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LETTER



Bedside ultrasound monitoring of prone position induced lung inflation

David Rousset¹, Benjamine Sarton^{1,2}, Beatrice Riu¹, Benoit Bataille³ and Stein Silva^{1,2*}  on behalf of the PLUS study group

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Dear Editor,

To date, lung computed tomography (CT) scan is the gold standard to assess the distribution of acute respiratory distress syndrome (ARDS) patient's lung strain [1]. Since CT-based methods are impractical and cannot be used to monitor ARDS lung characteristics throughout prone ventilation, methods feasible at the bedside are very attractive and lung ultrasound (LUS) is one of them. We aimed to compare for the first time, LUS to the end-expiratory lung volume (EELV, measured by automated nitrogen washout/washin technique) [2] for assessing prone positioning-induced lung inflation.

At variance with previous reports [3] and because at best we can only expect LUS techniques to quantitate the degree of “inflation” induced by lung recruitment, we have decided to compare LUS to a lung inflation reference method (EELV), rather than using arterial gas exchange (which depends on both lung ventilation and perfusion) as the main study endpoint. A threshold of EELV of 500 ml was used to define a binarized prone positioning response (responders vs not responders) [2]. Ultrasound examinations were performed and analyzed only by physicians with advanced LUS experience and previously reported interobserver agreement [4, 5]. Forty-five patients with moderate-to-severe ARDS ($\text{PaO}_2/\text{FiO}_2 < 150$ with FiO_2 at least 0.6 and positive end-expiratory (PEEP) at least 5 mmHg) were prospectively included. LUS data, arterial blood gas analysis, and ventilator variables were systematically recorded immediately before prone positioning (PP), 1 h (early) and 16 h (late) after PP onset. Lung hyperinflation was not specifically

assessed. Thereby, we have observed in this proof-of-concept study that:

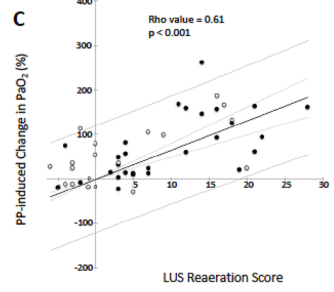
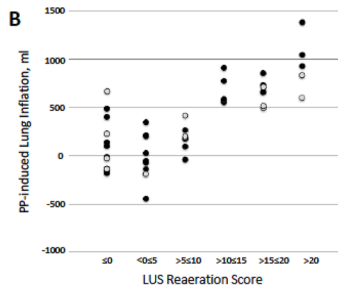
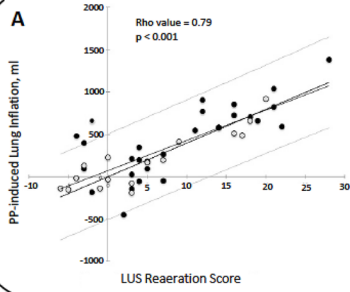
- LUS score variations throughout PP session (Fig. 1, upper panel), but not basal LUS data in a supine position, are significantly associated with PP response both in terms of lung inflation and blood oxygen level improvement.
- PP-induced lung inflation greater than 500 ml can accurately be estimated by a LUS re-aeration score [3] of 10 or greater (Fig. 1, upper panel).
- LUS appears to be a reliable bedside tool to evaluate regional PP-induced gain or loss of lung aeration (Fig. 1, lower panel). Moreover, ultrasound analysis of pulmonary aeration changes at both early and late PP assessments, showed that a significant response to PP was related to a reduced number of pattern's transitions: B2 (multiple coalescent B lines) to normal, C (lung consolidation) to normal and C to B1 (multiple well-defined either regularly spaced 7-mm apart or irregularly spaced B lines). It is worth noting, that at the late-PP time point a significant increase of B-lines profiles was also observed in previously normally aerated lung regions.
- Repeated LUS assessment across the time, accurately allow lung inflation monitoring during PP sessions (Fig. 1, upper and lower panels). However, neither LUS nor EELV can detect lung hyperinflation and as a consequence, should not be used in isolation as methods of respiratory monitoring in ARDS.

We believe that our data make a significant contribution to advancing the understanding and care of ARDS. We suggest that these findings have clinical implications and might be particularly relevant for further personalize the use of PP in this challenging clinical setting.

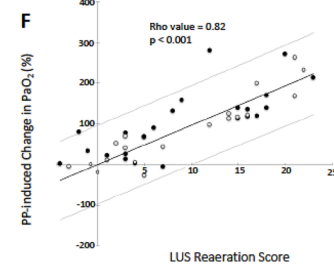
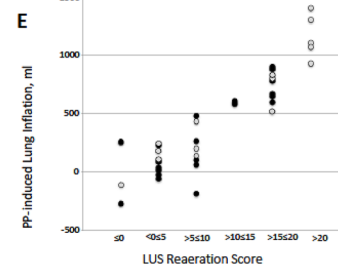
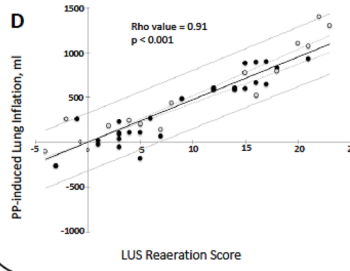
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David Rousset and Benjamine Sarton have contributed equally. Members of the PLUS study group are listed in the Acknowledgement section.

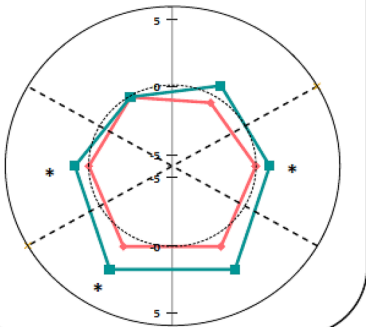
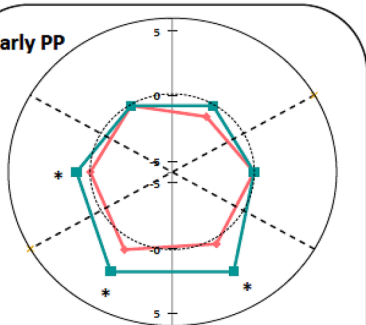
Early PP



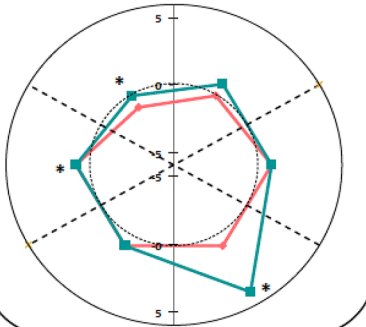
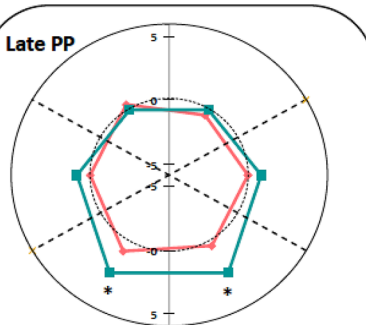
Late PP



Early PP

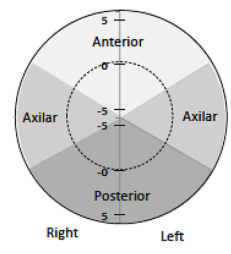
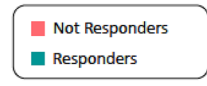
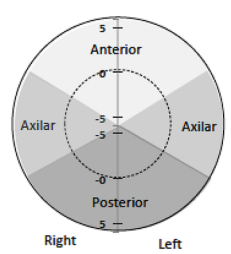


Late PP



Upper regions

Lower regions



(See figure on previous page.)

Fig. 1 Correlation between ultrasound reaeration score and lung inflation induced by early (**A**) and late (**D**) prone positioning (upper panel). Lung inflation was measured as end-expiratory lung volume (EELV) using the multibreath nitrogen-wash-out technique. Accuracy of lung ultrasound score for estimating early (**B**) and late (**E**) prone positioning induced lung inflation. Correlation between ultrasound reaeration score and early (**C**) and late (**F**) prone positioning induced increase in PaO₂. Early and late time points correspond to study assessments made at 1 h and 16 h after prone positioning onset, respectively. Each closed circle represents an individual patient. Gray lines represent 95% confidence intervals. Black circles represent patients with diffuse loss of aeration; open circles represent patients with focal loss of aeration. Anatomical mapping of lung ultrasound reaeration score changes induced by prone positioning (lower panel). Graphical representation as a two-dimensional polar coordinate system of LUS reaeration score across the prone positioning session for each group (responders vs. not responders). Patient's response to prone positioning was defined by EELV equal or greater than 500 ml. Comparison between groups was made using a Mann–Whitney test. Significant difference correspond to a *p* value < 0.05. LUS lung ultrasound, PP prone position

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Compliance with ethical standards

Conflicts of interest

The authors declare that they have no conflict of interest.

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