

N. Deye
F. Lellouche
S. M. Maggiore
S. Taillé
A. Demoule
E. L'Her
F. Galia
A. Harf
J. Mancebo
L. Brochard

The semi-seated position slightly reduces the effort to breathe during difficult weaning

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This article is dedicated to Professor A. Harf who died on 8 July 2003.

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N. Deye · F. Lellouche · S. M. Maggiore · S. Taillé · A. Demoule · E. L'Her · F. Galia · L. Brochard
Medical Intensive Care Unit (ICU), Henri Mondor University Hospital, AP-HP, Créteil, France

N. Deye (✉)
Medical and Toxicological ICU, Lariboisiere Hospital, AP-HP, Paris Diderot University, Inserm U942, 2 rue Ambroise Paré, 75010 Paris, France
e-mail: nicolas.deye@lrb.aphp.fr

F. Lellouche
Cardiac surgery ICU, Laval University Hospital, Québec City, Canada

S. M. Maggiore
Department of Anesthesiology and Intensive Care, Agostino Gemelli Teaching Hospital, Università Cattolica del Sacro Cuore, Rome, Italy

A. Demoule
Medical ICU, La Pitié Salpêtrière University Hospital, Paris, France

E. L'Her
ICU, La Cavale Blanche University Hospital, Brest, France

A. Harf · L. Brochard
INSERM U955, Université Paris 12, Créteil, France

J. Mancebo
Servei de Medicina Intensiva, Hospital de la Santa Creu i Sant Pau, Barcelona, Spain

L. Brochard
Intensive Care Department, University Hospital, University of Geneva, Geneva, Switzerland

Abstract Purpose: The influence of posture on breathing effort in patients with difficult weaning is unknown. We hypothesized that posture could modulate the breathing effort in difficult-to-wean patients. **Methods:** A prospective, crossover, physiologic study was performed in 24 intubated patients breathing with pressure support who had already failed a spontaneous breathing trial or an extubation episode. Their median duration of mechanical ventilation before measurements was 25 days. Breathing pattern, occlusion pressure ($P_{0.1}$), intrinsic PEEP ($PEEP_i$), and inspiratory muscle effort evaluated by the pressure–time product of the

respiratory muscles and the work of breathing were measured during three postures: the seated position in bed (90° LD), simulating the position in a chair, the semi-seated (45°), and the supine (0°) positions consecutively applied in a random order. A comfort score was obtained in 17 cooperative patients. The influence of position on chest wall compliance was measured in another group of 11 sedated patients. **Results:** The 45° position was associated with the lowest levels of effort ($p \leq 0.01$) and occlusion pressure ($p < 0.05$), and tended to be more often comfortable. Respiratory effort was the lowest at 45° in 18/24 patients. $PEEP_i$ and $PEEP_i$ -related work were slightly higher in the supine position ($p \leq 0.01$), whereas respiratory effort, heart rate, and $P_{0.1}$ values were increased in the seated position ($p < 0.05$). **Conclusion:** A 45° position helps to unload the respiratory muscles, moderately reduces $PEEP_i$, and is often considered as comfortable. The semi-seated position may help the weaning process in ventilator-dependent patients.

Keywords Work of breathing · Respiratory mechanics · Patient positioning · Supine · Semi-recumbent · Seated · Weaning failure · Mechanical ventilation

Introduction

The influence of posture on the respiratory system has been studied in different situations. In healthy human subjects, the functional residual capacity is reduced when switching from the seated to the supine posture, whereas respiratory resistances are increased [1–4]. The esophageal pressure values are slightly less negative seated versus supine [5], but transdiaphragmatic pressures are unchanged [5, 6].

These postural variations probably have a limited relevance for healthy subjects [7, 8], but could influence respiratory pattern and dyspnea in patients with severe chronic pulmonary disease. The supine posture can increase intrinsic positive end-expiratory pressure (PEEP_i), dynamic hyperinflation, airway resistances, expiratory flow limitation, or orthopnea in several patients with chronic obstructive pulmonary disease (COPD) [9–11], heart failure [12–14], or obesity [8, 15, 16]. Conversely, some authors have reported a relief of dyspnea for some non-ventilated COPD patients when supine versus seated [6, 17]. In patients with phrenic or neuromuscular paralysis, the functional residual capacity may also be markedly reduced supine versus seated [18, 19]. In mechanically ventilated patients, the supine posture can also induce increased expiratory flow limitation and PEEP_i [20, 21].

No major modification was reported for breathing effort seated versus supine in stable COPD patients under noninvasive ventilation [22], in elderly [23] or obese subjects [8, 24]. In patients with prolonged or difficult weaning, weakness of the respiratory muscles is often present [25]. The effects of posture on the work of breathing in these patients may be clinically relevant [26, 27]. Although a semi-recumbent position in bed is often recommended for mechanically ventilated patients [28] because of the decreased risk of microaspirations through the endotracheal tube [29], it is often difficult to maintain in clinical practice [30]. The aim of this study was to assess the physiologic effects of the body position on the work of breathing in patients with weaning difficulties to seek an optimal position regarding respiratory effort.

Methods

An expanded methods section is available in the Electronic Supplementary Material (ESM). The French Society of Intensive Care Ethics Committee approved this prospective, monocentric, randomized, open, crossover clinical study. Informed consent was obtained from all patients.

Patients

Twenty-four invasively ventilated patients with or without tracheostomy and experiencing weaning difficulties were enrolled over a 16-month period. Inclusion criteria were as follows: at least one failure of spontaneous breathing trial before the end of a 2-h trial and/or one unexplained extubation failure (need for reintubation within the 72 h after extubation not related to an untreated cardiac failure or an intercurrent infectious disease or to laryngeal dyspnea). Exclusion criteria were as follows: hemodynamic instability, uncontrolled sepsis, patient refusal, age less than 18 years, and current esophageal pathology. Three positions were applied during the procedure, in random order using a predefined computer-generated list: the supine position (0°), the semi-seated position (45° backrest elevation), and the seated position in bed with legs down (90°LD), simulating sitting in a chair.

Measurements

The ventilator settings were not modified during the procedure. All measurements were performed while the patients were on the same level of pressure support ventilation for the three positions (mean 14 ± 4 cmH₂O). Airway pressure (Paw) was measured at the Y connector with a pressure transducer (MP45; Validyne, Northridge, Ca). Flow was measured using a Fleisch no.1 pneumotachograph (Metabo, Lausanne, Switzerland), connected to a differential pressure transducer (DP45-16, Validyne, Northridge, Ca). Esophageal (Pes) and gastric pressures (Pga) were measured using a double-balloon catheter (Marquat, Boissy-Saint Léger, France). The correct placement of the catheter followed standard recommendations and was systematically assessed after each posture modification to obtain a Pes/Paw ratio as close as possible to unity during occlusion [31]. Pressure and flow signals were recorded using specific software (Acknowledge, version 3.5.3, Biopac, Santa Barbara, Ca) and were digitalized using an analog-to-digital converter system (MP100, Biopac, Santa Barbara, Ca).

Inspiratory work of breathing (WOB), esophageal pressure–time product (PTP_{es}), inspiratory time (T_i), total duration of the respiratory cycle (T_{tot}), RR, V_T, minute ventilation (V_E), PEEP_i, and the work due to PEEP_i (W_{PEEP_i}) were calculated for each position after 15 min of stabilization, during a quiet tidal breathing period for 1 min [21]. As previously described, effort-to-breathe calculations, PEEP_i, and respiratory center output, estimated by the decrease in Pes after 100 ms (P_{0.1}), were computed from Pes recordings [31]. The clinical values were also collected for each position. A global comfort score including dyspnea was assessed by asking the cooperative patients to compare

the comfort of the current position versus the previous and the initial positions. These comparisons allowed a score to be attributed for each position. Consequently, 17 cooperative patients classified each posture as the most comfortable position (score of 1), the intermediate position (score of 2), or the less comfortable position (score of 3).

Static chest wall compliance (Ccw)

Knowing passive chest wall compliance is necessary for calculations of PTPes and WOB. This could not be measured in these spontaneously breathing patients without using deep sedation and/or hyperventilation. The theoretical value of Ccw in normal supine subjects was used, amounting to 4 % of the predicted value of the vital capacity per cmH₂O [1]. This value, however, could be modified by posture and this could influence the WOB or PTPes calculations. To evaluate possible Ccw variations due to body position, we separately enrolled 11 sedated and paralyzed patients necessitating a pressure–volume curve determination with an esophageal pressure for another study (acute respiratory distress syndrome, 10 patients; acute lung injury, 1 patient). Patient characteristics for this substudy are reported in the ESM. Three positions were consecutively applied in these patients during 15 min: the supine position, the 45° semi-seated position, and the nearly seated position (simulating the 90°LD position), similar to the upright position proposed in these indications [32]. Pes was measured for each posture using a balloon catheter. The insertion of this esophageal catheter followed usual recommendations to ascertain a correct placement [33, 34]. For each posture, Ccw was calculated as the mean ratio between V_T and the corresponding Pes variations. The Ccw values were compared between the three positions. The median Ccw was 200, 197, and 142 mL/cmH₂O in the 0°, 45°, and 90°LD positions ($p = 0.03$), respectively. The first two positions had similar Ccw ($p = 0.8$), whereas it was significantly lower in the seated position versus the two others ($p < 0.05$). Thus, regarding the difficult-to-wean patients, a correcting factor was introduced for the seated Ccw values. The corrected Ccw in the 90°LD position ($C_{cw_{corr\ 90^\circ LD}}$) was calculated as the product between the theoretical Ccw ($C_{cw_{90^\circ LD}}$) and this correcting factor, expressed as a percentage: $C_{cw_{corr\ 90^\circ LD}} = 0.72 \times C_{cw_{90^\circ LD}}$ [35]. The corrected PTPes values in the 90°LD position were similarly calculated. WOB and PTPes values are expressed with this correcting factor for the 90°LD position.

Statistics

Results are expressed as median [25–75th percentiles]. The comparisons of quantitative values between the three

groups were performed with the non-parametric Friedman test, and Wilcoxon test for pairwise comparisons when required. As appropriate, categorical qualitative variables were analyzed using Fisher's test and quantitative continuous variables were compared using regression analyses. The two-sided level of significance was fixed at 0.05 or less.

Results

The characteristics of the difficult-to-wean patients are reported in Table 1. Nine patients suffered from a neurological disorder, five patients had a cardiac arrest, and nine were postoperative patients. Regarding inclusion criteria, 14 patients had experienced a spontaneous breathing failure and 15 patients had experienced at least one extubation failure. The patients were ventilated during the measurements with a pressure support level of 15 cmH₂O [12–16], an external PEEP of 5 cmH₂O [3–5], and an FiO₂ of 38 % [35–40]. Arterial blood gases before measurements were pH = 7.41 [7.36–7.44], PaCO₂ = 43 mmHg [39–48], and PaO₂ = 85 mmHg [61–101]. Sixteen patients eventually received a tracheostomy (8 after the measurements).

Clinical values in the patient population during the three periods are reported in Table 2. Three patients found the three positions similar in terms of global comfort. In addition, four patients had two preferred or two non-preferred positions. The 45° position was associated 12 times with the best score, the 0° position 7 times, and the 90°LD 6 times ($p = 0.09$ between the three positions). Respiratory parameters for the three postures are reported in Table 3.

Table 4 illustrates the changes in respiratory center output, respiratory effort, and PEEP_i. PEEP_i was slightly and significantly higher supine compared with the 45° and the 90°LD positions ($p < 0.01$; all patients except two had a higher PEEP_i supine). Similarly, W_{PEEP_i} was significantly lower in the 45° and the 90°LD positions than supine ($p \leq 0.01$). All parameters of respiratory effort were significantly lower in the semi-seated position, as compared with the other two positions (Figs. 1, 2). The seated position was significantly associated with the highest effort-to-breathe and $P_{0.1}$ values ($p = 0.01$). Respiratory effort, assessed by PTPes, was the lowest at 45° in all but six patients. Subgroups analyses (tracheostomized patients and patient–ventilator asynchronies) are described in the ESM.

For all three positions, a correlation was observed between PEEP_i values and the PTP expressed per minute ($p < 0.001$; $r = 0.63$; $r^2 = 0.4$; see the ESM), between PEEP_i values and the WOB expressed as J/min ($p < 0.001$, $r = 0.53$; $r^2 = 0.28$), and between PEEP_i and $P_{0.1}$ ($p < 0.001$; $r = 0.67$; $r^2 = 0.45$).

Discussion

To our knowledge, this is the first study evaluating the clinical and physiological effects of posture on the effort-to-breathe measurements during difficult weaning from mechanical ventilation. The main results of this study can be summarized as follows: (1) respiratory effort parameters were slightly but significantly decreased in the semi-seated position compared with the other two positions, (2) comfort in the semi-seated position was at least as good compared with the other positions, (3) the seated position was associated with the highest effort-to-breathe values, (4) the respiratory drive was significantly higher seated compared with the semi-seated position, (5) PEEP_i and PEEP_i-related work were moderately but significantly increased supine compared with the two other positions.

Effect of posture on the breathing pattern, PEEP_i, and dyspnea

No significant modification regarding the respiratory pattern was found according to postural changes in our study. The slight PEEP_i and dyspnea sensation changes according to posture are in accordance with several studies. In healthy subjects, respiratory pattern modifications according to posture have been thoroughly investigated. The functional residual capacity is reduced by 20–30 % when switching from the seated to the supine posture [1, 2, 4, 13]. This effect is related to the increased intrathoracic blood volume, the more cephalic position of the diaphragm, and small airway closure. This effect leads to increased resistances supine versus seated.

In COPD patients, the supine posture is associated with dyspnea, i.e. orthopnea, and expiratory flow limitation at rest is an earlier manifestation in supine than in sitting position [10, 11]. Although some COPD patients

report a supine relief of dyspnea [6, 17], several patients with COPD experience more severe dyspnea in the supine position [9–11]. Increased dynamic hyperinflation, airway resistances, PEEP_i, and expiratory flow limitation could play a role in orthopnea genesis. In several patients with heart failure [12–14] or obese subjects [8, 15, 16], airway resistances, PEEP_i, expiratory flow limitation, and orthopnea are also increased supine versus seated. Patients with severe phrenic or neuromuscular paralysis experience a major reduction of functional residual capacity when supine [18, 19]. In mechanically ventilated patients [20], the supine posture can enhance expiratory flow limitation and can increase PEEP_i and PEEP_i-related work compared with the 30° position in adults with acute respiratory distress syndrome [21]. In ventilated patients with abdominal distension or obesity, comfort is reduced seated and supine in comparison with the semi-seated position [36].

The correlations observed between PEEP_i and all respiratory effort parameters in our study support that PEEP_i seems to be one of the determinants explaining the increased effort observed supine during weaning: the higher was the PEEP_i, the higher was the inspiratory effort. A higher central respiratory drive and “stimulation” induced by the seated position itself could explain in part why the inspiratory muscles’ efforts are higher seated despite lower PEEP_i. The potential role of the changes in Ccw when seated should be further evaluated: Ccw was not directly measured during weaning and results are based on the hypothesis that similar changes should occur as in our group of paralyzed patients.

Effect of posture on respiratory effort

The semi-seated position induces a decreased respiratory effort in the present study, as compared with the supine

Table 1 Characteristics of the difficult-to-wean patients

Patients	<i>n</i> = 24
Age (years), median [25–75th percentiles]	65 [56–74]
Male/female	16/8
Body mass index (kg/m ²), median [25–75th percentiles]	23 [21–29]
SAPS II, median [25–75th percentiles]	51 [39–67]
Previous COPD, <i>n</i> (%) ^a	8 (25)
Left heart dysfunction, <i>n</i> (%)	7 (29)
Polyneuromyopathy, <i>n</i> (%) ^b	9 (38)
Phrenic disorder, <i>n</i> (%) ^c	6 (25)
Tracheostomy before measurements, <i>n</i> (%)	8 (33)
Duration of ventilation before measurements (days), median [25–75th percentiles]	25 [16–38]
Overall duration of mechanical ventilation (days), median [25–75th percentiles]	43 [28–51]
Duration of hospitalization (days), median [25–75th percentiles]	62 [30–112]
Survival, <i>n</i> (%)	13 (58)

SAPS II simplified acute physiologic score II, COPD chronic obstructive pulmonary disease

^a Data not available for 5 patients (1 patient with previous restrictive chronic respiratory failure)

^b Data not available for 3 patients

^c Tested in only 12 patients

Table 2 Clinical and hemodynamic parameters during the three study periods

	0°	45°	90°LD	<i>p</i>
SBP (mmHg)	116 [104–123]	123 [108–133]*	123 [110–132]*	0.05
DBP (mmHg)	59 [50–65]	57 [49–71]	57 [51–68]	0.58
HR (beats/min)	95 [79–108] [£]	98 [79–109] [£]	104 [84–114]	0.02
SpO ₂ (%)	97 [96–98]	97 [96–97]	97 [95–98]	0.94
EtCO ₂ (mmHg)	36 [31–41]	36 [32–42]	35 [29–40]	0.51

A moderate but significant lower systolic arterial blood pressure was observed supine, as compared with the other positions. Pulse rate was slightly but significantly higher seated, as compared with the other positions (0° = supine position; 45° = semi-seated position; 90°LD = seated position with legs down)

SBP systolic arterial blood pressure; DBP diastolic arterial blood pressure; HR heart rate; SpO₂ oxygen saturation using pulse

oximetry; EtCO₂ end-tidal carbon dioxide partial pressure (data available for 21 patients)

* *p* < 0.05 compared with 0°

[£] *p* < 0.05 compared with 90°LD

Table 3 Respiratory pattern during the three study periods

	0°	45°	90°LD	<i>p</i>
V _T (L)	0.463 [0.361–0.546]	0.462 [0.393–0.569]	0.442 [0.401–0.518]	0.99
V _E (L/min)	11.7 [9.4–15.6]	12.0 [9.7–14.3]	12.6 [10.5–15.3]	0.21
RR (breaths/min)	30 [24–32]	30 [22–31]	30 [22–34]	0.08
RR/V _T (breaths min ⁻¹ L ⁻¹)	66 [47–95]	60 [44–85]	72 [49–90]	0.13
Ti/Ttot (%)	34 [32–40]	35 [30–38]	35 [31–39]	0.01
V _T /Ti (L/s)	0.564 [0.466–0.669]	0.583 [0.483–0.654]	0.595 [0.528–0.689]	0.32
Paw _m (cmH ₂ O)	8.6 [7.1–10.1]	8.2 [7.2–9.7]	8.4 [6.7–10.0]	0.30
R _{max} (cmH ₂ O L ⁻¹ s ⁻¹)	19.7 [15.9–26.1]	20.7 [15.4–24.3]	19.2 [16.8–22.5]	0.75

A trend toward a decreased RR was found in the semi-seated versus the seated position. Ti/Ttot ratio seemed different between the three positions (0° = supine position; 45° = semi-seated position; 90°LD = seated position with legs down) but the pairwise comparisons did not reach significance

V_T tidal volume; V_E minute ventilation; RR respiratory rate; Ti inspiratory time; Ttot total duration of the respiratory cycle; V_T/Ti mean inspiratory flow; Paw_m mean airway pressure; R_{max} maximal inspiratory resistances, calculated as the ratio between the maximal Paw and the maximal inspiratory flow

Table 4 Respiratory drive, effort, and intrinsic positive end-expiratory pressure during the three study periods

	0°	45°	90°LD	<i>p</i>
WOB (J/L)	0.50 [0.36–0.62]	0.43 [0.32–0.57]* [§]	0.56 [0.34–0.66] [£]	<0.0001
WOB (J/min)	7.5 [3.9–8.2]	5.9 [3.4–8.0]* [§]	6.7 [3.6–10.2] [£]	0.003
PEEP _i (cmH ₂ O)	0.8 [0.4–1.5]	0.5 [0.2–1.4]*	0.5 [0.2–1.1]*	0.0009
W _{PEEP_i} (J/L)	0.08 [0.04–0.15]	0.05 [0.02–0.16]*	0.05 [0.02–0.11]*	0.0003
W _{PEEP_i} (J/min)	0.8 [0.4–1.7]	0.6 [0.2–2.1]*	0.6 [0.2–1.8]*	0.004
PTPes (cmH ₂ O s min ⁻¹)	114 [75–140]	102 [65–124]* [§]	116 [73–158] [£]	<0.0001
P _{0.1} (cmH ₂ O)	1.7 [1.2–2.5]	1.5 [0.9–2.2] [§]	1.6 [1.0–2.9] [£]	0.02

A trend toward a decreased P_{0.1} was found in the semi-seated versus the supine position (*p* = 0.06)

0° supine position; 45° semi-seated position; 90°LD seated position (with legs down); WOB inspiratory work of breathing; PEEP_i intrinsic positive end-expiratory pressure; W_{PEEP_i} work related to intrinsic positive end-expiratory pressure, calculated as the product between tidal volume and PEEP_i, and expressed as J/L and J/min;

PTPes pressure–time product for the respiratory muscles; P_{0.1} respiratory center output estimated by the decrease in esophageal pressure developed at 100 ms, after onset of a triggered breath

* *p* < 0.05 compared with 0°

[£] *p* < 0.05 compared with 45°

[§] *p* < 0.05 compared with 90°LD

and the seated positions. This is the first study to evaluate the effects of posture in patients with difficult weaning using measurements of breathing effort. Patients with weaning failure experience a marked increase in respiratory load and respiratory muscle effort [25, 27]. One of

the most important objectives of mechanical ventilation is to decrease the work of breathing to a level acceptable for the patient. Weaning failure often results from an imbalance between mechanical load and respiratory muscle activity.

Fig. 1 Individual work of breathing changes during the three studied postures ($n = 24$). *WOB* work of breathing; 0° supine position; 45° semi-seated position; 90° LD seated position (with legs down). $*p = 0.001$. Eighteen patients showed a lower *WOB* value in the semi-seated position compared with the supine and the seated postures

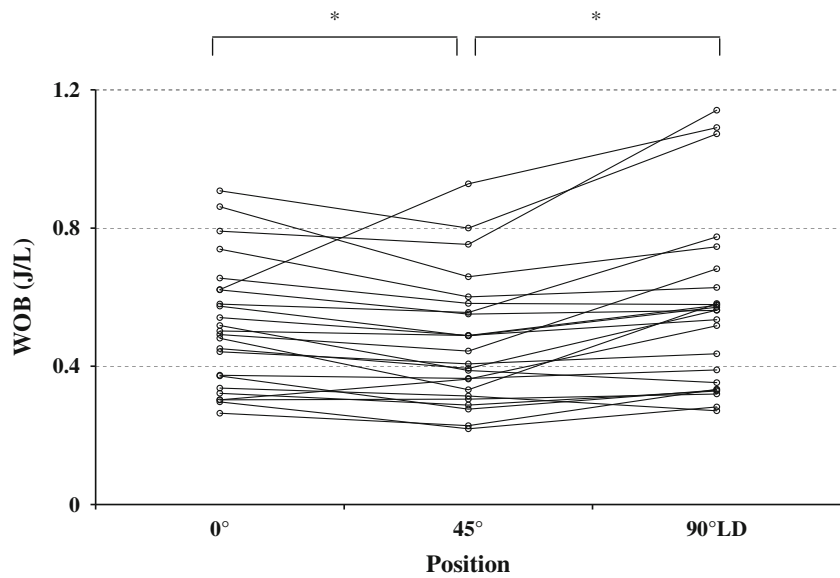
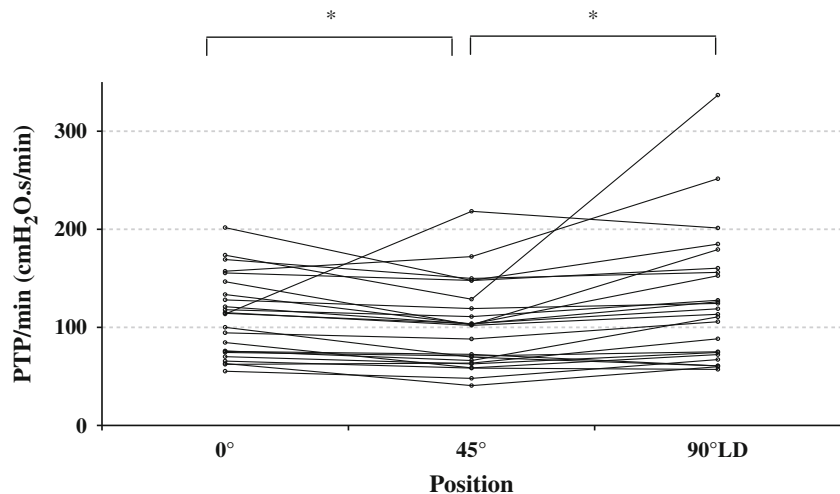


Fig. 2 Individual changes of PTP/min during the three studied postures ($n = 24$). *PTP/min* pressure–time product of the respiratory muscles, expressed per minute; 0° supine position; 45° semi-seated position; 90° LD seated position (with legs down). $*p = 0.002$. Eighteen patients showed a lower *PTP/min* value in the semi-seated position compared with the supine and the seated postures



Most studies evaluating the respiratory effort changes according to posture reported no difference or minor differences. In healthy subjects, the transdiaphragmatic pressures remained unchanged between the supine, semi-seated, and seated postures [5–8]. In elderly subjects, *WOB*, $P_{0.1}$, *PTP*, and transdiaphragmatic pressures were found to be unchanged seated versus supine [23]. In stable COPD patients, the transdiaphragmatic pressures decreased seated versus supine [6, 17, 37], whereas the *PTP* and the swings of *Pes* were similar [22]. In obese subjects, mean transdiaphragmatic pressures and *WOB* seemed unchanged supine versus seated [8, 24]. None of these studies evaluated the semi-seated position, and most of them included a small number of stable and not severe patients. Postural variations are probably not relevant for healthy or stable subjects [7, 8], but the influence of posture may be greater for the most severe patients, with

little respiratory reserve and important respiratory efforts. The current study concerns a selected population with severe patients, as indicated by multiple co-morbidities, elevated severity scores at admission and mortality rate, and a prolonged mechanical ventilation duration and length of hospitalization. Indeed, the largest change obtained in adopting the semi-seated position was found for patients presenting the highest effort-to-breathe levels supine or seated (data shown in the ESM).

Study limitations

The simple score used in our study to assess the global comfort could lead to bias, as it represents a subjective evaluation and not a visual quantitative scale. Other more recognized scores should have been used to assess

dyspnea. Our simplified score was adapted from a previous study to specifically evaluate this population of ventilated or tracheostomized patients [31]. Bias was prevented using the randomization to determine the order of postures and always asking the same question after stabilization for each position.

It was not possible to obtain the C_{cw} , which is an important factor for the respiratory effort calculations, in the studied patients during the effort-to-breathe measurements. Major differences in C_{cw} were found only in the seated position in our separate study performed in paralyzed patients. Although this may differ in sedated and spontaneously breathing patients, it was important to take it into account. Because C_{cw} was not directly measured in the difficult-to-wean patients, this constitutes a limitation of the study. It could be argued that the difficult-to-wean patients are not strictly comparable with these paralyzed patients. However, most of clinical characteristics were similar between these two groups: age, body mass index, SAPS II, and V_T that could influence C_{cw} variations according to posture [38]. Because C_{cw} was different only in the seated position (90° LD) versus the other two positions, it could not have influenced the effort-to-breathe differences found between the supine and semi-seated positions. Conversely, the correcting factor increased the respiratory effort differences found between the semi-seated and seated positions.

The validity of the P_{es} measurements according to postural changes has been discussed elsewhere [8]. Additionally, the occlusion tests expressed as the P_{es}/P_{aw} ratio were similar for all positions.

The pressure support ventilation with a median level of 15 cmH₂O may explain the low respiratory efforts levels recorded in our patients. It could also explain in part why WOB and PTP values are statistically different between postures with differences which do not seem to be really clinically relevant at these levels of pressure support. Results could be different if measured at lower

pressure support levels or during spontaneous unassisted breathing.

Clinical implications

Several studies pointed out that many ICU patients are not positioned in a semi-recumbent position despite recommendations to do so [39, 40]. The 45° position in the bed is recommended for mechanically ventilated patients [28], mainly because of the decreased risk of microaspirations along the endotracheal tube walls [29]. This position, however, is often difficult to maintain in clinical practice [30]. Our study provides a new rationale for implementing the semi-seated position when difficult weaning is considered. Difficult-to-wean patients are often ventilated for prolonged periods and postural recommendations could have a clinical impact, especially when weaning tests are performed using low levels of pressure support or T-tube tests.

In summary, the semi-seated position at 45° decreases the inspiratory effort and is found to be at least as comfortable as other positions for difficult-to-wean patients. $PEEP_i$ and $PEEP_i$ -related work are moderately higher supine and could explain part of these findings. In the seated position compared with supine, $PEEP_i$ and $PEEP_i$ -related work are lower but the effort-to-breathe is not, possibly because of a higher central respiratory drive. The potential role of a reduced chest wall compliance when seated, as measured in paralyzed patients, must be clarified. These results are clinically relevant because they show that the recommended semi-seated position represents a good compromise to decrease $PEEP_i$ and to unload the respiratory muscles in the situation of difficult weaning.

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