Using lung ultrasound to guide PEEP determination in mechanically ventilated patients with acute respiratory distress syndrome

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Abstract

Supportive care with mechanical ventilation is the cornerstone of management for acute respiratory distress syndrome (ARDS). Positive end-expiratory pressure (PEEP) is often applied in mechanically ventilated patients with ARDS to improve oxygenation; however, determining the optimal PEEP level—the pressure that maximizes clinical benefit while minimizing risks of ventilator-induced lung injury and other harms—for each patient can be challenging. Recently, transthoracic lung ultrasonography (also called lung ultrasound) has been proposed as a tool to guide PEEP determination in patients with ARDS. This paper reviews the history of use of lung ultrasound as a method to guide PEEP determination and the four published studies which compared it to other techniques of PEEP determination, such as the oxygenation and PV-curve methods.

Keywords: Acute respiratory distress syndrome, lung ultrasound, PEEP

Introduction

The application of positive end-expiratory pressure (PEEP) during mechanical ventilation has long been recognized as beneficial in patients with acute respiratory distress syndrome (ARDS).[1–3] The use of PEEP to improve arterial oxygenation in ARDS patients is so rapid and profound that, to date, no controlled clinical trial has been conducted to validate its perceived benefits. “We were never willing to treat patients without PEEP,” wrote ARDS pioneer Thomas L. Petty after he and David Ashbaugh found that PEEP improved survivability from 29% to 71% in the first 21 patients treated for ARDS. “We were never the same again.”[4]

As quickly as PEEP seemed to enter mainstream medical practice, so did questions about its basis and application: how does it confer benefits? To what values should PEEP be set and titrated? When should it be used? What are its risks? These questions, in large part, remain unanswered.[5] And while fifty-five years of ARDS research have yielded some insights regarding ventilator management—including the concepts of lung-protective ventilation to prevent ventilator-induced lung injury (VILI) and prone positioning to improve oxygenation—there is still little agreement on how to optimize PEEP levels in patients with ARDS.[6–12]

Transthoracic lung ultrasonography, also known as lung ultrasound, has recently been proposed as a tool to guide PEEP determination.[13–17] Lung ultrasound is a non-invasive imaging method that can be used to detect lung abnormalities present in ARDS (e.g., pulmonary consolidations and edema), distinguish between focal and non-focal ARDS morphologies, and quantify the extent of lung injury in ARDS, all with accuracies comparable to the current gold standard of chest imaging, computed tomography (CT).[18–20] Lung ultrasound can also be used to assess changes in lung aeration brought on by adjustments in PEEP, although its ability to guide clinical decisions regarding PEEP setting is disputed.[16,20–22] This article reviews the use

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of lung ultrasound in finding optimal PEEP values and evaluates its usefulness in ARDS management.

Background

Historically, the lungs were considered poor subjects for ultrasonographic examination because ultrasound does not penetrate healthy lung tissue well.[23] The acoustic impedance of air within alveoli is approximately 450 times smaller than that of surrounding parenchyma. This dramatic difference in acoustic impedance causes nearly all ultrasound waves to be reflected at the lung wall (just deep to the level of the visceral pleura).[24] Imaging lung parenchyma is therefore impossible unless a pathological process (e.g., atelectasis, consolidation) has displaced air from the alveoli. While it is impossible to image the lung under normal circumstances, it is possible to visualize the parietal and visceral pleurae, which have similar acoustic impedances to each other and superficial tissue. The boundary between these pleurae, referred to as the pleural line, is the tissue from which all lung ultrasound signs arise.[25]

The first documented use of transthoracic lung ultrasonography occurred in 1964 when R.L. Pell obtained echograms of lung pleura in a patient with a right-sided pleural effusion.[26] In the 1980s, radiologists began associating artifacts—ultrasound patterns that do not portray anatomy but provide information about the area under examination—with lung conditions such as pleural effusions and interstitial syndrome.[27–29] In 1997, Daniel Lichtenstein and his colleagues at the Hôpital Ambroise-Paré in Paris demonstrated that lung ultrasound can detect the presence of alveolar-interstitial syndrome with sensitivity and specificity similar to the gold standard, CT.[30] Soon, researchers began evaluating the diagnostic accuracies of lung ultrasound in other conditions, such as ARDS, pneumonia, pneumothorax, pulmonary embolism, and pulmonary edema, and found them comparable to CT and superior to chest radiography.[31–36] Lung ultrasound has since gained traction as a quick and powerful method to diagnose pulmonary disorders in intensive care units. Today, lung ultrasound is considered an essential component of critical care sonography and an invaluable skill for intensivists.[37]

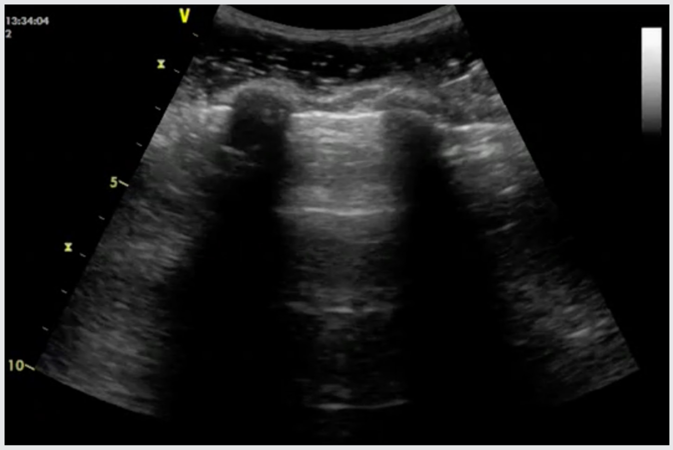

Figure 1. Normal sonographic appearance of the lung (reproduced with kind permission from the author, Ashley Miller, MBChB).

Lung ultrasound—routine and ARDS-related findings

Many techniques and protocols have been developed to guide lung ultrasonography.[38–40] All rely on visualizing the pleural line (and, in instances where the lungs are no longer aerated, any subpleural structures) through acoustic windows in the intercostal spaces. When examining the lungs using transthoracic ultrasonography, the following findings are considered normal: a bright, shimmering pleural line; the presence of lung sliding, which can be verified by the appearance of a "seashore" sign on M-mode; A-lines (echogenic, horizontal line artifacts that appear in regularly spaced intervals below the pleural line); and two or fewer isolated B-lines (echogenic, vertical line artifacts that shoot downwards from the pleural line) (Figure 1).

The sonographic appearance of the lungs in patients with ARDS depends on the etiology and morphology (e.g., focal vs. non-focal ARDS) of their disorder.[40,41] However, several findings are typical. In ARDS, lung sliding is often diminished or completely absent. Patients will also often have subpleural consolidations, which are represented sonographically by either the presence of multiple, coalescing B-lines or direct visualization of the lung parenchyma (which looks very similar to liver tissue, hence the term "hepatization") depending on the extent of aeration present. The observation that the sonographic appearance of the lung changes depending on the level of aeration present is the basis for the ultrasound reaeration score, the lung ultrasound score, and the methods that use these scores to determine optimal PEEP levels in patients with ARDS.

Scoring lung aeration in ARDS

Ultrasound reaeration score

In 2011, Bouhemad et al. published a method of scoring the degree of lung aeration in patients with ARDS based on sonographic appearance.[20] In this method, termed the ultrasound reaeration score, 12 thoracic regions (six per lung) are examined using a 2–4 MHz phased-array ultrasound probe (Figure 2). If a region appears normally aerated—defined by the appearance of normal lung sliding and the presence of two or fewer isolated B-lines—that region is categorized as N. If the region has greater than two well-defined B-lines, indicating moderate loss of aeration, it is categorized as B1. If the B-lines start to coalesce, indicating severe loss of aeration, the region is categorized as B2. If the region no longer reflects waves and takes on the appearance of tissue (hepatization), indicating consolidation, that region is categorized as C. In cases where the sonographic appearance is not homogenous within a region, that region is categorized according to the worst abnormality present. Any change in appearance before and after an intervention (e.g., antibiotics, application of PEEP) corresponds to a change in ultrasound reaeration score.

Lung ultrasound score

Soummer et al. modified the ultrasound reaeration score and created the lung ultrasound score (LUS).[42] Instead of scoring regions based on their change before and after an intervention, this method scores regions based on present appearance. Lung regions that appear normally aerated (N) receive a score of 0; moderate loss of aeration (B1) a score of 1; severe loss of aeration (B2) a score of two; and complete loss of aeration (consolidation; C) a score of three. The values for all 12 regions are summed, resulting in an LUS between 0 and 36. Lower LUS scores correspond to better lung aeration, and higher LUS scores correspond to poorer aeration (Figure 3). This method can be repeated to track changes in aeration during the course of a pulmonary illness. Or—as demonstrated by several authors in the next section—to guide PEEP determination in patients with ARDS.[13–17]

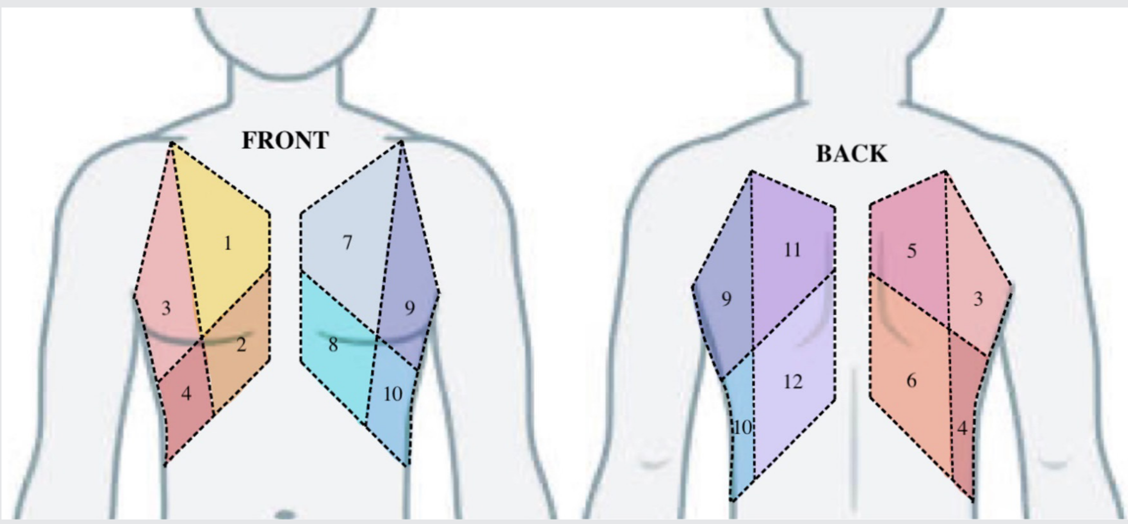

Figure 2. Twelve lung regions examined when calculating the Lung Ultrasound Score (LUS).

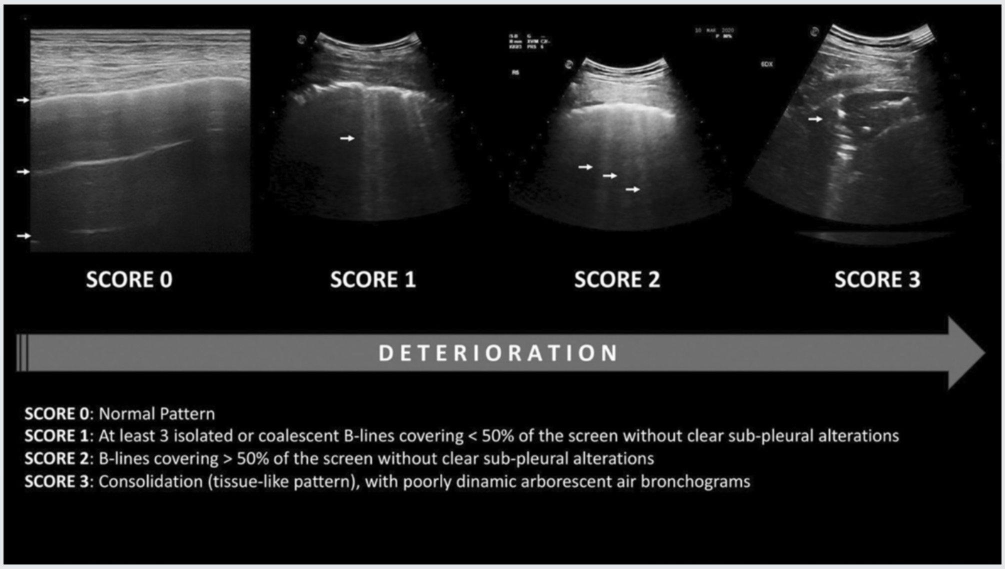

Figure 3. Typical findings for each lung ultrasound score (LUS), reproduced from Dell'Aquila et al. 2022 under Creative Commons Attribution 4.0 License.

Using Lung Ultrasound to Guide PEEP Determination in ARDS

To date, four studies have been published that evaluate ultrasound-guided PEEP determination methods in patients with ARDS. This section reviews those studies and their major findings. A summary of this review is provided in Table 1.

Rode-2012-Ultrasound vs. LIP-guided PEEPs

In the first study of its kind, Rode et al. used lung ultrasound to guide PEEP determination in 17 patients with acute lung injury (ALI) and ARDS.[13] Unfortunately, since the patients were enrolled from October 2009 to November 2011 (before the Berlin Definition of ARDS was established in 2012), ARDS cases were not classified as mild, moderate, or severe, nor were they distinguished from ALI.

All patients in the study had at least two crater-like subpleural consolidations—one in a dependent lung region, and one in an independent lung region—no deeper than 1.5 cm from the pleural line upon ultrasound examination at zero end-expiratory pressure. Patients were deeply sedated or relaxed throughout the trial. Patients who were pregnant or had intracranial hypertension or had known pre-existing bronchial, parenchymal, or pleural disorders were excluded. Ultrasound examinations were performed using a 5–10 MHz linear probe set to a depth between 3.3–6 cm.

To guide PEEP determination, the authors first determined the quasi-static pressure-volume (PV) curve for each patient using the continuous-flow method established by Lu et al. and approximated the lower inflection point (LIP).[43] PEEP was then set to 2 cmH_2O below the LIP and incrementally increased by 2 cmH_2O until the lower border of the subpleural consolidations came within 0.25 cm of the pleural line, obliterating the "shred sign" and suggesting sufficient recruitment of alveoli. These changes correspond roughly to a C to B2 change in Bouhemad et al.'s reaeration scoring system (which had not yet been published at the time of the trial). If a subpleural consolidation did not approach the pleural line by a PEEP of 22 cmH_2O, the titration was stopped and the optimal PEEP was considered 22 cmH_2O. The mean PEEP was then calculated for each patient as the average between optimal PEEP values for each consolidation.

Table 1. Summary of Reviewed Studies

Authors	Study Type	Aim	Main Findings	Limitations
Rode et al. (2012)	Case series 17 patients with ALI/ARDS	To compare PEEP values determined via lung ultrasound with those found via lower inflection point method	Ultrasound-guided PEEP levels correlated with lower inflection points on PV curves	• Non-randomized • No control group • Did not distinguish between varying ARDS severities or types • Did not report clinical outcomes
Tang et al. (2017)	Non-randomized, controlled trial 40 patients with mild or moderate ARDS evenly divided into ultrasound (ULS, experimental) or oxygenation (OXY, control) group	To compare ultrasound-guided PEEP values with those found using the oxygenation method and assess differences in short-term outcomes including oxygenation, mean arterial pressure, and dynamic lung compliance	ULS group had higher mean PEEPs, better oxygenation levels, and higher dynamic lung compliance values 2 hours after the trial than the OXY group	• Non-randomized • Only assessed patients 2 hours after trial (i.e., did not evaluate long-term outcomes) • Excluded patients with severe ARDS
Radwan et al. (2021)	Non-randomized, controlled trial Total: 65 patients with ARDS 40 patients were assigned to the experimental group (ULS), 15 assigned to control group (OXY)	To assess differences in oxygenation, duration of mechanical ventilation, incidence of pneumothorax, and mortality between ULS and OXY groups	ULS group had significantly higher mean PEEP values and percent change in P/F ratios than OXY group. No significant differences in duration of mechanical ventilation, incidence of pneumothorax, or mortality prior to discharge found between the groups	• Non-randomized • Small size of control group • Did not distinguish between mild, moderate, or severe ARDS • Control group did not have PEEP determined by the standard-of-care method • (ARDSNet protocol)
Salem et al. (2020)	Randomized controlled trial Total: 60 patients meeting Berlin Definition of ARDS 30 assigned to ULS group —Later divided into subgroups based on morphology (focal vs. non-focal) 30 assigned to OXY group	To compare outcomes between patients who had PEEP determined via lung ultrasound scoring (LUS) vs. those who had PEEP determined with current standard-of-care method	ULS group had higher mean PEEP values, increased P/F ratios, more organ-dysfunction-free and ventilator-free days, lower sequential organ failure assessment scores, smaller durations of mechanical ventilation, and lower mortality measured at day 28 of hospital stay than the control group	• Did not stratify results based on experimental subgroup—difficult to tell whether differences in mortality were due to method of PEEP determination or study design • Relatively few patients with severe ARDS (n = 5)

The main finding from this study was that ultrasound-guided mean PEEP always exceeded the LIP, indicating incomplete lung recruitment at the LIP. This result is not surprising. Due to protocol design, ultrasound-guided PEEP trials always started 2 cmH_2O below the LIP (rather than at zero end-expiratory pressure), and therefore did not have room to be very much lower than LIP. Additionally, LIP is the PEEP at which alveoli are just starting to become recruited in large numbers; upper inflection point would better represent PEEP of maximum recruitability on the PV curve.[44] Another finding from this study was that ultrasound-guided mean PEEP correlated with LIP ($r = 0.839$; $p < 0.05$), indicating ultrasound arrives at optimal PEEPS close to the LIP, and may be a valid method to guide PEEP determination.

This study was limited by its low number of patients, non-randomized nature of comparing between LIP and ultrasound-guided optimal PEEP, and lack of distinction between ALI and ARDS. In addition, its qualitative method of determining optimal PEEP (finding the point at which subpleural consolidations rise to meet the pleural line) has not been repeated or validated by other studies, which use semi-quantitative methods to determine optimal PEEP by maximizing LUS (as proposed by Soummer et al.) or reaeration score (as proposed by Bouhemad et al.). Nonetheless, it provides support for the use of lung ultrasound as a tool to help guide optimal PEEP determination.

Tang-2017-Lung ultrasound vs. oxygenation index during recruitment maneuvers

Between January 2015 and June 2017, 40 patients who met the Berlin Definition for mild or moderate ARDS (hospitalized within three days of onset, 100 mmHg < $PaO_2/FiO_2 < 300$ mmHg, patchy infiltrates on chest radiograph, respiratory failure not fully explained by cardiac failure or volume overload), in a Shanghai hospital were randomly and evenly divided into two groups, the ultrasound (ULS) group and the oxygenation (OXY) group.[14] Both groups underwent lung recruitment using a stepwise recruitment method (PEEP increased in intervals of 5 cmH_2O, maintained for 15 minutes, then increased again) while in the supine position and heavily sedated. Recruitment endpoints were determined by reaeration scoring in the ULS group; if an increase in PEEP failed to increase the reaeration score, the lungs were considered fully recruited and the recruitment maneuver was terminated. In the OXY group, blood-gas measurements were taken after every PEEP increase; once the blood-gas analysis showed a $PaO_2/FiO_2 > 400$ mmHg, pulmonary recruitment was considered sufficient, and the recruitment maneuver was terminated. At the recruitment endpoints, the mean peak pressures for the ULS and OXY groups were 46 ± 6 mmHg and 42 ± 4 mmHg, respectively ($p = 0.033$).

Following the recruitment maneuvers, PEEP was set to 20 cmH_2O. Blood gas measurements were taken in the OXY group and ultrasound examinations were performed and scored according to the reaeration score described by Bouhemad et al in the ULS group.[20] Optimal PEEP was then determined by decreasing PEEP by 2 cmH_2O every five minutes and repeating blood gas measurements or ultrasound examinations. If the reaeration score suddenly increased (indicating a loss of aeration) by more than 30% between two PEEP values, the previous PEEP value was considered optimal. If the PaO_2/FiO_2 decreased by more than 10% between two PEEP values, the previous PEEP value was considered optimal.

The mean optimal PEEPs in the ULS and OXY groups were 13.1 ± 3.1 and 15.7 ± 1.8 cmH_2O, respectively ($p = 0.003$). Two hours following the maneuver, the ULS group had a significantly higher mean oxygenation index (253.1 ± 28.7 mmHg) than the OXY group (195.6 ± 24.7 mmHg) ($t = 4.289$, $p = 0.000$), as well as a higher dynamic compliance (36.1 ± 5.2 mL/cmH_2O in the ULS group and 31.1 ± 4.1 mL/cmH_2O in the OXY group; $p = 0.000$), suggesting that the ultrasound-guided maneuver could have recruited more functional units than the oxygenation-guided maneuver. The mean arterial pressure and heart rate were not significantly different between the two groups at any measurement points during the trial.

This randomized controlled trial is notable because it was the first documented attempt to determine optimal PEEP using lung ultrasound. Interestingly, the optimal PEEP in the ultrasound group was significantly higher than the optimal PEEP in the oxygenation group. This suggests that either lung reaeration scoring is more sensitive to the de-recruitment of alveoli than the oxygenation index, or, because lung ultrasound appearances are discretely (rather than continuously) categorized, each morphological change results in a significant scoring change that may end the protocol earlier than a 10% decrease in oxygenation index.

Since this trial did not report differences in clinical outcomes (e.g., mortality, ventilator-free days) between the two groups, it's impossible to tell whether the significantly different optimal PEEP values were clinically relevant. The lack of measured and reported outcomes is a major limitation to the trial. Another major limitation was the exclusion of patients with severe ARDS ($PaO_2/FiO_2 < 100$ mmHg) since patients with severe ARDS have been shown to have greater lung recruitability on average than patients with mild or moderate ARDS.[45] Still, this study demonstrated that minimizing lung reaeration score may be an effective way to arrive at an optimal PEEP value.

Radwan-2021-Lung ultrasound vs. oxygenation index to determine best PEEP

In this non-randomized, interventional prospective study, Radwan et al. divided 65 patients meeting the Berlin Definition of ARDS between February 2017 and April 2019 into two groups.[16] The first group, Group A (N = 40), received PEEP levels according to lung reaeration score, similar to the ULS group in the Tang et al. study. The second group, Group B (N = 15), had PEEP set according to oxygenation index. There were no significant differences between sex, age, rates of diabetes mellitus, hypertension, or chronic obstructive pulmonary disease, or APACHE II scores between the two groups, although these statistical comparisons are somewhat weakened by the small number of patients in Group B.

In Group A, the optimal PEEP level was determined by first identifying the most dependent region of the lung—the last region of a lung to change from a B1 pattern (i.e., more than 2 isolated B-lines) into a normal pattern—using lung ultrasound. The PEEP at which the B1 $\rightarrow$ N change occurred was defined as the opening pressure. Then, PEEP was decremented incrementally until the dependent region changed from N $\rightarrow$ B1. This was defined as the closing pressure. Optimal PEEP was set for 2 cmH_2O above the closing pressure. In Group B, patients underwent a recruitment maneuver, taking 10 breaths at 25 cmH_2O, then 20 cmH_2O, then 30 cmH_2O, then 20 cmH_2O, then 36 cmH_2O (or 38 cmH_2O depending on the institution), then finally 10 breaths at 20 cmH_2O. PEEP was then decreased in 1 cmH_2O steps until the P/F ratio began to fall. PEEP was set at 2 cmH_2O above the previous value.

Several outcomes were measured in the trial, including optimal PEEP, percent change in P/F ratio measured immediately after the PEEP trial and 12 hours later, duration of mechanical ventilation, incidence of pneumothorax, and mortality rate prior to discharge. Group A, the ultrasound-guided PEEP group, had a significantly higher mean optimal PEEP value than the oxygenation index group (14.64 ± 1.08 mmHg vs. 13.13 ± 0.74 mmHg, respectively; $p < 0.001$). The ultrasound-guided group also had a significantly higher mean percent change in P/F ratio both immediately after the trial ($98.07 \pm 46.19\%$ vs. $68.57 \pm 15.90\%$, $p = 0.009$) and twelve hours later ($69.95 \pm 33.02\%$ vs. $37.85 \pm 18.31\%$, $p < 0.001$). Duration of mechanical ventilation, incidence of pneumothorax, and mortality rates (36% vs. 40%) did not differ significantly between the groups.

This study, like Tang et al., suggests that lung ultrasound may be a non-inferior way to determine PEEP when compared to a stepwise, decremental oxygenation index method. However, there are several limitations to this experiment and its findings. First, the trial was not randomized, nor was the PEEP determination method used in Group B an adequate control method (it was not the standard-of-care, ARDSNet method). Second, the number of patients in Group B is too small to make any meaningful comparisons between the two trial groups. Third, the patients were not subdivided by ARDS severity, nor is that information available for secondary analysis. The main conclusion is that opening and closing pressures can be identified using lung ultrasound, and that the ultrasound-guided PEEP determination method used in this trial did not increase duration of mechanical ventilation, incidence of pneumothorax, or mortality rate when compared to a stepwise, decremental oxygenation-guided PEEP method.

Salem-2020-Lung ultrasound score vs. ARDSNet protocol to determine best PEEP

In perhaps the most well-designed ultrasound-guided PEEP study to date, Salem et al. compared ultrasound-guided PEEP determination against the standard-of-care method of PEEP determination, the ARDSNet protocol.[17] In this randomized controlled trial, 60 patients meeting the Berlin Definition of ARDS were randomly divided into two groups. In the experimental group, PEEP was determined according to lung ultrasound scoring (as established by Soummer et al., abbreviated LUS), where the lowest PEEP with the lowest LUS (indicating best possible recruitment) was considered optimal. In the control group, PEEP was determined according to the ARDSNet protocol, where the PEEP value in the lowest FiO_2-PEEP combination (according to the established ARDSNet table) that maintained PaO_2 between 60–80 mmHg or SpO_2 88–95% was defined as optimum.

Importantly, patients in the LUS group were first divided into two subgroups based on their ARDS morphology—focal ARDS and diffuse ARDS. These two morphologies were determined via lung ultrasound according to the method proposed by Costamagna et al.[18] Based on the findings by Chiumello et al. that ultrasound-guided PEEP determination may not be useful in patients whose lungs are not highly recruitable, and previous studies that have found higher lung recruitability in diffuse ARDS, this design element allowed patients who may not benefit from lung ultrasound-guided PEEP titrations to be separated from those who may.[22,46,47]

Oxygenation, represented by the PaO_2/FiO_2 ratio, was the primary outcome of the trial. Secondary outcomes included length of stay in ICU, 28-day mortality, time spent on mechanical ventilation, ventilator-free days at day 28, incidence of barotrauma and organ dysfunction, number of days free of organ dysfunction, static compliance, hemodynamics (MAP and HR), and weaning categories (simple, difficult, prolonged, or no weaning). Differences in age ($p = 0.793$), sex ($p = 0.278$), ARDS classification ($p = 0.892$), and cause of ARDS ($p = 0.993$) were not significantly different between the two groups. Patients who were pregnant or suffering from hemodynamic instability, hypotension, barotrauma, or organ dysfunction were excluded from the trial.

At the conclusion of the trial, the LUS group had significantly higher mean values for optimal PEEP, P/F ratio, static compliance, organ-dysfunction-free days, and ventilator-free days. It also had significantly lower mean values for Sequential Organ Failure Assessment (SOFA) score and duration of mechanical ventilation. Most notably, the 28-day mortality in the LUS group was 6.7%—significantly lower than the 28-day mortality rate of 30.0% in the OXY group ($p = 0.041$). In other words, at day 28, the survival probability for a patient in the LUS group was 93.3% compared to 70.0% in the OXY group. This improvement in survivability is remarkable.

There are some limitations to this study. First, the LUS subgroups (i.e., focal vs. diffuse ARDS) were not separately considered in the statistical analyses. It is therefore difficult to say whether the impressive results in the LUS group are attributable to the use of lung ultrasound as a method of PEEP determination, the cap of 10 cmH_2O PEEP in the focal ARDS subgroup, or some mixture of both. Second, although this trial is large for an experimental study, it is limited by being a single-center study and having relatively few patients ($N = 5$) with severe ARDS. If its results are true and not attributable to an extreme tail of statistical variance, lung ultrasound may be the most effective method yet established to guide optimal PEEP determination in patients with ARDS. More studies are clearly needed to validate or refute this protocol.

Discussion

Lung ultrasound, as demonstrated most convincingly by Salem et al., may be an effective method to guide PEEP determination in patients with ARDS. Lung ultrasound has several advantages over other imaging modalities, namely that it is relatively cheap, available in most intensive care units, easy to teach, and does not expose patients to ionizing radiation.[48–51]

In addition, using lung ultrasound to determine optimal PEEP values does not require taking measurements with blood-gas analyzers, which may be common in higher-income settings but are still uncommon as a whole.[52]

The use of lung ultrasound to guide clinical decisions regarding PEEP does have limitations. First, as other authors have pointed out, lung ultrasound cannot be used to detect lung hyperinflation. However, while hyperinflation is a readily conceivable concept, it is not easily defined, nor is there a gold standard for detecting lung hyperinflation before it occurs. Therefore, it cannot be said whether this is truly a limitation of lung ultrasound or a limitation of our understanding of pulmonary pathophysiology. Second, some studies have accurately pointed out that the Lung Ultrasound Score (LUS, the basis for the ultrasound-guided PEEP determination method used in Salem et al.) has its own limitations, namely that it is a discretely scored system and ARDS is not a discretely scored disorder. Chiumello et al. found that, when compared to lung CT, LUS correlates well with tissue density and lung aeration but not with differences in lung recruitment brought on by changes in PEEP.[22] The discrepancy may be explained by the fact that LUS score changes only after profiles completely change (e.g., from C → B2 → B1 → N) and not when consolidations shrink but still keep the same sonographic profile. These criticisms of LUS are valid, and improvements should be made to the scoring system to better grade subcategorical changes in sonographic appearance.

Conclusion

Transthoracic lung ultrasonography has been demonstrated to be a reliable and effective method of determining optimal positive end-expiratory pressure in patients with acute respiratory distress syndrome. In one randomized, controlled trial of 60 patients with ARDS, lung ultrasound-guided PEEP conferred significant survival and morbidity benefits over the standard-of-care method of determining PEEP. Ultrasound is relatively cheap, available in many intensive care units, repeatable, and does not expose patients to ionizing radiation like other thoracic imaging methods. As a result, the use of lung ultrasound is quickly becoming a core skill for practicing intensivists. If the findings demonstrated by Salem et al. are validated in future trials, their method of using lung ultrasound to differentiate ARDS into clinical subtypes and guide PEEP determination would drastically improve outcomes for patients with ARDS and break the stalemate between the disease and intensivists that has persisted for decades.

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