPS.

Since VAP fills the alveoli with respiratory secretions, the thickness of the membrane increases. Also, it can lead to diminished lung volume, functional residual capacity (FRC), lung compliance, and surfactant activity, resulting in gas exchange impairments (19, 20). The beneficial effects of PEEP and CPS are based on improving these pathological changes. CPS, especially head-down maneuvers, facilitates the movement and drainage of secretions (12, 21-24). Whereas, PEEP helps improve gas exchange by promoting the opening of the alveoli and preventing their collapse (25). PEEP also reduces the leakage of pharyngeal secretions into the lower airways (26).

Although CPS and PEEP are among the primary measures performed in patients with respiratory failure, to our knowledge, this is the first survey comparing the efficacy of the PEEP-5-to-10 with CPS-5. Studies have reported conflicting therapeutic and preventing effects for PEEP and CPS regarding VAP. The study by Ferrel et al (27) indicated that an increase in the initial PEEP of 5 cm H_2O to 6 cm H_2O was associated with a significant reduction in ventilator-associated events. In contrast, in the study by Garcia et al. (28), there was no difference in VAP events between PEEP settings of 5 cm H_2O and 8 cm H2O. Another research by de Jong et al. (29) showed that the protective effects of PEEP would depend on the type of intervention so that the beneficial effects were observed in abdominal surgeries but not in craniotomy. Regarding the treatment of acute respiratory distress syndrome (ARDS), a meta-analysis by Briel et al. (30) revealed that higher levels of PEEP were associated with reduced mortality compared to lower levels. However, some studies have shown that higher levels of PEEP are associated with improved outcomes only in selected patients (31, 32). Although capnography results were not assessed in these studies, similar to our study, they show that elevation of PEEP is associated with improved ventilation in pulmonary compromised patients.

The effects of CPS have also been studied on the treatment and prevention of VAP as well as other types of pneumonia, though the results of capnography have been less studied. In a study by Pattanshetty and Gaude (33), multimodality CPS was associated with reduced mortality and incidence of VAP in mechanically ventilated patients. Also, in the study by Kubo et al. (34), CPS was associated with a reduction in the incidence of pneumonia following inhalation injury in both ICU and ward-admitted patients.

However, opposite results have also been reported. For example, in the study by Wang et al. (35), CPS was not associated with a reduction in the incidence of VAP or mortality in mechanically ventilated patients. The results on the therapeutic benefits of CPS are also contradictory. In most studies, CPS has not been associated with reduced mortality (36-40). It has even been observed that CPS could be associated with increased duration of fever and hospital stay in young patients and smokers (41). However, some studies point to its essential effects in treating pneumonia and improving physical function in ICU survivors (42-44). Overall, in patients with high sputum production, CPS can help facilitate sputum clearance and has been recommended in many cases (23, 45-47). Notably, we examined the effects of CPS and PEEP on capnography parameters, while the mentioned studies have mainly examined mortality.

In our study, capnography waveforms were significantly different in the PEEP-5-10 group, while these changes were not significant in the CPS-5 group. As mentioned above, the effects of PEEP and CPS may be different in prevention and treatment as well as patients' conditions; so, the study population is influential when comparing the results.

This study had some limitations. Firstly, the study was conducted at a single center with a relatively small sample size. Secondly, although CPS and increasing PEEP were associated with improved capnography parameters, we did not evaluate the effect of these interventions on VAP outcomes, including length of hospital stay and intubation, course of antibiotic therapy, and mortality.

CONCLUSION

Both PEEP-5-to-10 and CPS-5 were associated with a rise in ETCO2, while the increase in ETCO2 was greater in the CPS-5 group. Also, unlike CPS-5, the capnography waveform changed with increasing PEEP.

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