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Short-term effects of prone position in critically ill patients with acute respiratory distress syndrome

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Abstract. *Objective:* Changing the position from supine to prone is an emerging strategy to improve gas exchange in patients with the acute respiratory distress syndrome (ARDS). The aim of this study was to evaluate the acute effects on gas exchange, hemodynamics, and respiratory system mechanics of turning critically ill patients with ARDS from supine to prone.
Design: Open, prospective study.
Setting: General intensive care units.
Patients: 23 patients [mean age 56 ± 17 (SD) years] who met ARDS criteria and had a Lung Injury Score > 2.5 (mean 3.25 ± 0.3).
Interventions: The decision to turn a patient was made using a protocol based on impaired oxygenation despite the use of positive end-expiratory pressure and a fractional inspired oxygen (FIO_2) of 1.
Measurements and results: We measured gas exchange and hemodynamic variables in all patients and in 16 patients calculated respiratory system compliance when they were supine and 60 to 90 min after turning them to a prone position. This latter position was remarkably well tolerated, and no clinically relevant complications or events were detected either during turning or while prone. The partial pressure of oxygen in arterial blood (PaO_2)/FIO_2 ratio improved from 78 ± 37 mm Hg supine to 115 ± 31 mm Hg prone ($p < 0.001$), and intrapulmonary shunt decreased from 43 ± 11 to 34 ± 8 % ($p < 0.001$). Cardiac output and other hemodynamic parameters were not affected. Respiratory system compliance slightly improved from 24.7 ± 10.2 ml/cmH_2O supine to 27.8 ± 13.2 ml/cmH_2O prone ($p < 0.05$). An improvement in PaO_2/FIO_2 of more than 15 % from changing from supine to prone was found in 16 patients (responders). Responders had more hypoxemia (PaO_2/FIO_2 70 ± 23 vs 99 ± 53 mm Hg in non-responders, $p < 0.01$), more hypercapnia (partial pressure of carbon dioxide in arterial blood (70 ± 27 vs 64 ± 9 mm Hg, $p < 0.01$), and a shorter elapsed time to the onset of ARDS and turning to the prone position (11.8 ± 16 vs 32.8 ± 42 days, $p < 0.01$).
Conclusions: Turning critically ill, severely hypoxemic patients from the supine to the prone position is a safe and useful therapeutic intervention. Our data suggest that prone positioning should be carried out early in the course of ARDS.

Key words Prone position · Gas exchange · Respiratory system mechanics · Acute respiratory distress syndrome

Introduction

The acute respiratory distress syndrome (ARDS) is characterized by non-cardiogenic pulmonary edema which increases ventilation/perfusion heterogeneity, causes intrapulmonary shunt, and severely impairs oxygenation. The application of high fractional inspired oxygen levels (FIO_2) and positive end-expiratory pressure (PEEP) generally improves oxygenation in these patients to some extent [1–3]. An additional therapeutic intervention is to use the prone position [4, 5]. In 1976, Piehl and Brown [6] demonstrated that the prone position improved oxygenation in five ARDS patients without any deleterious effect. Despite the encouraging results of this simple technique, prone positioning is not yet a routine intervention in ARDS patients [7–13]. Moreover, it is still not known whether the evolution of ARDS or abnormalities of respiratory system mechanics can exert an influence on the response to the prone position. Accordingly, the objective of the present study was to analyze the short-term physiologic effects of turning critically ill patients with ARDS and multiple organ failure from the supine to the prone position.

Materials and methods

Patients

We prospectively studied 23 patients, aged between 21 and 78 years (mean 56) who were admitted to the general intensive care units (ICUs) of the Hospital of Sabadell and Hospital of Sant Pau between 1994 and 1995. All of them had ARDS diagnosed according to the criteria of the expanded definition of the syndrome [14]. The Lung Injury Score (LIS) averaged 3.25 (range 2.75–3.75), indicating severe ARDS [14]. Patients with previous chronic obstructive pulmonary disease, chest wall abnormalities, evidence of left heart failure, or cranial trauma were excluded. Patients were sedated with intravenous midazolam in combination with morphine. Muscle relaxing agents were given for patient care. Demographic data for the patients, PEEP levels, number of days on mechanical ventilation, and outcome are listed in Table 1. The protocol was approved and conducted in accordance with the requirements of the Clinical Research Committees of both hospitals and conducted according to the principles established in Helsinki [15]. Inclusion criteria were a partial pressure of oxygen in arterial blood (PaO_2) less than 200 mm Hg for at least 12 h despite PEEP and an FIO_2 of 1.

Materials

Patients were orally intubated with a cuffed endotracheal tube with an inner diameter ranging from 8 to 9 mm. Mechanical ventilation was carried out with Siemens 900C Servo-Ventilator (Solna, Sweden) and Puritan Bennet 7200 (Carlsbad, Calif., USA) ventilators. Patients were ventilated in the volume assist/control mode with a constant inspiratory flow. Tidal volume was set at 6–10 ml/kg and the initial external PEEP level was titrated to keep the elastic recoil pressure of the respiratory system (Pel,rs) between 30 and 40 cmH_2O. The level of PEEP that was set was kept constant throughout the study. Standard monitoring included heart rate, electrocardiogram, and continuous noninvasive assessment of oxygen saturation with pulse oximetry (HPM1020A, Palo Alto, Calif., USA). All patients had indwelling radial or femoral artery catheters for blood gas collection and hemodynamic monitoring. If not previously inserted, a 7.5-Fr pulmonary artery thermodilution catheter (93A831H Baxter, Irvine, Calif., USA) was placed in the pulmonary artery when patients met entry criteria in order to measure pulmonary artery pressure and pulmonary capillary wedge pressure, to calculate cardiac output by thermodilution (HPM1012A, Palo Alto, Calif., USA), and to sample mixed venous blood. All pressures were measured by pressure gauge transducers (HPM1006A, Palo Alto), which were calibrated in reference to atmospheric pressure at the level of the mid-ventral–dorsal thoracic diameter. Cardiac output was taken as the mean from three consecutive measurements. The iced indicator (saline) was injected at the beginning of the expiratory phase of the respiratory cycle. Arterial and mixed venous blood samples were simultaneously withdrawn for blood gas determinations (ABL 30 and ABL 500, Radiometer Copenhagen, Copenhagen, Denmark), hemoglobin concentration, and hemoglobin saturation (Hemoximeter Osm3, Radiometer Copenhagen).

Measurements and calculations

Arterial and mixed venous blood gases, mean systemic and pulmonary artery pressures, central venous pressure, capillary wedge pressure and cardiac output were first measured in the supine position and then 60–90 min after turning the patients prone. We calculated the following parameters using standard formulas: index of oxygenation (PaO_2/FIO_2), right-to-left shunt (Qs/Qt), and oxygen delivery.

Respiratory system compliance (Crs) was measured in supine and prone positions in 16 paralyzed patients. The technique used to measure Crs was end-inspiratory occlusion at constant flow inflation in 9 patients [16] and, the inspiratory limb of the static pressure-volume curve of the respiratory system in 7 patients [17]. Static airway pressure and airflow were measured with the pressure transducers and pneumotrachographs built into the ventilators. The pressure plateau recorded during occlusion was taken to represent the elastic recoil pressure of the respiratory system. Static Crs was obtained by dividing the tidal volume by the difference between Pel,rs and the total PEEP (external PEEP + autoPEEP) [16, 18]. Static inflation pressure–volume curves were constructed using the constant flow technique [17], which allowed the measurement of static pressure at different inflation volumes. The upper pressure limit was set at 40 cmH_2O. Crs, using pressure volume curves, was measured at a fixed volume (tidal volume).

Protocol

Careful aspiration of pulmonary secretions was performed when the patients were supine and after they were turned to the prone position before each measurement. The change in body position was carried out by a trained team of five nurses and one physician. Patients were first turned to the lateral position and then prone. The prone position was applied in a prone-restricted manner – that is, with the entire body in contact with the bed. During the first hour in the prone position the patient was not left unattended and the ICU team was prepared to turn the patient supine in case of important cardiac or respiratory events. As a part of the turning routine, pressure to the neck and face was alleviated. Protective pads were placed at shoulders, iliac crests, and knees. Shoulders and elbows were

Table 1 Demographic characteristics of patients (*LIS* Lung Injury Score, *PEEP* positive end-expiratory pressure, *ARDS* acute respiratory distress syndrome, *CT* chest tubes, *CVVH* continuous venovenous hemofiltration)

Patient	Age (years)	Diagnosis	LIS	PEEP (cmH_2O)	Onset of ARDS (days)[a]	Outcome
1	75	Bacterial pneumonia	3.75	16	4	Died
2	71	Bacterial pneumonia (CT)	3	10	13	Survived
3	49	Bacterial pneumonia (CT)	3.75	12	2	Died
4	34	Aspiration pneumonia	3.25	12	2	Survived
5	76	Cholangitis, laparotomy	3	9	2	Survived
6	77	Bacterial pneumonia (CVVH)	3.25	10	1	Died
7	71	Bacterial pneumonia	3.25	12	16	Survived
8	55	Peritonitis, laparotomy	3.5	12	65	Survived
9	68	Viral pneumonia (CVVH)	3.5	13	25	Died
10	57	Peritonitis, laparotomy	2.75	6	22	Survived
11	61	Bacterial pneumonia	3.25	10	20	Died
12	57	Peritonitis, laparotomy	3.25	11	32	Survived
13	51	Bacterial pneumonia	3.75	11	125	Survived
14	21	Military tuberculosis (CT)	3	5	18	Died
15	75	Bacterial pneumonia	2.75	8	7	Died
16	78	Peritonitis, laparotomy	3.5	8	5	Died
17	57	Fungal pneumonia	3.5	16	16	Died
18	39	Peritonitis, laparotomy (CVVH)	3.75	12	1	Survived
19	33	Pancreatitis, laparotomy (CVVH)	3.25	13	28	Survived
20	36	Acute leukemia	3.5	12	3	Died
21	55	Bacterial pneumonia	2.75	8	7	Died
22	55	Aspiration pneumonia	3	0	1	Survived
23	73	Wound infection	3	14	5	Survived

[a] Number of days receiving mechanical ventilation since the diagnosis of ARDS

placed in physiological positions and the arms were put along the side of the body. The correct positioning of the endotracheal tube and pulmonary artery catheter was checked by a chest X-ray. Measurements were obtained under steady-state conditions after a minimum of 20 min of ventilation without variation in pulse oximetry readings. Patients did not undergo extra volume infusions between the two comparisons, nor changes in the doses of vasoactive drugs.

Statistics

The data are expressed as the mean ± SD. Statistical analysis was performed using (1) Student's *t*-test for paired data to compare means between the supine and prone position and (2) Student's *t*-test for unpaired data to compare means between prone position responders and nonresponders. Significance was taken at $p < 0.05$.

Results

All the patients tolerated turning from the supine to the prone position remarkably well and all completed the study. No clinically relevant complications or events were detected during the turning or during the period when the patients remained prone. Minor clinical events included facial edema in the majority of patients and intolerance to enteral feeding in two. The usual treatment (antibiotics, vasopressor agents, sedation, analgesia, and prophylactic heparin) was continuously administered without modifications. After the study protocol was completed, the decision to return the patient to a supine position was left to the attendant physician.

In the supine position the PaO_2/FIO_2 and Qs/Qt were 78 ± 37 mm Hg and 43 ± 11 %, respectively; when prone, PaO_2/FIO_2 increased to 115 ± 51 mm Hg ($p < 0.001$), Qs/Qt fell to 34 ± 8 % ($p < 0.001$), and hemoglobin oxygen saturation increased from 90 ± 6 to 95 ± 4 % ($p < 0.001$) (Fig. 1). No significant differences were observed in mean systemic arterial or pulmonary pressures, central venous pressure, pulmonary capillary wedge pressure, heart rate, cardiac output, or oxygen delivery between body positions (Fig. 1). An increase in oxygenation in the prone position (responder), arbitrarily defined as a 15 % increase in PaO_2/FIO_2 with respect to the supine value, was observed in 16 out of 23 patients (70 %). Crs was 24.7 ± 10.2 ml/cmH_2O when supine and 27.8 ± 13.2 ml/cmH_2O when prone ($p < 0.05$) (Fig. 1).

We performed a subgroup analysis based on an arbitrarily chosen clinical criterion of achieving ⩾ 15 % improvement in the PaO_2/FIO_2 ratio. To this end, we compared the data of 16 prone responders with the data of 7 prone nonresponders. As shown in Table 2, age, LIS, and the supine values for minute ventilation, FIO_2, and PEEP level were comparable in the two groups. Time elapsed since the onset of ARDS (number of days receiving mechanical ventilation since the diagnosis of ARDS) was shorter in the responders than in the nonresponders (12 ± 20 vs 33 ± 72 days, $p < 0.01$). No clinically relevant differences in hemodynamics and cardiac function were observed between responders and nonresponders (Table 3). When supine, PaO_2/FIO_2 was lower and the partial pressure of carbon dioxide in arterial blood

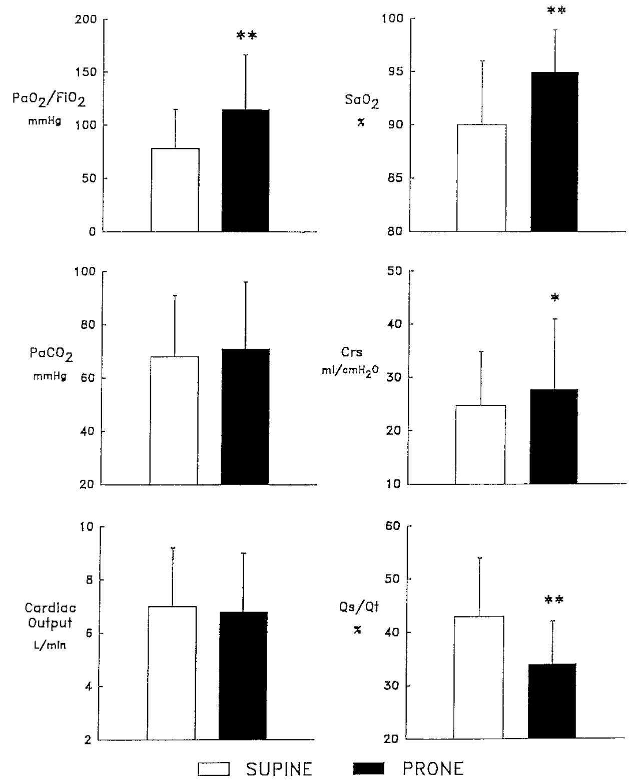

Fig. 1 Mean (± SD) PaO_2/FIO_2 ratio, hemoglobin oxygen saturation SaO_2, $PaCO_2$, respiratory system compliance *Crs*, cardiac output, and intrapulmonary shunt *Qs/Qt* in 23 patients with ARDS in the supine and prone positions. $*p < 0.05$ and $**p < 0.001$ between the supine and prone positions

was higher in responders than in nonresponders (70 ± 23 vs 99 ± 57 mm Hg and 70 ± 27 vs 64 ± 9 mm Hg, respectively, $p < 0.01$) for both comparisons). Crs was 25.2 ± 10.9 ml/cmH_2O in responders and 23.2 ± 8.9 ml/cmH_2O in nonresponders (NS).

Physiologic measurements in the subgroups of patients with and without a significant increment in oxygenation in the prone position are given in Table 4, and the individual variations of PaO_2/FIO_2 in both subgroups are shown in Fig. 2. Besides improvements in oxygenation, turning the patients from supine to prone also increased oxygen delivery (832 ± 254 to 904 ± 311 ml/min, $p < 0.05$) because of an increase in oxygen content, and increased Crs from 25.2 ± 10.9 to 29.4 ± 14.2 ml/cmH_2O ($p < 0.05$).

Table 2 Comparison of clinical data for patients lying supine between the subgroup with a significant increase in oxygenation after being turned prone (responders) and the subgroup with no significant change in oxygenation after being turned prone (nonresponders). Values are mean ± SD (*LIS* Lung Injury Score, *VE* minute ventilation)

	Responders (n = 16)	Nonresponders (n = 7)	p
Age (years)	54 ± 19	60 ± 16	NS
LIS	3.2 ± 0.3	3.3 ± 0.3	NS
VE (l/min)	10.7 ± 2.4	9.8 ± 2.2	NS
FIO_2	0.97 ± 0.1	1 ± 0	NS
PEEP (cmH_2O)	10.6 ± 4	10 ± 2.4	NS
Onset of ARDS (days)[a]	11.8 ± 16	32.8 ± 42	< 0.01

[a] Number of days receiving mechanical ventilation since the diagnosis of ARDS

Table 3 Comparison of physiologic measurements in patients lying supine between the subgroup with a significant increase in oxygenation after being turned prone (responders) and the subgroup without a significant change in oxygenation after being turned prone (nonresponders). Values are mean ± SD (*MAP* mean arterial pressure, *CVP* central venous pressure, *MPAP* mean pulmonary artery pressure, *PCWP* pulmonary capillary wedge pressure, *HR* heart rate, *CO* cardiac output, DO_2 oxygen delivery, SaO_2 hemoglobin oxygen saturation, *Qs/Qt* intrapulmonary shunt, *Crs* respiratory system compliance)

	Responders (n = 16)	Nonresponders (n = 7)	p
MAP (mm Hg)	74 ± 15	77 ± 9	NS
CVP (mm Hg)	8.9 ± 3.3	9.3 ± 3.9	NS
MPAP (mm Hg)	31.9 ± 9.4	29 ± 5.8	NS
PCWP (mm Hg)	13.6 ± 4.9	13.4 ± 4.7	NS
HR (min^{-1})	112 ± 24	92 ± 21	NS
CO (l/min)	7.1 ± 2.2	6.7 ± 2.2	NS
DO_2 (ml/min)	832 ± 254	761 ± 187	NS
PaO_2/FIO_2 (mm Hg)	70 ± 23	99 ± 53	< 0.01
$PaCO_2$ (mm Hg)	70 ± 27	64 ± 9	< 0.01
SaO_2 (%)	88 ± 6	93 ± 5	NS
Qs/Qt (%)	44 ± 12	41 ± 10	NS
Crs (ml/cmH_2O)[a]	25.2 ± 10.9	23.2 ± 8.9	NS

[a] Calculated in 16 patients

Discussion

Our results indicate that the prone position improved oxygenation in the majority (69 %) of our critically ill patients with ARDS, without any deleterious effect on hemodynamics or respiratory system mechanics. The process of turning patients from supine to prone carried out by a trained team is therefore considered, in our experience, as clinically safe, since complications or meaningful side effects were not observed. Subgroup analysis revealed that patients in whom PaO_2/FIO_2 improved more than 15 % after being turned also showed improvement in oxygen delivery and respiratory system compliance.

Despite the prone position being recommended for more than 20 years, only a small number of patients have been studied in this position, and the physiologic explanation for the beneficial effect had not been clarified until recently. In anesthetized and paralyzed ani-

Table 4 Physiologic measurements in the patient subgroup with a significant increase in oxygenation after being turned prone (responders) and the subgroup without a significant change in oxygenation after being turned prone (nonresponders). Mean ± SD

	Prone responders (n = 16)			Prone nonresponders (n = 7)		
	Supine	Prone	p	Supine	Prone	p
MAP (mm Hg)	74 ± 15	76 ± 11	NS	77 ± 9	74 ± 8	NS
CVP (mm Hg)	8.9 ± 3.3	8.4 ± 4.7	NS	9.3 ± 3.9	10.6 ± 2.3	NS
MPAP (mm Hg)	31.9 ± 9.4	32 ± 9.1	NS	29 ± 5.8	31 ± 3.9	NS
PCWP (mm Hg)	13.6 ± 4.9	11.2 ± 5.4	NS	13.4 ± 4.7	17.3 ± 3.5	NS
HR $(min)^{-1}$)	112 ± 24	111 ± 22	NS	92 ± 21	91 ± 25	NS
CO (l/min)	7.1 ± 2.2	7.1 ± 2.4	NS	6.7 ± 2.2	6.1 ± 1.6	NS
DO_2 (ml/min)	832 ± 254	904 ± 311	< 0.05	761 ± 187	695 ± 115	NS
PaO_2/FIO_2 (mm Hg)	70 ± 23	121 ± 50	< 0.001	99 ± 53	101 ± 54	NS
$PaCO_2$ (mm Hg)	70 ± 27	73 ± 30	NS	64 ± 9	68 ± 7	NS
SaO_2 (%)	88 ± 6	96 ± 4	< 0.001	93 ± 5	93 ± 4	NS
Qs/Qt (%)	44 ± 12	34 ± 9	< 0.001	41 ± 10	35 ± 6	NS
Crs (ml/cmH_2O)[a]	25.2 ± 10.9	29.4 ± 14.2	< 0.05	23.2 ± 8.9	23.2 ± 10.1	NS

[a] Calculated in 16 patients

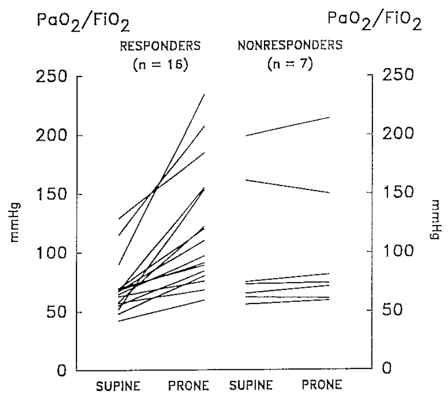

Fig. 2 Individual PaO_2/FIO_2 ratios in 16 and 7 of 23 patients with ARDS who presented with an increment of $PaO_2/FIO_2 \geqslant$ or < 15 %, respectively, in the prone compared to the supine position (i. e., responders vs non-responders)

mals [19, 20], alterations in hemodynamics, regional diaphragm movements or lung volumes are no different in the prone position versus the supine position and edema is uniformly distributed [21]. In anesthetized normal prone subjects, diaphragm excursions in non-dependent (dorsal) regions are more pronounced [22] and measured functional residual capacity (FRC) is higher than in supine subjects [23, 24]. It is not known, however, if FRC increases in ARDS patients as well. On turning prone, a vertical gradient of perfusion is not found [25, 26], and the gravitational distribution of pleural pressure is more uniform, suggesting that large dorsal (dependent) lung areas are below their closing volumes when the patients are supine, a phenomenon that improves when they are turned prone [20]. These interesting findings were confirmed in animals with oleic acid-induced acute lung injury [27] and in humans with ARDS [9]. Pappert et al. [9] assessed the ventilation–perfusion (V/Q relationships) in 12 patients with ARDS using the multiple inert gas elimination technique. Improvement of oxygenation in the prone position was associated with an improvement in V/Q heterogeneity, which was interpreted as being due to shifting of perfusion away from shunt regions. However, improvement more likely resulted from the institution of ventilation in dependent regions following a favorable change in transpulmonary pressures, which would have had the same beneficial effect on V/Q heterogeneity. Also, a more homogeneous vertical pleural pressure gradient in the prone position favors a higher regional FRC for the same static airway pressure.

Due to the clinical setting and our study design, we were not able to attribute the observed improvement in oxygenation exclusively to the prone positioning as we did not control for time related changes. However, clinical parameters in the supine position at the onset of the study were similar between responders and nonresponders with the exception of the number of days receiving mechanical ventilation since the diagnosis of ARDS. Duration of ARDS affects lung structure, and progression of fibroproliferation is characterized by deposition of collagen, thereby worsening gas exchange and lung mechanics and reducing the ability of PEEP to recruit airspaces. Late stages may be described as restrictive lung disease with superimposed emphysema-like lesions [28, 29]. Improvements in respiratory system compliance were seen only in the responder group suggesting that, in this group, the prone position favored ventilation of recruitable lung regions. We also found that the number of days on mechanical ventilation since the diagnosis of ARDS was higher in the patients in whom oxygenation did not improve in the prone position. This finding suggests that a more favorable distribution of ventilation and perfusion is not produced in the prone position in patients with late ARDS.

Pelosi et al. [23] examined the partitioning of the mechanics of the respiratory system into its pulmonary and chest wall components in subjects during general anesthesia. Interestingly, gas exchange and functional residual capacity improved but no positional differences were found in lung and chest wall compliances. However, in patients with ARDS, the behavior of the vertical pleural pressure gradient is not known after turning from the supine to the prone position [30]. In experimental animals, Mutoh et al. [20] examined the effect of the prone position on lung volumes and on the pressure–volume relationships of the respiratory system, chest wall, and lung after volume infusion. While FRC was essentially the same in both the supine and prone positions, the pressure–volume relationship above FRC showed a slight improvement in lung compliance without changes in chest wall compliance. In our study, respiratory system compliance improved on turning to the prone position, and this effect was observed only in the responder group. Nevertheless, from the data we obtained, we cannot find out whether this improvement was due to an improvement in chest wall compliance, in lung compliance, or in both. Interestingly, the patients who were responders in terms of oxygenation to the change in position exhibited a significant improvement in respiratory system compliance. These findings probably indicate recruiting of previously atelectatic lung regions.

In ARDS, Gattinoni et al. [11, 30] have shown that lung densities distribute from the dorsal to the ventral region when the patients are turned prone and the decay in regional inflation is greater in supine compared to prone. This finding suggests that regional inflation is more homogeneously distributed in the prone position, as also indicated by the findings of Lamm et al. [27]. Experimentally, tidal ventilation at high inspiratory airway pressures can cause lung rupture [31–33]. In line with these findings, Broccard et al. [34] have demonstrated in dogs that mechanical ventilation induced less lung edema in the prone than in the supine position. Therefore, both the more uniform distribution of inspired tidal volume and the potentially less ventilator-induced injury in the prone position may be important physiologic effects that could explain beneficial effects of this therapeutic strategy.

Nursing care and cooperation are essential to treat patients in the prone position. This therapeutic strategy was well accepted by the ICU nurses. In our experience, the prone position did not increase nursing workload, with the exception of carrying out the turn, nor the need for more sedation or paralysis, since these patients are routinely sedated. Use of the prone position was only limited by the impossibility of turning the patient – for instance, due to trauma with pelvic fractures. Although some clinical evidence suggests that prone positioning with a freely protruding abdomen may help to further increase oxygenation [7], we chose in our patients to apply the prone restricted manner, i. e., with the entire abdomen in contact with the bed, because it is easiest to carry out clinically. Moreover, some patients had had recent laparotomies and we do not know to what exent a freely protruding abdomen, not touching the bed, might alter healing of the wound. In fact, active intra-abdominal processes are considered a contraindication for using a prone position [35].

Our short-term study shows a significant improvement in gas exchange. Recently, two studies have evaluated the long-term effects of prone position in patients with ARDS [12, 13]. In both, this position markedly improved oxygenation, which in responders was long lasting. Moreover, side effects were very few or none. This is consistent with the present investigation that included patients with laparotomy, continuous venovenous hemofiltration, and chest drainage tubes. Finally, gross increments of pulmonary secretions immediately after the turn to the prone position were not detected.

The results of our study further suggest that prone positioning may be considered as routine practice in hypoxemic ARDS patients. More studies are needed to evaluate the physiologic mechanisms that affect respiratory system mechanics, the influence of prone position on the time course of the ARDS and, finally, outcome. In conclusion, prone positioning is a simple and safe procedure to improve oxygenation in many critically ill patients with ARDS, eventually allowing for reduction of inspired oxygen concentration. Furthermore, neither clinically relevant complications nor impairments in oxygenation or hemodynamics were observed during this short-term study.

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