Egyptian Journal of Medical Research (EJMR)

Usefulness of lung ultrasound in assessment of aeration before and after Recruitment maneuver in ARDS patients

Mohamed Sayed Mohamed[a], Ahmed Abdel Fattah Abdel Aal. Zidan [b] and Mohamed Abd alkader Abo Hamila [a]

Critical Care medicine department, Faculty of Medicine, Beni-Suef University, Egypt

Radiology department, Faculty of Medicine, Beni-Suef University, Egypt.

Abstract:

Objective: The aim of this study is to evaluate the usefulness of lung ultrasound in assessment of lung aeration and to follow up Recruitment Maneuver in ARDS patients. **Methods:** A total of 40 patients with ARDS were given the standard sustained inflation recruitment manoeuvre. The utility of lung ultrasound in assessing lung aeration and lung recruitment was evaluated using the Lung Ultrasound Score, PO2, PO2/FIO2, and lung compliance before and after recruitment. **Results:** RM with sustained inflation technique lead to an improvement in lung compliance and PO2/FIO2 in studied ARDS patients ($P < .05$) LUS decreased from (25.3±6.3) before RM to (17.4±6.5) after RM with a (p value $\leq$ 0.001), and after 12 hours it significantly decreased to (15.38±8.62) with a (p value $\leq$ 0.001), there is a significant negative correlation between LUS and PO2/FIO2, also a strong negative correlation between LUS and lung compliance. **Conclusion:** Bedside ultrasonography can be used in the evaluation and management of mechanically ventilated patients in intensive care units, also to assess lung aeration and the effectiveness of the recruitment maneuver in ARDS patients.

Keywords: Lung Ultrasound, ARDS, Recruitment Maneuver.

1. Introduction:

One of the common causes of respiratory failure in critical care unites is The Acute Respiratory Distress Syndrome (ARDS) [1], with Mechanical ventilation is still the backbone of its management [2].

Low tidal volumes and limited airway pressure were recommended by the ARDS network trial to avoid overdistension, along with high or moderate positive end-expiratory pressure (PEEP) to prevent alveolar collapse; these were found to improve survival in patients with ARDS [3]

Recruitment maneuvers (RM) which is a transient dynamic rise in transpulmonary pressure [4], have been used as an adjunct to mechanical ventilation in ARDS. RM during general anaesthesia has been shown in several studies to re-expand lung atelectasis in healthy patients [5].

Chest radiography was the first radiographic modality for diagnosing lung consolidation, but it has limitations as compared to other imaging modalities such as computed tomography in terms of accuracy and sensitivity in detecting pulmonary infiltrates [6,7]. Using the CT chest as a slandered tool for diagnosis of consolidation and determine lung aeration [8].

Lung ultrasound may be a good alternative to chest radiography for ARDS diagnosis. Compared to ordinary chest radiography, it had a high sensitivity and accuracy in detecting lung consolidation of pneumonia [9, 10]. Lung ultrasound has also been shown to be useful in detecting pathological features like lung edoema, consolidation, and pleural effusion [11,12]. Finally, it is low-cost and compact, making it ideal for use in resource-constrained environments [8].

In intensive care units, bedside ultrasonography can be used to evaluate and control patients on mechanical ventilation. The role of ultrasound is not only to diagnose, but it can also be used as a guide for mechanical ventilation management from start to finish. Also, in ARDS patients,to direct the recruitment manoeuvre. [13].

2. Patients and Methods:

2.1Type, site and time of study:

An observational study held on 40 Patients fulfilling the criteria of ARDS according to Berlin definition [14], admitted to critical care department; Beni-Suef University hospital from October 2017 to March 2019 were included in the study. The study was approved by the ethical committee of faculty of medicine Beni-Suef University

2.2 Inclusion and exclusion criteria:

1 -Inclusion criteria

Patients were diagnosed as ARDS according to the Berlin definition; 2012 or developed ARDS during their hospital stay [14].

2 -Exclusion criteria

1. Patients age less than 18 years old.
2. Patients with severe hemodynamic instability.
3. Patients with severely deformed chest cage, subcutaneous emphysema or chest wall surgery not fit for lung ultrasound.
4. Pregnancy.

2.3 All patients were subjected to:

A. Clinical assessment: full clinical examination to all patients including hemodynamic monitoring with full chest examination. Chest x-ray, CT chest and Echo, APACHE II and SOFA score

B. Full labs including: ABG before, after recruitment maneuver and12 hours later.

C. Lung Ultrasonography:

Lung ultrasonography was done to all included patients immediately after the diagnosis of ARDS has been established as a baseline ultrasound and during or after recruitment. Using a 2- to 4-MHz convex probe-EDAN DUS 60 Ultrasound [15]. Lung ultrasound score (LUS) was then calculated to providing a quantifiable comparable measures of lung aeration change [16].

AQs a result the score ranging from 0 to 36, which is the sum of scores from 0 to 3 given for each 12 regions examined (anterior, lateral and posterior regions) delimited by anatomic landmarks as declared in the consensus conference recommendations for point of-care LUS [17]. Both intercostal spaces in the upper and lower parts of the anterior, lateral, and posterior regions of both sides were meticulously examined.

D. Mechanical ventilation

Patients were completely sedated, well adapted to the ventilator using low tidal volume lung protective strategy using a Puritan Bennet 840 ventilator [18].

Sustained inflation recruitment maneuver was applied: continuous positive airway pressure was applied at 40 cm H2O for 30 seconds while keeping FiO2 unchanged then PEEP was set according to ARDS network oxygenation goals using PEEP incremental FiO2\PEEP combination.

2.4 Statistical analysis:

Data analysis was performed using SPSS v. 25 (Statistical Package for Social science) for Windows. Description of quantitative variables was done in the form of mean, standard deviation (SD), description of qualitative variables was done in the form of numbers (No.) and %. Comparing between quantitative variables was carried out by independent t-test that was used to test the difference between the means of 2 groups of a scale variable. Comparing between categorical data was done using the Chi square test, to test the statistical difference between the 2 groups. Correlation was done to test the association between 2 scale variables. The significance of the results was assessed in the form of P-value that was differentiated into non-significant when P-value > 0.05 and significant when P-value ≤ 0.05.

2.5 Ethical Considerations and Review:

Study protocol was approved by Faculty of Medicine, Beni-Suef University, Research Ethics Committee.

3. Results

The study included 40 ARDS patients with age 43.8 13.72 years there were 40% females and 60 % males, 10 patients were diabetic while 13 were hypertensive and 12 had dyslipidemia, 65% of causes of ARDS were pulmonary and 35% were extrapulmonary.

All the mentioned basic characters showed non-significant correlation with LUS (p value> .05).

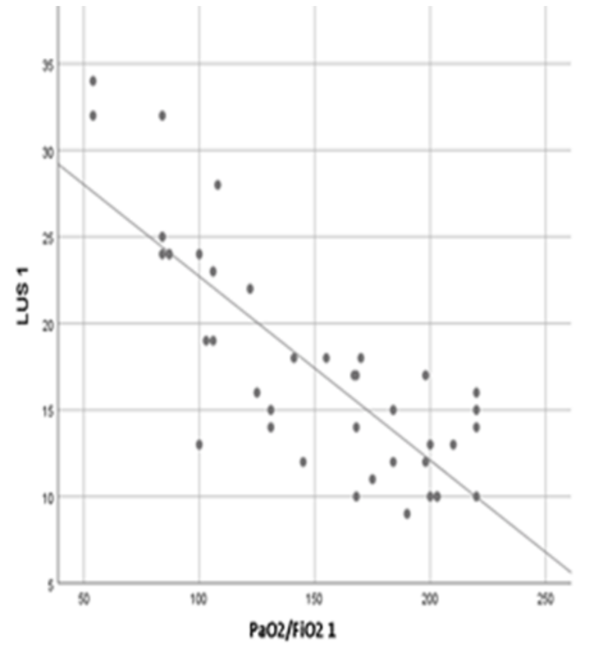
Comparison between LUS before and after the RM of the lung:

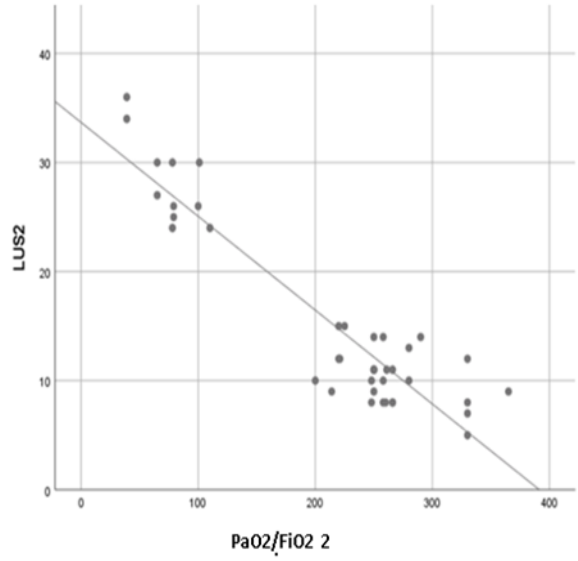
LUS was decreased from (25.3±6.3) before RM to (17.4±6.5) after RM with a (p value ≤ 0.001) which is significantly important and after 12 hours it significantly decreased to (15.38±8.62) with a (p value ≤ 0.001).

Comparison between PO2/Fio2 before and after the RM of the lung:

PaO2/FiO2 was significantly increased from (101.95±42.4) before RM to (149.33±50.4) after RM with a (p value ≤ 0.001) and after 12 hours it increased to (212.6 ±92) with a (p value<0.001).

By correlation between LUS and PaO2/FiO2 after RM it shows a significant negative correlation between LUS and PaO2/FiO2 after RM (p value ≤ 0.001 r = -٠.8) same after 12 hours with (p value ≤ 0.001, r = -٠.8) by other word the high the PaO2/FiO2 the low the LUS [Figure (1, 2)].





[Figure (1,2)]. Correlation between PO2/Fio2 after the RM of the lung.

Comparison between Compliance before and after the RM of the lung:

Compliance was significantly increased from (30.68±4.7) before RM to (35.9 ±7.6) after RM with a (p value ≤ 0.001) and after 12 hours it increased to (41.6 ±13.6) with a (p value ≤ 0.001)

By correlation between LUS and compliance before RM it shows a negative correlation between LUS and compliance (p value = 0. 01, r = -٠.3) and after RM by 1 and 12 hours it shows a significant negative correlation (p value ≤ 0. 001, r = -٠.6) & (p value ≤ 0. 001, r = -.7) respectively by other word the high the compliance the low the LUS.

Complication and Mortality

5 (12.5%) patients became hypotensive during recruitment and 5 (12.5%) patients experienced arrhythmias during recruitment with only 3 (7.5%) patients had pneumothorax during the study.11 (27.5%) patients died throughout the study [Table (1)].

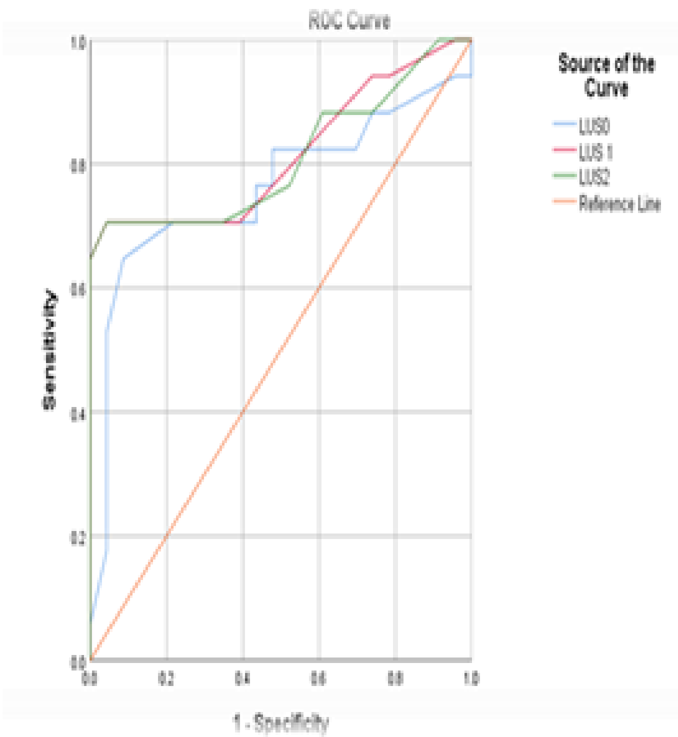
[Table (1)]: complications and Mortality.

Items	Groups (N=40) no.(%)
Hypotenion	5(12.5)
Arrhythmia	5(12.5)
Pneumothorax	3(7.5)
Outcome **Favorable** **Unfavorable**	 11(27.5) 29 (72.5)
Complications	8(20)
Mortality	17(42.5)
ICU stay	8.55±3.348
Ventilation days	5.90±2.22

ROC curve analysis

In our study; ROC Curve analysis for prediction of mortality using LUS in ARDS patients, The optimal cut-off point of baseline LUS for prediction of death was ≥28.50 with a sensitivity of 70.6%% and a specificity of 77.9% and with a P value of <0.05.

The optimal cut-off point of LUS just after RM for prediction of death was ≥18.50 with a sensitivity of 70.6%% and a specificity of 95.7%and with a P value of 0.01 while 12 hours after recruitment The optimal cut-off point of LUS for prediction of death was ≥14.50 with a sensitivity of 70.6%% and a specificity of 95.7%and with a P value of 0.01 [Figure (3)].



[Figure (3)].ROC curve analysis

4. Discussion:

We used LUS to measure lung aeration before and after recruitment at the bedside, avoiding the complications and workload associated with using a CT scan and with PaO2/FiO2 was used to assess oxygenation improvement.

LUS was decreased from (25.3±6.3) before RM to (17.4±6.5) after RM with a (p value ≤ 0.001) which is significantly important and after 12 hours it significantly decreased to (15.38±8.62) with a (p value ≤ 0.001).

In the same context Bouhemad B et al, also discovered a strong significant correlation between CT scan and ultrasound lung reaeration (Rho = 0.85, p < .0001). Chest radiography was inaccurate in predicting lung reaeration [19].

Algieri et al compared transthoracic lung US with CT for the assessment of lung aeration and recruitment in 7 patients with ARDS and found a positive link between the two methods [20].

As a result to RM in our study PaO2/FiO2 was significantly increased from (101.95±42.4) before RM to (149.33± 50.4) after RM with a (p value ≤ 0.001) and after 12 hours it increased to (212.6 ±92) with a (p value<0.001).

When LUS and PaO2/FiO2 were compared before and after RM, it was discovered that there is a strong negative association between the two, meaning that the higher the PaO2/FiO2, the lower the LUS.

Lianhua Li et al. discovered the same thing when they observed 62 ARDS patients and discovered that LUS had a negative association with with oxygenation index (r=-0.755, P<0.001) [21].

Juan p boriosi et al, studying LUS and RM in ARDS children found that there was a variable increase in aerated and poorly aerated lung after the RM ranging from 3% to 72% (median 20%; interquartile range 6, 47; P = 0.03). All patients had improvement in the ratio of partial pressure of arterial oxygen over fraction of inspired oxygen (PaO(2) /FiO(2)) after the RM [22].

This is side by side with Stefanidis K et al, who reported a significant correlation between the lung reaeration assessed by LUS and oxygen partial pressure as he found that the nonaerated areas in the dependent lung regions were significantly reduced during PEEP increases from 5 to 10 to 15 cm H2O (27 ± 31 cm2 to 20 ± 24 cm2 to 11 ± 12 cm2, respectively; P < 0.01). These changes were associated with a significant increase in arterial oxygen partial pressure (74 ± 15 mmHg to 90 ± 19 mmHg to 102 ± 26 mmHg; P < 0.001, respectively)[23].

In a study of 50 patients with paraquat intoxication for the prediction of ARDS growth, Xiao Lu et al found that patients with ARDS have a lower PaO2/FiO2 (p 0.001) and a higher lung ultrasound score (p 0.001) than non-ARDS patients, and that the decrease in PaO2/FiO2 was associated with the increase in LUS between days 3 and 7 [24].

Again in our study LUS obtained before and after 12 hours after RM was correlated with lung compliance at same time, there were a strong negative correlations between compliance and LUS with (P<001 r -.87) and. (P=, 001 r -.66) respectively

By other wards the less LUS the more the lung compliance improvement

This agreed with Hodgson cl et al 2011 who randomly studied 20 ARDS patients treated with PEEP titration Vs ARDS net control ventilation strategies they found improvement in PaO2/FIO2 in treatment group vs control group (204 ± 9 versus 165 ± 9 mmHg, P = 0.005) and static lung compliance (49.1 ± 2.9 versus 33.7 ± 2.7 mls/cm H2O, P < 0.001) over 7 days [25].

Also George Ntoumenopoulos et al, who studied Lung ultrasound score as an indicator of dynamic lung compliance during veno-venous ECMO showed that there was a strong negative association between LUS-score and dynamic lung compliance (rs(33) = –0.66, p < .001) providing some validation on the use of the LUS score as a potential surrogate measure of lung aeration and lung mechanics during VV-ECMO weaning[26].

Same by A.Lehr et al who Correlation Between the Simplified Lung Ultrasound Score and Measures of Static Lung Compliance he found that the ultrasound B line score inversely correlated with lung static compliance ((r=-0.62, P<0.001)[27].

Throughout the study patients from the 2 groups faced some complication; 5 patients (12.5%) became hypotensive during recruitment،

5 patients (12.5%) experienced arrhythmias during recruitment 3 patients (7.5%) were complicated with pneumothorax during recruitment

All showed no statically significant difference between the two groups

Patients included in the study were segregated according to outcome into 23 survivors (57.5%) and 17 (42.5%) non survivors.

In our study; ROC Curve analysis for prediction of mortality using LUS in ARDS patients ,The optimal cut-off point of LUS for prediction of death was ≥28.50 with a sensitivity of 70.6%% and a specificity of 77.9%and with a P value of 0.05.while 12 hours after recruitment The optimal cut-off point of LUS for prediction of death was ≥14.50 with a sensitivity of 70.6%% and a specificity of 95.7%and with a P value of 0.01.

5. Conclusion and Recommendations

In conclusion

Bedside ultrasonography can be very useful in the evaluation of lung aeration and efficacy of RM in ARDS patients

6.References :

1- Kim, S. Y., Kim, Y. H., Sol, I. S., Kim, M. J., Yoon, S. H., Kim, K. W., ... & Kim, K. E. (2016). Application of the Berlin definition in children with acute respiratory distress syndrome. *Allergy, Asthma & Respiratory Disease*, *4*(4), 257-263.

2- Fan, E., Del Sorbo, L., Goligher, E. C., Hodgson, C. L., Munshi, L., Walkey, A. J., ... & Brochard, L. J. (2017). An official American Thoracic Society/European Society of Intensive Care Medicine/Society of Critical Care Medicine clinical practice guideline: mechanical ventilation in adult patients with acute respiratory distress syndrome. *American journal of respiratory and critical care medicine*, *195*(9), 1253-1263.

3- Laffey, J. G., & Kavanagh, B. P. (2000). Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury. *N Engl J Med*, *343*(11), 812.

4- Brunner, J. X., & Wysocki, M. (2012). Is there an optimal breath pattern to minimize stress and strain during mechanical ventilation?. In *Applied Physiology in Intensive Care Medicine 1* (pp. 25-29). Springer, Berlin, Heidelberg.

5- *Figueroa-Casas, J. B., Brunner, N., Dwivedi, A. K., & Ayyappan, A. P. (2013). Accuracy of the chest radiograph to identify bilateral pulmonary infiltrates consistent with the diagnosis of acute respiratory distress syndrome using computed tomography as reference standard. Journal of critical care, 28(4), 352-357.*

6- Baston, C., & West, T. E. (2016). Lung ultrasound in acute respiratory distress syndrome and beyond. *Journal of thoracic disease*, *8*(12), E1763.

7- Rothen, H. U., Neumann, P., Berglund, J. E., Valtysson, J., Magnusson, A., & Hedenstierna, G. (1999). Dynamics of re-expansion of atelectasis during general anaesthesia. *British journal of anaesthesia*, *82*(4), 551-556.

8- Sippel, S., Muruganandan, K., Levine, A., & Shah, S. (2011). Use of ultrasound in the developing world. *International journal of emergency medicine*, *4*(1), 1-11.

9- Ye, X., Xiao, H., Chen, B., & Zhang, S. (2015). Accuracy of lung ultrasonography versus chest radiography for the diagnosis of adult community-acquired pneumonia: review of the literature and meta-analysis. PloS one, 10(6), e0130066..

10- Llamas-Alvarez, A. M., Tenza-Lozano, E. M., & Latour-Perez, J. (2017). Accuracy of lung ultrasonography in the diagnosis of pneumonia in adults: systematic review and meta-analysis. *Chest*, *151*(2), 374-382.

11- Lichtenstein, D., Goldstein, I., Mourgeon, E., Cluzel, P., Grenier, P., & Rouby, J. J. (2004). Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. *The Journal of the American Society of Anesthesiologists*, *100*(1), 9-15.

12- Lichtenstein, D. A., & Mezière, G. A. (2011). The BLUE-points: three standardized points used in the BLUE-protocol for ultrasound assessment of the lung in acute respiratory failure. *Critical Ultrasound Journal*, *3*(2), 109-110..

13- Tobin, M. J. (2006). Principles and practice of mechanical ventilation..

14- Ferguson, N. D., Fan, E., Camporota, L., Antonelli, M., Anzueto, A., Beale, R., ... & Ranieri, V. M. (2012). The Berlin definition of ARDS: an expanded rationale, justification, and supplementary material. *Intensive care medicine*, *38*(10), 1573-1582.

15- Bouhemad, B., Zhang, M., Lu, Q., & Rouby, J. J. (2007). Clinical review: bedside lung ultrasound in critical care practice. *Critical care*, *11*(1), 1-9.

16- Bouhemad, B., Brisson, H., Le-Guen, M., Arbelot, C., Lu, Q., & Rouby, J. J. (2011). Bedside ultrasound assessment of positive end-expiratory pressure–induced lung recruitment. *American journal of respiratory and critical care medicine*, *183*(3), 341-347.

17- Volpicelli, G., Elbarbary, M., Blaivas, M., Lichtenstein, D. A., Mathis, G., Kirkpatrick, A. W., & Petrovic, T. (2012). International evidence-based recommendations for point-of-care lung ultrasound. *Intensive care medicine*, *38*(4), 577-591.

18- Kallet, R. H., Corral, W., Silverman, H. J., & Luce, J. M. (2001). Implementation of a low tidal volume ventilation protocol for patients with acute lung injury or acute respiratory distress syndrome. *Respiratory care*, *46*(10), 1024-1037.

19- Bouhemad, B., Liu, Z. H., Arbelot, C., Zhang, M., Ferarri, F., Le-Guen, M., ... & Rouby, J. J. (2010). Ultrasound assessment of antibiotic-induced pulmonary reaeration in ventilator-associated pneumonia. *Critical care medicine*, *38*(1), 84.

20- Chiumello, D., Mongodi, S., Algieri, I., Vergani, G. L., Orlando, A., Via, G., & Mojoli, F. (2018). Assessment of lung aeration and recruitment by CT scan and ultrasound in acute respiratory distress syndrome patients. *Critical care medicine*, *46*(11), 1761-1768.

21- Li, L., Yang, Q., Guan, J., Liu, Z., Han, J., Chao, Y., ... & Yu, X. (2015). The value of lung ultrasound score on evaluating clinical severity and prognosis in patients with acute respiratory distress syndrome. *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue*, *27*(7), 579-584.

22- Boriosi, J. P., Cohen, R. A., Summers, E., Sapru, A., Hanson, J. H., Gildengorin, G., ... & Flori, H. R. (2012). Lung aeration changes after lung recruitment in children with acute lung injury: a feasibility study. *Pediatric pulmonology*, *47*(8), 771-779.

23- Stefanidis, K., Dimopoulos, S., Tripodaki, E. S., Vitzilaios, K., Politis, P., Piperopoulos, P., & Nanas, S. (2011). Lung sonography and recruitment in patients with early acute respiratory distress syndrome: a pilot study. *Critical Care*, *15*(4), 1-8.

24- Lu, X., Wu, D., Gao, Y., & Zhang, M. (2017). Lung ultrasound predicts acute respiratory distress syndrome in patients with paraquat intoxication. *Hong Kong Journal of Emergency Medicine*, *24*(6), 275-281..

25- Hodgson, C. L., Tuxen, D. V., Davies, A. R., Bailey, M. J., Higgins, A. M., Holland, A. E., ... & Nichol, A. D. (2011). A randomised controlled trial of an open lung strategy with staircase recruitment, titrated PEEP and targeted low airway pressures in patients with acute respiratory distress syndrome. *Critical care*, *15*(3), 1-9.

26- Ntoumenopoulos, G., Buscher, H., & Scott, S. (2020). Lung ultrasound score as an indicator of dynamic lung compliance during veno-venous extra-corporeal membrane oxygenation. *The International Journal of Artificial Organs*, 0391398820948870.

27- Lehr, A., Pradhan, D., Zakhary, B., Amdo, T. D., & Mukherjee, V. (2019). Correlation between the simplified lung ultrasound score and measures of static lung compliance. In A43. CRITICAL CARE: MAXIMUM OVERDRIVE-ACUTE RESPIRATORY FAILURE AND MECHANICAL VENTILATION (pp. A1655-A1655). American Thoracic Society