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BRIEF REPORT

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Short-term effects of prone position in chronic obstructive pulmonary disease patients with severe acute and hypercapnic respiratory failure

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Abstract *Objective:* To assess the short-term effects of prone positioning (PP) in chronic obstructive pulmonary disease (COPD) patients with severe hypoxemic and hypercapnic respiratory failure requiring invasive mechanical ventilation. *Design and setting:* Prospective observational study in the general intensive care unit of a university-affiliated hospital. *Patients:* 11 consecutive COPD patients with persistent hypoxemia ($PaO_2/FIO_2 \leq 200$ mmHg with $FIO_2 \geq 0.6$) and hypercapnia requiring invasive mechanical ventilation. Patients with adult respiratory distress syndrome or left ventricular failure were excluded. Mean age was 73±11 years, mean weight 86±31 kg, mean SAPS II 53±10, and ICU mortality 36%. *Interventions:* Patients were turned every 6 h. *Measurements and results:* A response to PP (20% or greater PaO_2/FIO_2 increase) was noted in 9 (83%) patients. Blood gases were measured in the PP and supine (SP) positions 3 h after each turn, for 36 h, yielding six measurement sets (SP1, PP1, SP2, PP2, SP3, and PP3). PaO_2/FIO_2 was significantly better in PP: 190±26 vs. 113±9 mmHg for PP1/SP1, 175±22 vs. 135±16 mmHg for PP2/SP2, and 199±24 vs. 151±13 mmHg for PP3/SP3. After PP1 PaO_2/FIO_2 remained significantly improved, and the PaO_2/FIO_2 improvement from SP1 to SP2 was linearly related to PaO_2/FIO_2 during PP1 (r=0.8). The tracheal aspirate volume improved significantly from SP1 to PP1. $PaCO_2$ was not significantly affected by position. *Conclusions:* PP was effective in treating severe hypoxemia in COPD patients. The first turn in PP was associated with increased tracheal aspirate.

Keywords Chronic obstructive pulmonary disease · Prone position · Mechanical ventilation

Introduction

When instituted promptly, treatment with antibiotics, steroids, oxygen, and noninvasive mechanical ventilation (MV) is successful in most patients with acute exacerbation of chronic obstructive pulmonary disease (COPD) [1, 2]. However, invasive MV is required in the most serious cases. In spite of this treatment some patients remain severely hypoxemic and hypercapnic [3]. Hypoxemia is independently associated with death in these patients [4]. In our institution we use prone positioning (PP) routinely in patients with severe hypoxemic respiratory failure, including those with COPD [5]. Moreover, COPD exacerbation is characterized by increased sputum, and PP may enhance bronchial secretion drainage. We designed a prospective study in COPD patients with severe acute hypoxemic and hypercapnic respiratory failure to assess the short-term effects of PP on hypoxemia and bronchial secretion drainage.

Materials and methods

COPD patients receiving invasive MV were treated with intermittent PP if they met the criteria used routinely in our unit, namely PaO_2/FIO_2 remaining at or below 200 mmHg despite FIO_2 being 0.6 or higher. The diagnosis of COPD was based on medical history, physical examination, chest radiography, and, if available, previous lung function tests [2]. Exclusion criteria were acute left ventricular failure, pulmonary embolism, adult respiratory distress syndrome, contraindication to PP (unstable hemodynamics or fractures), and decision to withhold or withdraw therapy. According to French law on biomedical research, neither ethics committee approval nor informed consent from the patients or relatives was required for this observational study that involved no specific therapeutic interventions or additional investigations as compared to routine practice in our ICU.

All patients were deeply sedated with continuously infused midazolam and fentanyl. Siemens Servo-300 or Taema Horus ventilators were used, with volume-controlled ventilatory mode and constant inspiratory flow. Settings were as follows: respiratory rate 16±1/min, tidal volume (VT) 7.2±1.8 ml/kg, ratio of inspiratory time over expiratory time (Ti/Te) 0.27±0.03, and extrinsic positive end-expiratory pressure (PEEP), 7±3 cmH_2O. The maximum tolerated inspiratory plateau pressure was 28 cmH_2O.

Each patient was turned every 6 h. In PP the head was kept slightly elevated on a pillow and the rest of the body horizontal in a physiological position with cushions under the trunk and the arms by the sides; to limit the risk of facial injury the head was turned from one side to the other midway through each 6-h PP period. When supine, the patients were in a semirecumbent position. Tracheal suctioning was performed routinely after each turn and before each set of respiratory measurements (including baseline); additional suctioning was carried out as needed. The nurses in our unit are trained to perform routine semiquantitative assessments of tracheal aspirates. Suctioning is recorded on the patient's chart with the following assessments: "0" for no secretions, "+" for moderate secretions, "++" for abundant secretions, and "+++" for very abundant secretions.

During the 36-h study, there were six consecutive 6-h periods of alternating supine position (SP) and PP, as follows: SP1 (baseline), PP1, SP2, PP2, SP3, and PP3. Patient characteristics were recorded before PP1. Arterial blood gases were measured 3 h after the start of each period.

Mean values of quantitative data (PaO_2/FIO_2 and $PaCO_2$) in the PP and SP were compared using the Newman-Keuls test. Median tracheal aspirate semiquantitative scores in the PP and SP were compared using the Friedman test. Differences with p values less than 0.05 were considered statistically significant.

Results

Eleven consecutive patients with a medical history of COPD were included over a 6-month period; at baseline their mean age was 73±11 years, body weight 86±31 kg, Simplified Acute Physiology Score II 53±10, and pH was 7.28±0.11. All had chronic cough, sputum production, dyspnea, and factors associated with COPD (smoking and/or chronic work-related dust exposure, n=7; asthma, n=2; and previous severe tuberculosis, n=2). Spirometry was performed in only four patients (all with forced expiratory volume 1 s less than 40% of predicted). Vasoactive drugs were used in five patients. The mortality rate was 36%. A patient with multiorgan failure received a single PP period (PP1) but was considered moribund and withdrawn from the study after SP2. No clinically relevant deleterious events occurred in the PP.

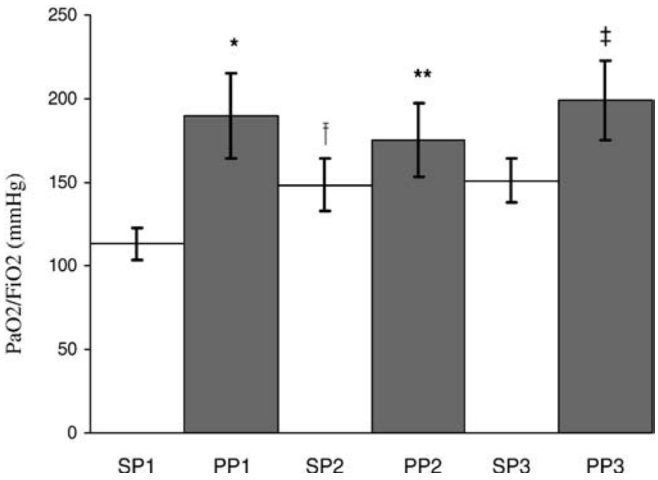

Fig. 1 Variations in PaO_2/FIO_2 according to patient position. $^*p<0.001$ vs. SP1, $^{\neq}\ p<0.05$ vs. SP1, $^{**}p<0.05$ vs. SP2, $^{\ddagger}p=0.01$ vs. SP3

Compared to SP, significant improvements in PaO_2/FIO_2 occurred in PP1 (190±26 vs. 113±9 mmHg in SP1; $p<0.001$), PP2 (175±22 vs. 135±16 mmHg in SP2; $p<0.05$), and PP3 (199±24 vs. 151±13 mmHg in SP3; $p=0.01$; Fig. 1). After PP1 9 of the 11 patients (83%) had at least 20% increases in PaO_2/FIO_2 and were classified as responders (Table 1). PaO_2/FIO_2 increased by 4% in one of the nonresponders and decreased by 3% in the other. One of these two patients responded to PP2. The other patient was withdrawn after SP2, as explained above. Of the 9 responders to PP1, 6 were persistent responders, i.e., experienced persistence during SP2 of some of the improvement obtained during PP1. Mean PaO_2/FIO_2 was 29% higher in SP2 than in SP1 (Fig. 1; $p<0.05$). The analysis of individual patients showed that higher PaO_2/FIO_2 values obtained during PP1 were associated with a greater increase between SP1 and SP2 (Pearson correlation coefficient r=0.8, $p<0.001$). When we considered all the SP-PP-SP sequences in the study, we found that the PaO_2/FIO_2 increase between two SP periods was linearly related to the PaO_2/FIO_2 value obtained in PP (Pearson correlation coefficient r=0.54, $p<0.01$).

$PaCO_2$ did not vary significantly with position (61±9 mmHg in SP1 vs. 56±7 mmHg in PP1, 56±9 mmHg in SP2 vs. 62±12 mmHg in PP2, and 60±10 mmHg in SP3 vs. 59±11 mmHg in PP3). Semiquantitative assessments of tracheal aspirates showed a significant increase in median values during PP1 compared to SP1:2 (interquartile range 2–4) in PP1 vs. 1.5 (0–2) in SP1 ($p<0.05$). Changes during PP2 and PP3 were not signifi-

Table 1 Characteristics of the study patients. Time to PP was the time from initiation of endotracheal mechanical ventilation to the first turn in the prone position (hours). Criteria for prone positioning were predefined as $PaO_2/FIO_2 \leq 200$ with $FIO_2 \geq 0.6$. Pneumonia was defined as the concomitant presence at admission of a new pulmonary lobar infiltrate on the chest radiograph, a temperature higher than 38.5°C, and a positive result from a bronchoscopy specimen culture. (*PEEP* extrinsic positive end-expiratory pressure, *SAPS II* Simplified Acute Physiology Score II)

Patient no.	Sex	Age (years)	Weight (kg)	SAPS II	Cause of exacerbation	Time to PP	PaO_2 (mmHg)	FIO_2	PEEP (cmH_2O)	$PaCO_2$ (mmHg)	ICU mortality
1	F	45	44	51	Bronchitis	72	81	0.6	5	72	Alive
2	M	80	90	57	Bronchitis	20	86	0.7	5	70	Dead
3	M	73	71	68	Pneumonia	24	79	0.8	5	56	Dead
4	M	79	94.6	60	Bronchitis	48	104	0.6	9	86	Dead
5	M	81	103	49	Bronchitis	16	84	0.6	10	45	Alive
6	F	78	112	47	Pneumonia	20	92	0.9	5	55	Alive
7	M	81	45	55	Pneumonia	144	80	0.6	4	66	Alive
8	M	73	75	68	Pneumonia	196	67	0.8	8	72	Dead
9	M	57	123	31	Pneumonia	18	63	1	5	53	Alive
10	M	75	134	52	Bronchitis	40	58	1	15	59	Alive
11	M	76	56.8	48	Bronchitis	24	69	0.6	5	63	Alive

cant: 0 (0–2) in SP2 vs. 2 (1–3) in PP2 and 0.5 (0–2) in SP3 vs. 2 (2–2) in PP3.

Discussion

Hypoxemia, acidosis, and extrapulmonary organ failure have been associated with increased mortality in COPD patients with acute respiratory failure [6, 7]. PP has produced lasting oxygenation improvements in 60–70% of patients in various clinical settings including acute respiratory distress syndrome, pneumonia, lung trauma, heart failure, and aspiration [8, 9, 10, 11, 12]. Moreover, PP has a very low-cost, a good-safety profile, and an ability to minimize ventilator-induced lung injury [13, 14, 15, 16]. Although no beneficial effects on survival have been found, these data have led many clinicians to include PP in their management protocols. At our institution PP is used routinely in patients with severe hypoxemic respiratory failure, including those with COPD. A recent study reported improvements in lung mechanical behavior and gas exchange in ten COPD patients receiving MV in the PP [17]. However, this study used an experimental design and included a single turn of the patients with a very brief period of PP (65–75 min). In the present study 83% of COPD patients responded to PP. Our PaO_2/FIO_2 value required for inclusion was similar or more severe than those reported in previous studies. Response rates and PaO_2/FIO_2 improvements were at the higher end of the range of values reported in similar studies of patients with other conditions [8, 9, 10, 11, 12, 14]. Furthermore, after PP PaO_2/FIO_2 remained significantly improved in the SP as compared to baseline, and improvements were proportional to the PaO_2/FIO_2 value in the PP. Thus the beneficial effects obtained during PP may persist after the patient is turned back to the SP.

The design of the present study precludes conclusions regarding the mechanisms involved in the PaO_2/FIO_2 improvement provided by PP in our COPD patients. In theory, mechanical factors that may produce beneficial effects during PP in patients with acute lung injury/acute respiratory distress syndrome include better drainage of secretions, greater uniformity in ventilation distribution, and decreased ventilation-perfusion heterogeneity [18, 19, 20]. Whether these factors are operative in COPD patients is unknown. However, abnormalities reported in COPD patients include increased mucus secretion, airflow limitation, and gas exchange abnormalities [2]. The improved drainage of bronchial secretions found in our study may benefit oxygenation by reducing areas of atelectasis and improving the distribution of ventilation.

Our study has several limitations. First, the observational design precluded an assessment of the effect of time since ICU admission comparatively with a control group. Thus the PaO_2/FIO_2 improvement observed in our study during PP may not be entirely ascribable to PP. Second, no validated method for evaluating the drainage of bronchial secretions is available. We used semiquantitative assessment of the tracheal aspirate volume. Although this method has not been validated, it is used routinely in our ICU, and the nurses are thoroughly familiar with it. Third, despite the beneficial effects of PP the absence of proof that survival improves continues to generate controversy about the use of PP in patients receiving MV [14]. Studies are needed to assess potential effects on survival.

This study indicates that prone positioning deserves consideration in COPD patients with severe hypoxemia requiring invasive MV ventilation. Prone positioning was associated with improved bronchial secretion drainage.

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