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LETTER

Effect of body position and inclination in supine and prone position on respiratory mechanics in acute respiratory distress syndrome

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Introduction

The mechanism by which prone position (PP) reduces mortality in moderate-to-severe acute respiratory distress syndrome (ARDS) patients as compared to supine (SP) [1] likely includes reduction/homogenization of lung stress/strain. The common accepted scenario is that this effect stems from an increase in chest wall elastance (Est,cw) in PP. However, whether, and to what extent, the angulation of the body may affect Est,cw is unclear. Our hypothesis is that thorax inclination significantly changes respiratory system mechanics and lung volume from SP to PP, as previously suggested in healthy humans [2] and anesthetized patients [3].

Methods

The present report is an ancillary study of a previous published work [4]. In ARDS patients receiving continuous infusion of sedative and neuromuscular blockade agents, lung and chest wall mechanics, end-expiratory lung volume (EELV), and transcutaneous oxygen saturation (SpO_2) were measured in the following order: SP 30° head-up (SP30°), SP flat (SP0°), PP flat (PP0°), and PP 15° head-up (PP15°). Each position was applied during 10 min, at constant ventilator settings. Esophageal pressure (Pes) was measured via Nutrivent catheter (Sidam, Mirandola, Italy) and EELV by nitrogen washin-washout technique from the ventilator. Complete methodology can be found in ESM. The primary outcome was Est,cw.

Data is expressed as mean (95% confidence intervals) and compared by using analysis of variance for repeated measures with pairwise comparisons with the Holm test.

Results

Data was prospectively acquired in 24 consecutive ARDS patients (21 moderate and 3 severe). ARDS etiology was mainly pneumonia. Average tidal volume was 0.385 (0.357–0.414) L or 5.9 (5.7–6.1) mL/kg predicted body weight), positive end-expiratory pressure (PEEP) 11 (10–12) cmH_2O, and respiratory rate 31 (29–33) breaths/min.

Static end-expiratory Pes (PEEPtot,es) significantly increased from SP30° to SP0°, then decreased at PP0°, and further declined at PP15° at which baseline value was returned (Table 1). Because plateau Pes exhibited similar changes as PEEPtot,es, both driving Pes and Est,cw decreased at SP0°, then increased and so went lung elastance across positions.

EELV significantly and continuously dropped from SP30° to PP0° and then increased but did not recover the SP30° level.

Discussion

This is the first study that systematically assesses respiratory mechanics in various inclinations and positions in the modern era of ARDS management. It confirms that Est,cw increases from SP to PP [5]. It discloses the significant role of body inclination. Indeed, the change in Est,cw with change in position is significant at 0° inclination only. PP15° is associated with higher EELV and static

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Table 1 Impact of position and inclination on respiratory system mechanics, oxygenation, and lung volume

Variables ($n=24$)	SP30° (1)	SP0° (2)	PP0° (3)	PP15° (4)	Anova *P* value	Pairwise comparisons *P* value[#]					
						1 vs 2	1 vs 3	1 vs 4	2 vs 3	2 vs 4	3 vs 4
PEEPtot,rs (cmH$_2$O)	11 [10–12]	12 [10–13]	12 [11–13]	11 [10–12]	< 0.001*	< 0.001	0.001	–	–	0.008	0.001
PEEPtot,es (cmH$_2$O)	10 [8–12]	14 [12–15]	11 [9–12]	9 [7–10]	< 0.001*	< 0.001	–	–	< 0.001	< 0.001	< 0.001
PEEPtot,L (cmH$_2$O)	1 [0–3]	− 2 [− 3 to − 1]	1 [0–2]	2 [1–4]	< 0.001*	< 0.001	–	–	< 0.001	< 0.001	0.002
PEEPtot,ga (cmH$_2$O)	12 [10–15]	12 [9–14]	18 [15–21]	18 [15–20]	< 0.001*	–	0.007	< 0.001	0.007	< 0.001	0.94
Plat,rs (cmH$_2$O)	23 [21–25]	21 [19–23]	22 [20–23]	22 [21–24]	< 0.001*	0.003	–	–	–	0.008	0.02
Pplat,es (cmH$_2$O)	13 [12–15]	16 [14–18]	14 [12–16]	12 [11–14]	< 0.001*	< 0.001	–	–	0.004	< 0.001	0.001
Pplat,L (cmH$_2$O) (absolute method)	9 [7–12]	5 [3–7]	8 [6–9]	10 [8–12]	< 0.001*	< 0.001	–	–	< 0.001	< 0.001	< 0.001
Pplat,L (cmH$_2$O) (elastance-ratio method)	15 [13–18]	15 [13–17]	14 [12–16]	15 [13–17]	0.06*	–	–	–	–	–	–
Pplat,L gradient (cmH$_2$O)	6 [4–8]	10 [9–12]	6 [5–8]	5 [3–6]	< 0.001*	–	–	–	–	–	0.03
Pplat,ga (cmH$_2$O)	14 [11–17]	12 [10–15]	19 [16–22]	20 [17–23]	< 0.001*	–	0.007	< 0.001	0.002	< 0.001	–
Est,rs (cmH$_2$O/L)	26 [22–30]	21 [18–24]	27 [22–32]	31 [25–37]	< 0.001*	< 0.001	–	0.03	0.003	< 0.001	0.001
Est,cw (cmH$_2$O/L)	8 [7–9]	6 [4–7]	9 [8–10]	9 [8–11]	< 0.001	< 0.001	–	–	< 0.001	< 0.001	–
Est,L (cmH$_2$O/L)	18 [14–22]	15 [13–18]	18 [13–23]	21 [15–27]	0.01*	0.04	–	–	–	0.04	0.005
ΔP,rs (cmH$_2$O)	12 [10–13]	9 [8–11]	10 [9–11]	11 [10–13]	< 0.001*	< 0.001	0.004	–	–	< 0.001	< 0.001
ΔP,es (cmH$_2$O)	3 [3–4]	2 [2–3]	3 [3–4]	4 [3–4]	< 0.001*	< 0.001	–	–	< 0.001	< 0.001	–
ΔP,L (cmH$_2$O)	8 [6–10]	7 [6–8]	7 [5–8]	8 [6–9]	0.002*	0.03	0.02	–	–	–	0.003
SpO$_2$[$] (%)	95 [93–96]	94 [93–96]	94 [92–96]	95 [93–97]	0.54*	–	–	–	–	–	–
EELV (mL)	1371 [1137–1606]	1203 [994–1412]	1148 [972–1325]	1213 [1029–1397]	< 0.001*	0.002	< 0.001	0.006	–	–	0.03

Values are reported as mean [95% confidence interval] in 24 patients

SP supine position, *PP* prone position, *rs* respiratory system, *es* esophageal, *L* transpulmonary, *ga* gastric, *Est,rs, Est,cw, Est,L* respiratory system, chest wall, and lung static elastance, respectively, *PEEPtot* static end-expiratory pressure, *Pplat* static end-inspiratory pressure, *ΔP* driving pressure, *SpO$_2$* pulse oximetry, *EELV* end-expiratory lung volume

*Sphericity assumption not met and hence *P* value was corrected with the Greenhouse–Geisser method

[#] Pairwise comparison *P* value adjusted for multiple comparisons with the Holm method

[$] $n=23$

– indicates that the *P* value was greater than 0.05 and was omitted for clarity end-expiratory transpulmonary pressure but higher lung driving pressure and elastance as compared to PP0°.

Two findings are worth noting. The first is the lower Est,cw in supine flat vs. supine 30° and in prone flat vs. prone 15°. Gastric pressure actually decreased in supine flat as compared to supine 30°, resulting in less impact of the abdominal content onto the thorax. Furthermore, as a result of the EELV decrease in flat positions, the chest wall may have been moved to a more compliant part of its volume–pressure curve. Second, at the clinical standard for positioning (supine 30° vs. prone 0°) elastances are the same. This finding emphasizes the importance of body angulation when dealing with respiratory mechanics during changing position.

This study is limited by both the short time of application and the lack of randomization of each position. However, it is the common way the procedure of proning is done in routine at the bedside, making the present results relevant in clinical practice.

To conclude, this study found that the body inclination may significantly affect respiratory mechanics, and hence should be taken into account in further clinical studies and in daily practice.

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s00134-018-5493-1) contains supplementary material, which is available to authorized users.

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Compliance with ethical standards

Conflicts of interest

The authors declare no conflict of interest.

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