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Case report

ANTICIPATED RESPONSE TO PRONE POSITION ASSESSED WITH LUNG ULTRASOUND

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Abstract

Acute respiratory distress syndrome (ARDS) presents a challenge for clinicians due to its high morbidity and mortality. Prone position (PP) has been used as a therapeutic strategy in ARDS patients, demonstrating benefits in respiratory mechanics and gas exchange. In SARS-CoV-2-related ARDS (C-ARDS), 80% of patients require PP to alleviate refractory hypoxemia. Lung ultrasound (LUS) has proven useful for evaluating lung reaeration, guiding PEEP titration, and differentiating ARDS phenotypes. The LUS score is a validated tool that correlates well with CT and mechanical parameters. In this case, a 60-year-old patient with C-ARDS, who experienced a drop in PaO_2/FiO_2 from 170 to 113, was placed in PP. Using LUS, a shift in aeration is associated with improved oxygenation, despite no significant changes in respiratory mechanics. This case highlights the usefulness of LUS in assessing PP response and the need for further studies to correlate changes in aeration with improvements in oxygenation and dead space, which could help identify patients who are responders to the maneuver.

Key words: lung ultrasound, ARDS, C-ARDS, prone position

Resumen

Respuesta anticipada a la posición prona evaluada con ecografía pulmonar

El síndrome de distrés respiratorio agudo (SDRA) es un desafío para los clínicos debido a su alta morbilidad y mortalidad. La posición en decúbito prono (DP) se ha utilizado como estrategia terapéutica en pacientes con SDRA, demostrando beneficios en la mecánica respiratoria y el intercambio gaseoso. En el SDRA relacionado con SARS-CoV-2 (C-ARDS), el 80% de los pacientes requieren PP para mejorar la hipoxemia refractaria.

El ultrasonido pulmonar (LUS) ha demostrado ser útil para evaluar la reaireación pulmonar, guiar la titulación de PEEP y diferenciar fenotipos del SDRA. El *score* de LUS es una herramienta validada que se correlaciona bien con la tomografía computarizada, aunque no tanto con parámetros de mecánica del sistema respiratorio. Se presenta el caso, de un paciente de 60 años con C-ARDS, que mostró una caída en su PaO_2/FiO_2 de 170 a 113, y que fue sometido a DP. A través del score de LUS, se observó un cambio en la aeración, asociado con mejora en la oxigenación, aunque sin cambios significativos en la mecánica respiratoria.

Este caso resalta la utilidad del score de LUS en la evaluación de la respuesta al DP y la necesidad de estudios adicionales para correlacionar los cambios en la aeración con la mejora en la oxigenación y el espacio muerto, lo que podría ayudar a identificar pacientes respondedores por la maniobra de forma temprana.

Palabras clave: ecografía pulmonar, SDRA, C-ARDS, posición prono

Acute respiratory distress syndrome (ARDS) poses a significant challenge for clinicians in intensive care and emergency settings due to its high morbidity and mortality, as well as the intensive use of critical healthcare resources[1]. Clinically defined by hypoxemia resulting from alterations in the ventilation-to-perfusion (V/Q) ratio and the presence of shunting, severe cases require endotracheal intubation and mechanical ventilation, often accompanied by the prone position (PP)[1].

Since the 1970s, PP has been used as a therapeutic strategy for ARDS patients, demonstrating beneficial effects on respiratory mechanics and gas exchange. The 'PROSEVA' study showed that prone invasive mechanical ventilation reduces mortality rates in severe ARDS patients, particularly those with a PaO_2/FiO_2 ratio less than 120mmHg[2]. In SARS-CoV-2-related ARDS (C-ARDS), about 20% of patients develop severe symptoms, with 5% requiring intensive care and mechanical ventilation; 80% need PP to alleviate refractory hypoxemia[3].

PP enhances gas exchange and optimizes ventilation/perfusion (V/Q) matching by reducing the pleural pressure gradient between dependent and non-dependent lung regions. Traditionally, the response to PP is assessed through direct measurements of lung mechanics and gas analysis[4]. However, lung mechanics like respiratory system compliance (Crs) or driving pressure alone are not a reliable parameter for distinguishing responders from non-responders. While computed tomography (CT) provides valuable insights, its use is limited by practical constraints and associated risks. Alternative imaging modalities, such as lung ultrasound (LUS) and electrical impedance tomography (EIT), have demonstrated utility in this context. EIT offers simultaneous global and regional lung assessments but remains limited in clinical availability[5]. In contrast, LUS has proven effective in evaluating lung reaeration, guiding positive end expiratory pressure (PEEP) titration[6], and identifying acute respiratory distress syndrome (ARDS) phenotypes. This is particularly significant, as failure to accurately identify ARDS phenotypes[7] and account for lung morphology may contribute to increased mortality.

The lung ultrasound score (LUS score) is a validated semi-quantitative metric that converts ultrasound imaging patterns into a numerical value, correlating well with CT measurements, mechanical power (MP)[8], C_{rs}. In patients with C-ARDS, sustained improvement in oxygenation after the initial session of PP is linked to improved survival rates and reduced duration of MV[9]. Identifying potential 'responders' in the first few hours of prone positioning could be key in daily assessment and management of these patients[10]. However, current evidence remains insufficient to describe lung parenchyma behavior post-positioning in prone, particularly in the context of C-ARDS.

Clinical case

This is a 60-year-old man who is on the thirteenth day since the onset of COVID-19 symptoms and who has been on mechanical ventilation for two days. At the time of the evaluation, he had suffered a sudden drop in the PaO2/FiO2 ratio, which had gone from 170 to 113.

The mechanical ventilation settings are as follows:

Mode: VC-CMVs; Tidal volume (VT): 420 ml (7 ml/kg of ideal body weight); Respiratory rate (RR): 24 breaths per minute; Inspiratory time (Ti): 0.7 seconds; Fraction of inspired oxygen (FiO_2): 0.6; Positive end-expiratory pressure (PEEP): 10 cmH_2O; Total positive end-expiratory pressure (PEEPtot): 11 cmH_2O; Airway pressure (Paw): 28 cmH_2O; Mean airway pressure: 20 cmH_2O (Fig. 1).

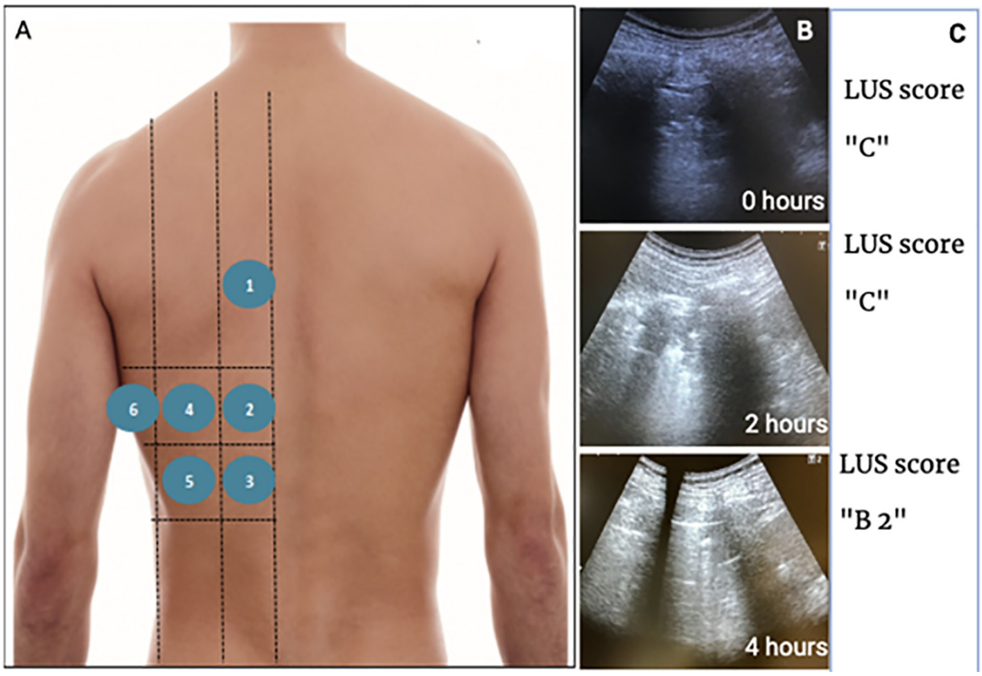
A decision was made to perform the PP maneuver, and the PEEP was adjusted based on the values obtained for the best C_{sr} and lowest airway driving pressure (DP_{aw}).

For ultrasound evaluation, a Sonosite Micromaxx® (SonoSite, Inc., 21919 30th Drive SE, Bothell, WA) portable device was used, along with a C60e/5-2 MHz convex transducer. The assessment was conducted in the prone position, dividing each hemithorax into three parts and further dividing each region into three equal areas. This resulted in six examination areas for each lung field, totaling twelve zones overall (Fig. 1A).

During PP, an ultrasound evaluation was conducted using LUS score, which initially measured 16 points. This evaluation revealed a predominance of C patterns in zone 4 of the right lung. After 2 hours in the prone position, the assessment was repeated using the LUS score, indicating a shift from pattern C to pattern B2 in the same area. Although there were no notable changes in lung mechanics, an improvement in oxygenation was observed, with a PaO_2/FiO_2 ratio of 140.

After 4 hours in the prone position, the LUS score was measured again, confirming the change from pattern C to

Figure 1 | A: Areas evaluated in each hemithorax. B: Zone 4 of the right hemithorax is shown as a reference, illustrating the evolution of images obtained during the evaluation, where aeration variation is observed. Measurements were taken at three time points, from top to bottom: immediately after prone positioning (0 hours), 2 hours after, and 4 hours after. C: LUS score for Zone 4: 0 hours – Consolidation (C), 2 hours – Consolidation (C), 4 hours – Coalescent B-lines (B2)



B2. This change did not correlate with any significant alterations in lung mechanics. However, the improvement in oxygenation continued, with a PaO_2/FiO_2 ratio of 160. Table 1 summarizes the score for each lung field at three measurement times, as well as total LUS score and the parameters of ventilatory and respiratory mechanics at the various time points of interest. Additionally, Figure 1B illustrates the ultrasound patterns observed in zone 4 of the right hemithorax.

The patient agreed to the presentation of the case report by signing informed consent.

Discussion

In this case report, we observed a change in aeration, suggesting recruitment of the posterior and basal lung zones, as assessed by the LUS score. For establishing a baseline for comparison, zone 4 of the right hemithorax was chosen as the reference point (Fig. 1). Although the LUS score is primarily designed for a global assessment of lung aeration, it also allows for regional and analytic evaluations. In this case, specific zones –1, 2, 3, and 4 of both lungs– showed improved aeration. Notably, zone 2 of the right lung exhibited the most significant regional aeration gain, changing from pattern C to pattern B1. This suggests a positive response to the prone position, particularly regarding aeration and oxygenation. This improvement in air distribution within the lungs and probably better V/Q match corresponded with an increase in the PaO_2/FiO_2 ratio.

Prone positioning (PP) is typically implemented in ARDS patients when the PaO_2/FiO_2 ratio falls below 150, especially if protective ventilation strategies, neuromuscular blockade, or PEEP titration fail to improve the condition. However, this remains controversial, as some studies report normal lung mechanics despite non-recruitable lung regions[10].

A recent study suggests that while low oxygenation correlates with poor lung aeration, mechanical power (MP) and driving pressure (DP_{aw}) are more closely linked to ventilation settings and the size of the “baby lung” (the well-ventilated lung areas). In fact, higher MP and

DP_{aw} values correspond to increased ventilation intensity and poorer lung mechanics, regardless of oxygenation level[11]. In fact, P_aO_2/F_iO_2 show inconsistent correlations with clinical outcomes and may not even correlate with mortality in early classic ARDS[11]. Reduced physiological dead space, rather than P_aO_2/F_iO_2 (insensitive to alveolar overdistension), correlates more strongly with survival and improved respiratory mechanics[12]. This is relevant because lung ultrasound (LUS) effectively detects lung recruitment[5], and this was associated with reduced dead space; however, direct comparisons between LUS-measured aeration changes, respiratory mechanics, and dead space are lacking.

The PP response varies with individual lung recruitment capacity, making assessment challenging without additional diagnostics. One method involves measuring airway opening pressure (AOP) and volume associated to estimate the potential of lung recruitability[13]. In our case, a >20% PaO_2/FiO_2 improvement led to continued PP, despite unchanged lung mechanics (Table 1).

However, studies on the correlation between LUS scores and PP response show conflicting results. Discrepancies arise because oxygenation depends on both ventilation and perfusion; improved LUS scores (potentially including hyperinflation) may not translate to improved oxygen-

Table 1 | Scores for each lung field, total lung ultrasound score and the parameters of ventilatory and respiratory mechanics

Variable ventilatory parameters	Baseline	2 hours	4 hours
Pplat (cmH_2O)	21	21	20
DPaw (cmH_2O)	10	10	9
Crs (ml/cmH_2O)	37	36	39
Rawi ($cmH_2O/L/s$)	13	13	13
PEEP (cmH_2O)	10	10	10
PEEPtot (cmH_2O)	11	11	11
FiO_2 (%)	60	50	50
SpO_2 (%)	94	98	99
PaO_2/FiO_2	113	140	160
Left Lung LUS Score	**16**	**14**	**12**
Z1	B1	B1	B1
Z2	C	B2	B1
Z3	C	B2	B1
Z4	C	C	C
Z5	C	C	C
Z6	C	C	C
Right Lung LUS Score	**16**	**15**	**11**
Z1	B1	B1	N
Z2	C	B2	B1
Z3	C	C	B2
Z4	C	C	B2
Z5	C	C	C
Z6	C	C	C

LUS score: lung ultrasound score; Z: regional score according to LUS pattern; Pplat: plateau pressure; DPaw: airway driving pressure; Crs: static compliance of respiratory system: Rawi: inspiratory airway resistance; PEEP: positive end-expiratory pressure; PEEPtot: total positive end-expiratory pressure; FiO_2: fraction of inspired oxygen; SpO_2: blood oxygen saturation; PaO_2/FiO_2: arterial oxygen partial pressure (mmHg)to fractional inspired oxygen ation if perfusion is reduced in the re-aerating regions. LUS may also not distinguish between recruited and overdistended tissue. In this sense, a specialized software appears to facilitate the assessment of this variable[14]. This regional overdistension could explain the decrease in blood flow in these areas and therefore an improvement in LUS but not in oxygenation. In fact, this discrepancy in oxygenation improvement was also observed when analyzing prone responses with the use of CT scan[15]. Furthermore, the predictive utility of LUS may depend on ARDS type (classic vs. C-ARDS) and the limitations of the LUS scoring system (which doesn't differentiate consolidation extent).

LUS score could be used to assess how C-ARDS patients respond to PP, in synergy with mechanical and dead space measures, potentially serving as an early indicator to identify patients who will or will not benefit from this maneuver. This report may be limited by the application of a "modified LUS score" based on the specific zones and divisions used for evaluation. However, previous studies have indicated that results are comparable to our findings[16].

The use of LUS provides valuable insights into the mechanisms behind the response to the prone position. It allows for the observation of how lung zones at bedside are recruited over time. Although the response to the prone position seems influenced by multiple factors, most changes can be attributed to the amount of lung tissue that is recruited and V/Q matching. This underscores the utility of lung ultrasound as an essential tool in clinical practice. Further studies involving a larger patient population are necessary. These studies would help to establish whether the changes in aeration observed by lung ultrasound are related to improvements in variables such as oxygenation or dead space.

Conflict of interest: None to declare

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