Lung Ultrasound as Bedside Tool for Assessment of Severity, Prognosis and Mortality Criteria in ICU Patients with ARDS

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Abstract

Aim of the Study: This study aims to assess the usefulness of lung ultrasound (LUS) score as a bedside tool for evaluating severity, prognosis, and mortality criteria in ICU patients with ARDS. **Methodology:** A prospective study was conducted on 30 ARDS patients admitted to Kasr Alaini Critical Care Department at Cairo University. The study collected clinical data and scores, including age, sex, and comorbidities such as hypertension, chronic obstructive pulmonary disease, diabetes mellitus, and ischemic heart disease. Respiratory parameters like tidal volume, positive end-expiratory pressure, lung compliance, peak inspiratory pressure, and plateau pressure were recorded. Other measurements included serum albumin, fluid balance, ejection fraction, Acute Physiology and Chronic Health Evaluation (APACHE), and ultrasound imaging of the anterior lung field. **Results:** LUS proves to be a simple and cost-effective method for predicting the prognosis of ARDS patients and can act as a diagnostic marker for the disease. **Conclusion:** Lung ultrasound is a useful prognostic and diagnostic tool for ARDS patients. It is easily accessible, user-friendly, and economical, and does not involve ionizing radiation. LUS complements bedside chest X-ray and reduces the need for CT scans. It is a valuable tool for diagnosing, managing, and predicting the outcomes of ARDS. Recommendation: It is recommended to use LUS for diagnosing and predicting the prognosis in ARDS patients. Further studies are needed to confirm the effectiveness of LUS in ARDS management.

Keywords: Lung- Ultrasound - Severity, Prognosis - Mortality Criteria - ICU Patients

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Introduction

Acute Respiratory Distress Syndrome (ARDS) is a critical condition that demands prompt and accurate management in intensive care units (ICUs) due to the challenges associated with its diagnosis, severity assessment, and monitoring of therapeutic response. While traditional imaging modalities, such as chest radiography and computed tomography (CT), remain standard tools for evaluating ARDS, these techniques can be impractical, costly, or pose risks during the transport of critically ill patients. (**Bellani et al., 2016**).

In this context, lung ultrasound (LUS) has emerged as a non-invasive, bedside, and effective modality, offering a unique combination of ease of use and the ability to provide immediate and precise insights into lung pathology. LUS enables the assessment of ARDS severity by identifying specific markers such as B-lines, lung consolidations, and pleural effusions. Furthermore, it holds significant potential as a prognostic tool for estimating disease outcomes and predicting mortality rates in ARDS patients. (**Virani et al., 2019**). This study aims to highlight the critical role of lung ultrasound in ICUs as a comprehensive bedside assessment tool, emphasizing its effectiveness in enhancing patient care and its utility in determining severity and prognostic criteria in ARDS patients. (**Gibelin et al., 2019**). While computed tomography (CT) is the gold standard for diagnosing ARDS, it usually shows severe, nonhomogeneous aeration loss, ground-glass opacities, and posterior consolidations (**Pesenti et al., 2016**). However, CT is not suitable for continuous lung monitoring. In recent years, lung ultrasound (LUS) has become an increasingly recognized tool for assessing and monitoring acute respiratory failure at the bedside (**Mojoli et al., 2019**).

Lung ultrasound (LUS) has emerged as a transformative diagnostic and monitoring tool in critical care, offering a non-invasive, radiation-free, cost-effective, and easily accessible alternative to traditional imaging methods. Over the past decade, its popularity in intensive care units (ICUs) has surged due to its practicality, portability, and ability to deliver real-time diagnostic insights. Unlike chest X-rays or CT scans, which may require patient transport and involve radiation exposure, LUS can be performed at the bedside, making it particularly advantageous for critically ill patients who are often

unstable and difficult to mobilize. This bedside capability reduces risks, enhances safety, and ensures that timely clinical decisions can be made. (**Riviello et al., 2016**).

Lung ultrasound has been extensively validated for numerous applications, including hemodynamic evaluation, detection of pleural effusions, pneumothorax diagnosis, and guidance for central venous catheter placement. Its ability to provide real-time visualization of the lung's superficial structures makes it particularly beneficial in critical care settings, where rapid and accurate diagnostic tools are essential **(Riviello et al., 2016).**

The versatility of LUS further underscores its value in ICU settings. It is widely validated for a range of applications, including hemodynamic assessment, detection of pleural effusions, pneumothorax diagnosis, and guidance during procedures such as central venous catheter placement. Moreover, LUS offers a unique view of the lung's superficial anatomy, allowing clinicians to detect abnormalities that may not be readily apparent on other imaging modalities. Its growing integration into critical care protocols reflects a paradigm shift toward using point-of-care ultrasound (POCUS) as a cornerstone of patient management, driven by its efficiency, accuracy, and ability to improve patient outcomes. (**Ibrahim et al., 2019; Mongodi et al., 2019**).

Early evaluation of ARDS severity and the identification of coexisting conditions are crucial for optimizing treatment and improving outcomes. LUS has been shown to correlate positively with established ARDS severity and prognosis measures, such as the Acute Physiology and Chronic Health Evaluation II (APACHE II) score, the Sequential Organ Failure Assessment (SOFA) score, and the Clinical Pulmonary Infection Score. Moreover, LUS is effective in assessing changes in pulmonary ventilation, determining disease severity, and predicting mortality in ARDS patients (**Zhou et al., 2018**).

Aim of the Work / Objectives

This study aims to evaluate the value of lung ultrasound score as bedside tool for assessment severity, prognosis and mortality criteria in ICU Patients with (ARDS).

Patients and Methods

Patients: This prospective study was conducted on 30 patients admitted to Kasr Alaini Critical Care Department, Cairo University.

Inclusion criteria:

All ARDS patients in the study satisfied the criteria set by the Berlin definition, which includes the presence of acute hypoxemic respiratory failure, onset within seven days of a triggering event or the worsening of respiratory symptoms, bilateral chest opacities on imaging (either X-ray or CT) not caused by effusions, lung collapse, or nodules, and the exclusion of cardiac failure as the primary cause of respiratory distress (**Kamo et al., 2019**).

Exclusion criteria

- Presence of massive subcutaneous emphysema or dressings over the examination area.
- Diagnosis of congestive heart failure.
- Severe chest cage deformities rendering lung ultrasound unfeasible.

Methodology in details:

All patients will undergo the following assessments, with clinical data and scores recorded to provide a comprehensive evaluation of their health status and prognosis:

1. **Demographic Data:**
   - Age and gender will be recorded to identify potential demographic risk factors.
2. **Comorbidities:**
   - Chronic health conditions such as hypertension (HTN), chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), and ischemic heart disease (IHD) will be reviewed to assess their impact on the patient's clinical condition.
3. **Respiratory Parameters:**
   - Measurements including tidal volume (Vt), positive end-expiratory pressure (PEEP), lung compliance, peak inspiratory pressure (PIP), and plateau pressure (Pplat) will be evaluated to assess respiratory function.
4. **Laboratory and Cardiac Indicators:**
   - Serum albumin levels will be measured to assess the patient's nutritional and protein status.
   - Fluid balance over a 24-hour period will be examined to evaluate hydration and fluid management.
   - Ejection fraction (EF%) will be assessed to gauge cardiac function and its role in the patient's overall clinical state.
5. **Acute Physiology and Chronic Health Evaluation II (APACHE II) Score:**
   - Lung Ultrasound Score (LUS) has been shown to have a positive correlation with traditional measures for ARDS severity and prognosis, such as the APACHE II score, Sequential Organ Failure Assessment (SOFA) score, and Clinical Pulmonary Infection Score (CPIS). LUS provides useful information on alterations in lung ventilation due to ARDS, as well as disease severity, prognosis, and mortality (Matthay et al., 2019).
   - The APACHE II score includes a range of variables: age, rectal temperature, mean arterial blood pressure (MAP), heart rate (HR), respiratory rate (RR), partial pressures of oxygen (PO_2) and carbon dioxide (PCO_2), alveolar-arterial oxygen gradient (A-a gradient), arterial pH, bicarbonate (HCO_3), sodium (Na), potassium (K), creatinine, hematocrit (HCT%), white blood cells (WBCs), Glasgow Coma Scale (GCS), and chronic diseases.
6. **Ultrasound System and Examination Protocol:**
   - A 5 MHz ultrasound system with a standard convex probe was used. Chest ultrasound was conducted using the 12-region method, covering both the upper

and lower parts of the anterior, lateral, and posterior lung regions.

- All intercostal spaces within the specified regions were examined, with the most severe abnormality identified to characterize each region.
- Lateral lung regions were evaluated from the anterior to posterior axillary lines, while the posterior lung regions were examined from the posterior axillary line to the spine.
- The upper and lower parts of the anterior, lateral, and posterior lung regions were defined using the horizontal mammillary line. Four distinct ultrasound patterns, corresponding to different levels of aeration loss, were identified in each intercostal space **(Volpicelli et al., 2014):**
  - (0) Normal lung aeration: identified by the presence of lung sliding along with horizontal "A lines," occasionally accompanied by one or two isolated vertical "B lines."
  - Moderate aeration loss: marked by multiple well-defined "B1 lines" approximately 7 mm apart, arising from the pleural line and indicative of interstitial fluid accumulation.
  - Severe aeration loss: demonstrated by numerous merged vertical "B2 lines" originating from the pleural line, corresponding to alveolar edema. Complete aeration loss: characterized by lung consolidation, which appears as a tissue-like pattern containing either small bright punctate images (static air bronchograms) or bright tubular structures (dynamic air bronchograms).
  - The lung ultrasound score (LUS score) was assigned based on four distinct ultrasonographic patterns: N = 0, B1 = 1, B2 = 2, and C = 3. Each patient underwent a comprehensive LUS assessment, during which 12 lung regions were systematically examined. The final LUS score was calculated as the sum of individual regional scores, yielding a total ranging from 0 to 36.

7-Examination of anterior lung field **(Babak and Paul, 2010).**

8-Examination of lateral lung field **(Babak and Paul, 2010).**

9-Partial examination of posterior lung field **(Babak and Paul, 2010).**

10. **Ultrasound Patterns Based on Lung Aeration (Zhao et al., 2015):** Four distinct ultrasound patterns are used to assess lung aeration:

- **(a) Normal Aeration (N):** This pattern is characterized by the presence of lung sliding with A lines, or by having fewer than two isolated B lines.
- **(b) Moderate Loss of Lung Aeration:** This is identified by multiple well-defined B lines (B1 lines) that indicate moderate loss of aeration.
- **(c) Severe Loss of Lung Aeration:** This pattern is characterized by numerous coalescent B lines (B2 lines), representing a severe loss of lung aeration.
- **(d) Lung Consolidation (C):** This is identified by a tissue-like pattern on the ultrasound, indicating consolidation in the lung.

For each region of interest, points were assigned based on the most severe ultrasound pattern observed:

a. N (Normal): 0 points
b. B1 lines (Moderate loss): 1 point
c. B2 lines (Severe loss): 2 points
d. C (Lung consolidation): 3 points

11- Lung ultrasound examination was studied and recorded as follows :

12- Total lung ultrasound score (LUS score):

- Lung ultrasound score at 1st day examination (LUS1).
- Lung ultrasound score at 2nd day examination (LUS2).
- Lung ultrasound score at 3rd day examination (LUS3).
- Lung ultrasound score at 4th day examination (LUS4).

2) Lung ultrasound score in every single region as follows:

LUS score in every single region

	LUS score in each single region
LUS(R1)	Lung ultrasound score in posterior lower right region
LUS(R2)	Lung ultrasound score in lateral lower right region
LUS(R3)	Lung ultrasound score in anterior lower right region
LUS(R4)	Lung ultrasound score in posterior upper right region
LUS(R5)	Lung ultrasound score in lateral upper right region
LUS(R6)	Lung ultrasound score in anterior upper right region
LUS(L1)	Lung ultrasound score in posterior lower left region
LUS(L2)	Lung ultrasound score in lateral lower left region
LUS(L3)	Lung ultrasound score in anterior lower left region
LUS(L4)	Lung ultrasound score in posterior upper left region
LUS(L5)	Lung ultrasound score in lateral upper left region
LUS(L6)	Lung ultrasound score in anterior upper left region

LUS score in every single region LUS score in each single region LUS(R1) lung ultrasound score in posterior lower right region LUS (R2) lung ultrasound score in lateral lower right region LUS (R3) lung ultrasound score in anterior lower right region LUS (R4) lung ultrasound score in posterior upper right region LUS(R5) lung

ultrasound score in lateral upper right region LUS (R6) lung ultrasound score in anterior upper right region LUS (L1) lung ultrasound score in posterior lower left region LUS(L2) lung ultrasound score in lateral lower left region LUS(L3) lung ultrasound score in anterior lower left region LUS (L4) lung ultrasound score in posterior upper left region LUS (L5) lung ultrasound score in lateral upper left region LUS (L6) lung ultrasound score in anterior upper left region.

3) Total number of affected lung regions for regions with LUS >1 for every single lung region.

4) Total number of severely affected regions with LUS > 2 for single lung region (B2, C).

- Total number of regions with LUS score of 2 named as: (B2).
- Total number of regions with LUS score of 3 named as: (C).

5) Lung ultrasound will be done daily for four consecutive days

6) Lung Ultrasonography will be correlated with;

- Respiratory parameters as tidal volume (Vt), positive end expiratory pressure (PEEP), lung compliance, peak inspiratory pressure (PIP), and plateau pressure (Pplat).
- APACHE 2 score.

Statistical analysis:

The data were entered and analyzed using IBM SPSS software, version 20.0 (Armonk, NY: IBM Corp). Qualitative data were presented as counts and percentages, and the normality of the distribution was assessed using the Kolmogorov-Smirnov test. Quantitative data were described using the range (minimum and maximum), mean, standard deviation, median, and interquartile range (IQR). Statistical significance was set at a 5% level.

The following statistical tests were applied:

1. **Chi-square test**:
   - Used to analyze categorical variables and compare different groups.
2. **Fisher's Exact Test or Monte Carlo Correction**:
   - Applied when more than 20% of the cells in a chi-square test have an expected count of less than 5.
3. **Student t-test**:
   - Used to compare two groups of normally distributed quantitative variables.
4. **Paired t-test**:
   - Used to compare two measurements from the same group at different times when the data are normally distributed.

Statistical Analysis:

Data were gathered through patient history, clinical examination, laboratory tests, and outcome measures. The data were then coded, entered, and analyzed using Microsoft Excel and SPSS (version 25.0; Armonk, NY: IBM Corp). Normality of the data was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests.

Two types of statistical analysis were performed:

Descriptive Statistics:

- Qualitative data were presented as counts and percentages. Quantitative data were expressed as the mean ± standard deviation (for parametric data) and median with interquartile range (for non-parametric data).

Analytic Statistics:

- **Chi-square test ($\chi 2$):** Used to assess the relationship between two qualitative variables.
- **Student t-test:** Applied to compare two groups with normally distributed quantitative variables (for parametric data).
- **Paired t-test:** Used to compare two periods in the same group with normally distributed quantitative variables.
- **Mann Whitney test:** Used to compare two groups with abnormally distributed quantitative variables.
- **Friedman test:** Used to compare more than two periods or stages in the case of abnormally distributed quantitative variables.

- A P-value of < 0.05 was considered statistically significant, and < 0.001 was considered highly significant for two-tailed tests.

The collected data were subjected to statistical analysis using the tests and parameters mentioned above.

Lastly, the goal of the return to activity phase (months 5-9) is to gradually reintroduce sports activities while maintaining mobility, strength, and stability.

Results

Table (1) shows A total of 30 patients with ARDS, their age ranged from 58 to 75 and the mean of age was 66.47 ± 6.40 years. The majority of the patients was males 21(70%). Regarding Co-morbidities, 21(70%) patients were smoking, 25(83.5%) having hypertension, and 26(86.7%) having diabetes.

Table (2) shows APACHE II score in day one was 13.66±2.58, in day two was 13.98±2.42, in day three was 15.07±2.25, then in day four was 16.78±3.46, there was

statistically significant increase in the score across days ($p<0.001$).

Table (3) shows the respiratory parameters change across days where, there was statistically significant decrease in the VT, Pao2/Fio2, Pco2, and Peak inspiratory pressure across days ($p<0.001$). VT in day one was 419.73±26.45, in day two was 412.00±24.23, in day three was 411.83±25.68, then in day four was 406.67±31.22, Pao2/Fio2 in day one was 171±35, in day two was 166±34, in day three was 163±35, then in day four was 163±42, Pco2 in day one was 33.03±6.93, in day two was 31.37±4.75, in day three was 29.83±5.07, then in day four was 30.13±6.88, Peak inspiratory pressure in day one was 33.17±1.82, in day two was 33.30±1.80, in day three was 33.67±2.14, then in day four was 29.90±10.89.

As regards PEEP, RR, and Plateau pressure there statistically significant increase in them across days, where PEEP in day one was 5.63±1.59, in day two was 5.63±1.59, in day three was 5.77±1.74, then in day four was 5.77±1.74, RR in day one was 26.40±1.63, in day two was 27.17±1.97, in day three was 26.63±1.19, then in day four was 27.20±1.79, Plateau pressure in day one was 17.57±4.78, in day two was 17.97±4.55, in day three was 17.93±4.93, then in day four was 18.67±5.02.

Table (4) shows the Lap data change across days where, there was statistically significant increase in the TLC, CRP and decrease in albumin across days ($p<0.001$). TLC in day one was 11.83±2.13, in day two was 15.00±2.10, in day three was 14.93±1.98, then in day four was 16.27±3.11, CRP in day one was 47.27±21.20, in day two was 67.27±24.07, in day three was 67.77±26.03, then in day four was 73.00±26.91, albumin in day one was 3.70±0.11, in day two was 3.64±0.12, in day three was 3.63±0.14, then in day four was 3.58±0.08.

As regards Urea, and Creatinine, there was no statistically significant difference between them across days.

Table (5) shows Lung ultrasonography score change across days where, there was statistically significant increase in the Right LUS and Left LUS across days ($p<0.001$). Right LUS score in day one was 4.43±1.23, in day two was 4.65±1.28, in day three was 5.32±1.34, then in day four was 5.64±1.41, Left LUS score in day one was 4.40±2.25, in day two was 4.67±2.59, in day three was 4.97±2.58, then in day four was 5.53±2.70.

Table (6) shows the CVP and fluid balance change across days where, there was statistically significant decrease in the CVP and fluid balance across days ($p<0.001$). CVP in day one was 8.53 ± 1.57, in day two was 8.13±0.35 , in day three was 7.00±2.39, then in day four was 7.33±2.04, fluid balance in day one was -26.67±44.98, in day two was -40.0±67.47, in day three was -46.0±48.25, then in day four was -54.33±62.57.

Table (1): Demographic data of patients

		Cases (n = 30)	
		No.	%
• Age	Mean ±SD	66.47 ± 6.40	
	Range	58 - 75	
• Sex	Male	21	70
	Female	9	30
• Comorbidity	Smoking	21	70.0
	Hypertension	25	83.3
	Diabetes mellitus	26	86.7

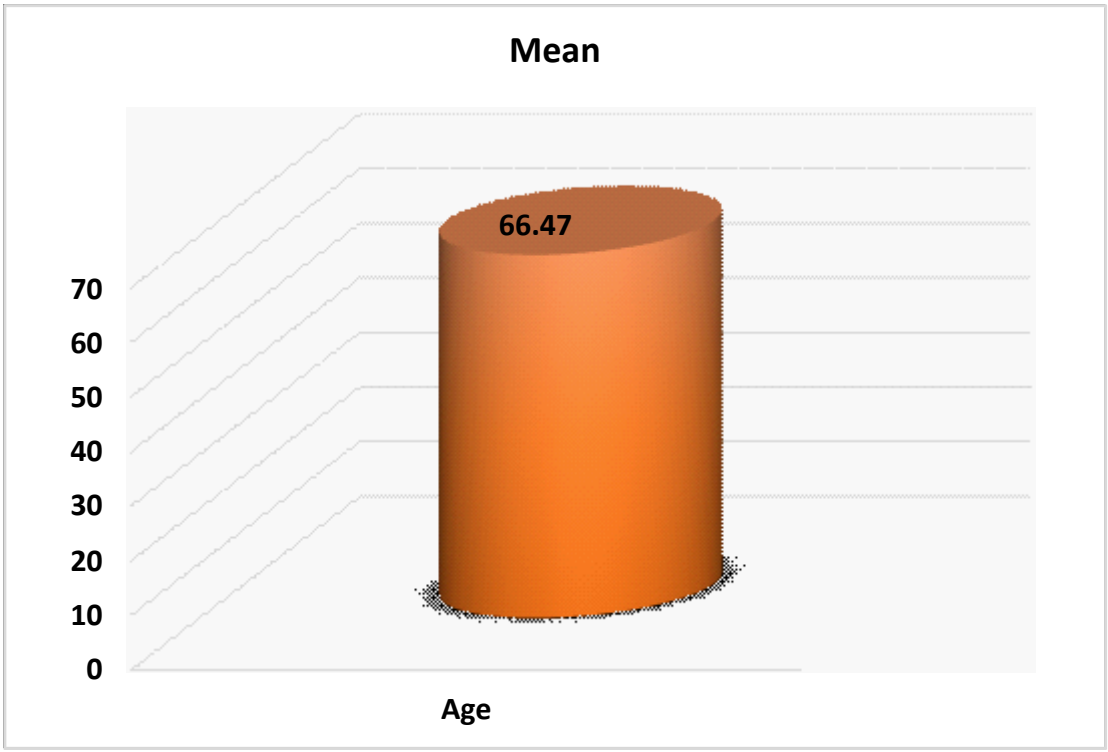


Figure (1): Mean of age of patients

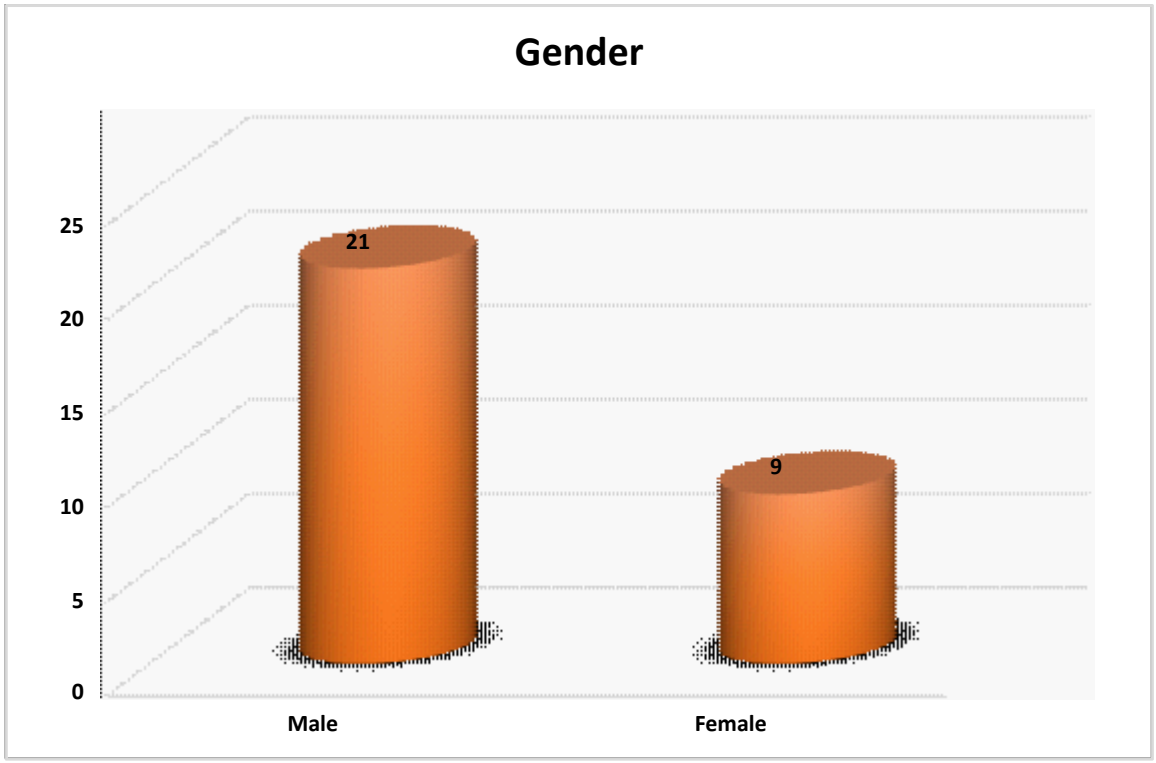


Figure (2): Distribution of the studied cases according to gender

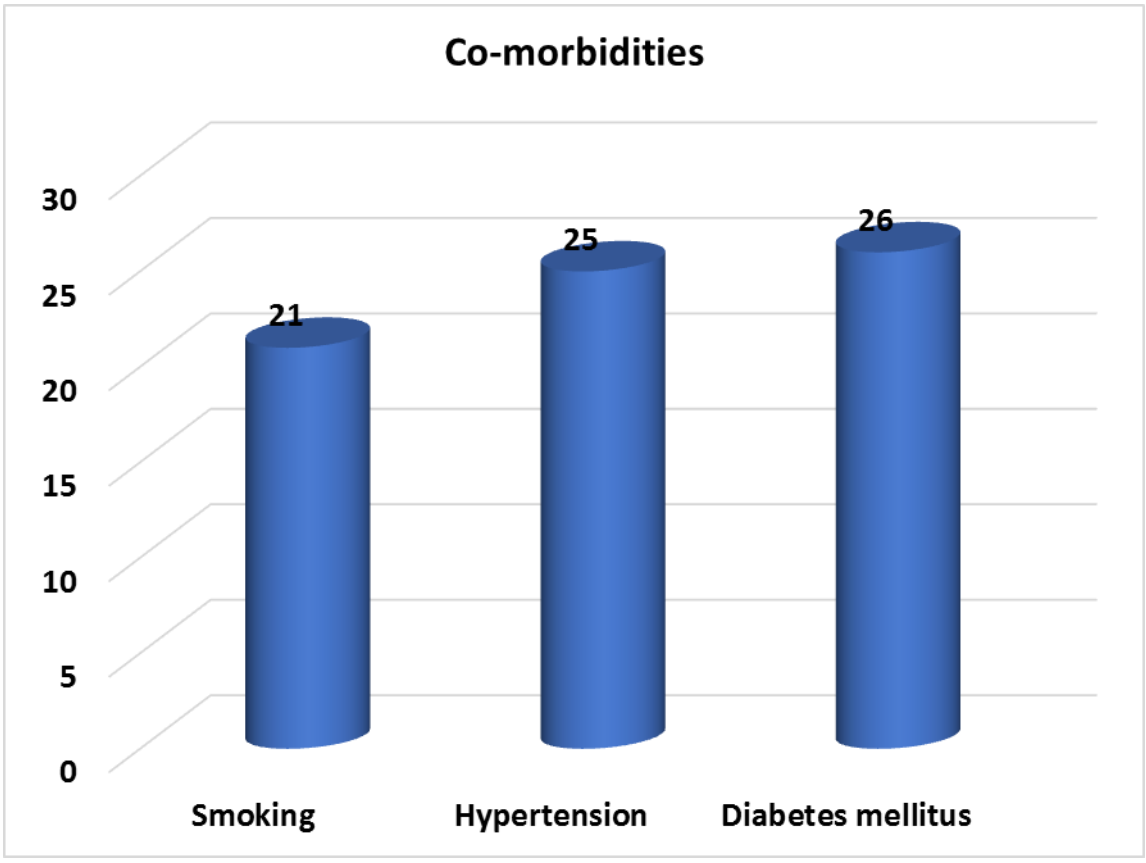


Figure (3): Distribution of the studied cases according to Co-morbidities

Table (2): APACHE II score comparison in four consecutive days in patients with ARDS

	Day 1			Day 2			Day 3			Day 4			Friedman Test
	Mean	±	S.D	Mean	±	S. D	Mean	±	S.D	Mean	±	S.D	p-value
• APACHE II score	13.66	±	2.58	13.98	±	2.42	15.07	±	2.25	16.78	±	3.46	0.001**

**p-value < 0.001 highly statistically significant

Table (3): Respiratory parameters comparison in four consecutive days in patients with ARDS

	Day 1			Day 2			Day 3			Day 4			Friedman Test
	Mean	±	S. D	Mean	±	S.D	Mean	±	S.D	Mean	±	S.D	p-value
PEEP	5.63	±	1.59	5.63	±	1.59	5.77	±	1.74	5.77	±	1.74	0.007*
VT	419.73	±	26.45	412.00	±	24.23	411.83	±	25.68	406.67	±	31.22	0.035*
RR	26.40	±	1.63	27.17	±	1.97	26.63	±	1.19	27.20	±	1.79	0.005*
Pao2/Fio2	171	±	35	166	±	34	163	±	35	163	±	42	0.000**
Pco2	33.03	±	6.93	31.37	±	4.75	29.83	±	5.07	30.13	±	6.88	0.000**
Peak inspiratory pressure	33.17	±	1.82	33.30	±	1.80	33.67	±	2.14	29.90	±	10.89	0.010*
Plateau pressure	17.57	±	4.78	17.97	±	4.55	17.93	±	4.93	18.67	±	5.02	0.000**

*p-value < 0.05 statistically significant **p-value < 0.001 highly statistically significant

Table (4): Lap data comparison in four consecutive days in patients with ARDS

	Day 1			Day 2			Day 3			Day 4			Friedman Test
	Mean	±	S. D	Mean	±	S. D	Mean	±	S. D	Mean	±	S.D	p-value
TLC	11.83	±	2.13	15.00	±	2.10	14.93	±	1.98	16.27	±	3.11	0.002*
CRP	47.27	±	21.20	67.27	±	24.07	67.77	±	26.03	73.00	±	26.91	0.003*
Urea	33.77	±	3.87	35.37	±	5.72	34.90	±	7.13	35.57	±	6.92	0.112
Creatinine	0.81	±	0.40	0.87	±	0.46	0.81	±	0.40	0.89	±	0.46	0.58
Albumin	3.70	±	0.11	3.64	±	0.12	3.63	±	0.14	3.58	±	0.08	0.000**

Table (5): Lung ultrasonography score comparison in four consecutive days in patients with ARDS

	Day 1			Day 2			Day 3			Day 4			Friedman Test
	Mean	±	S. D	Mean	±	S. D	Mean	±	S. D	Mean	±	S.D	p-value
Right LUS	4.43	±	1.23	4.65	±	1.28	5.32	±	1.34	5.64	±	1.41	0.000**
Left LUS	4.40	±	2.25	4.67	±	2.59	4.97	±	2.58	5.53	±	2.70	0.002*

Table (6): CVP and fluid balance comparison in four consecutive days in patients with ARDS

	Day 1			Day 2			Day 3			Day 4			Friedman Test
	Mean	±	S. D	Mean	±	S.D	Mean	±	S.D	Mean	±	S. D	p-value
CVP	8.53	±	1.57	8.13	±	0.35	7.00	±	2.39	7.33	±	2.04	0.001**
Fluid balance (CC)	-26.67	±	44.98	-40.0	±	67.47	-46.0	±	48.25	-54.33	±	62.57	0.001**

Table (7): Correlation between right and left ultrasonography and other parameters in day one

Day one	Right LUS		Left LUS	
	r	p	r	p
• APACHE II score	0.782	0.038*	-0.034	0.943
• PEEP	0.760	0.047*	0.460	0.299
• VT	-0.526	0.225	0.047	0.921
• RR	0.500	0.253	-0.336	0.461
• Pao2/Fio2	0.528	0.003**	-0.815	0.000**
• Pco2	-0.467	0.290	-0.048	0.919
• Peak inspiratory pressure	-0.180	0.699	0.664	0.104
• Plateau pressure	0.591	0.162	0.420	0.349
• TLC	0.837	0.019*	-0.253	0.584
• CRP	-0.054	0.909	-0.001	0.998
• Urea	0.167	0.721	-0.669	0.101
• Creatinine	0.621	0.137	-0.729	0.063
• Albumin	0.413	0.357	0.122	0.795
• CVP	-0.790	0.035*	0.248	0.591
• Fluid balance (CC)	0.688	0.000**	-0.708	0.000**

Table (8): Correlation between right and left ultrasonography and other parameters in day two

Day two	Right LUS		Left LUS	
	r	p	r	p
• APACHE II score	0.684	0.090	-0.003	0.994
• PEEP	0.760	0.047*	0.347	0.445
• VT	-0.589	0.164	0.096	0.837
• RR	0.444	0.319	-0.056	0.906
• Pao2/Fio2	0.568	0.001**	-0.848	0.000**
• Pco2	-0.108	0.817	0.039	0.933
• Peak inspiratory pressure	-0.582	0.170	0.879	0.009**
• Plateau pressure	0.520	0.231	0.421	0.347
• TLC	0.878	0.009**	-0.422	0.345
• CRP	0.022	0.963	0.058	0.902
• Urea	0.384	0.396	-0.727	0.064
• Creatinine	0.681	0.092	-0.705	0.077
• Albumin	0.680	0.093	-0.570	0.182
• CVP	0.180	0.699	-0.138	0.768
• Fluid balance (CC)	0.688	0.000**	-0.789	0.000**

Table (9): Correlation between right and left ultrasonography and other parameters in day three

Day three	Right LUS		Left LUS	
	r	p	r	p
● APACHE II score	0.529	0.222	0.053	0.910
● PEEP	0.731	0.062	0.364	0.422
● VT	-0.636	0.125	0.208	0.654
● RR	0.462	0.296	0.695	0.083
● Pao2/Fio2	0.588**	0.001**	-0.783	0.000**
● Pco2	-0.529	0.222	0.260	0.573
● Peak inspiratory pressure	-0.303	0.509	0.671	0.099
● Plateau pressure	0.594	0.160	0.398	0.376
● TLC	0.828	0.021*	-0.028	0.952
● CRP	0.194	0.676	-0.108	0.817
● Urea	0.305	0.506	-0.807	0.028*
● Creatinine	0.710	0.074	-0.711	0.073
● Albumin	0.622	0.136	-0.069	0.884
● CVP	0.170	0.716	-0.426	0.340
● Fluid balance (CC)	0.810	0.000**	0.051	0.789

Table (10): Correlation between right and left ultrasonography and other parameters in day four

Day four	Right LUS		Left LUS	
	r	p	r	p
● APACHE II score	0.438	0.325	-0.169	0.717
● PEEP	0.731	0.062	0.303	0.510
● VT	-0.664	0.103	0.365	0.420
● RR	0.768	0.044*	0.068	0.885
● Pao2/Fio2	0.537	0.002**	-0.816	0.000**
● Pco2	-0.513	0.239	-0.248	0.593
● Peak inspiratory pressure	0.468	0.289	-0.372	0.411
● Plateau pressure	0.515	0.237	0.393	0.384
● TLC	0.776	0.040*	-0.434	0.331
● CRP	0.379	0.402	-0.317	0.488
● Urea	0.351	0.440	-0.536	0.215
● Creatinine	0.653	0.112	-0.737	0.059
● Albumin	-0.076	0.872	0.046	0.922
● CVP	0.066	0.888	0.044	0.925
● Fluid balance (CC)	-0.019	0.921	0.843	0.000**

Discussion

In acute respiratory distress syndrome (ARDS), injury to the alveoli and increased alveolar-capillary barrier permeability lead to the development of interstitial and alveolar edema, often requiring mechanical ventilation. Based on the Berlin definition, ARDS is identified when hypoxemia and bilateral lung opacities occur within seven days of the onset of symptoms **(Gattupalli et al., 2019).** ARDS continues to be a significant contributor to both mortality and long-term morbidity in critically ill patients. The disruption of alveolar epithelial cells and pulmonary endothelial cells causes protein-rich inflammatory fluid to accumulate in the alveolar spaces **(Matthay et al., 2019).**

The pathophysiology of ARDS involves a complex interplay of inflammatory mediators, oxidative stress, and cellular injury, leading to impaired gas exchange and reduced lung compliance. The inflammatory response triggers the activation of neutrophils and the release of cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), further exacerbating alveolar damage. This inflammatory cascade disrupts the balance between pro-inflammatory and anti-inflammatory pathways, perpetuating lung injury. Additionally, microvascular thrombosis in pulmonary capillaries contributes to ventilation-perfusion mismatch and hypoxemia, hallmarks of ARDS. Early identification and precise monitoring of lung injury severity are critical for guiding therapeutic strategies and improving patient outcomes in intensive care units.

While computed tomography (CT) scans are considered the gold standard for diagnosing ARDS, they typically show a ground-glass appearance, posterior consolidations, and nonhomogeneous severe loss of aeration. However, CT scans are not suitable for routine lung monitoring. In recent years, lung ultrasonography has

emerged as a leading bedside imaging tool for evaluating and monitoring acute respiratory failure **(Gattupalli et al., 2019).**

Bedside ultrasonography is generally accessible, inexpensive, radiation-free, non-invasive, and simple to use. ICUs used it more last ten years. Pneumothorax, central venous catheter insertion, and pleural effusions can all be detected by US. The superficial lung aspect is also seen on lung ultrasonography. The loss of aeration in ARDS is nonhomogeneous, with normal zones (spared areas) close to severely damaged ones, in contrast to cardiogenic edoema. A common B-pattern results from this **(Matthay et al., 2019).**

There are several subpleural consolidations and an uneven pleural line. Tissue-like posterior lung consolidations without pleural effusion are visible on ultrasound. Frequently, lung slip goes away **(Gattupalli et al., 2019).**

Effective diagnosis and management of Acute Respiratory Distress Syndrome (ARDS) rely on the prompt evaluation of its severity and the identification of any accompanying conditions. Commonly used scoring systems, such as the Acute Physiology and Chronic Health Evaluation II (APACHE II), the Sequential Organ Failure Assessment (SOFA), and the Clinical Pulmonary Infection Score (CPIS), are considered standard tools for assessing the severity and diagnosing ARDS. These measures have demonstrated a positive correlation with lung ultrasound (LUS). LUS plays a valuable role in assessing the extent of lung injury, aiding in diagnosis, predicting mortality, and monitoring ventilation changes in ARDS patients **(Matthay et al., 2019).**

The aim of this study is to assess the utility of lung ultrasonography scores as a bedside tool for evaluating the severity, prognosis, and mortality risk of ARDS in ICU patients.

Gattupalli et al. (2019) conducted a study to assess the use of lung ultrasonography for measuring extravascular lung water (EVLW) in critically ill patients with head injuries. The researchers established a threshold of more than three B-lines per lung field to evaluate lung fluid content. The study focused on intubated adult patients with head injuries (Glasgow Coma Scale [GCS] 4–15) admitted to the Trauma ICU. Daily assessments using both lung ultrasonography and chest X-rays were performed, with the number of B-lines per intercostal space being used to grade the lung fluid content. The grading system categorized fluid burden into three levels: low (0–10 B-lines), moderate (11–20 B-lines), and high (21–32 B-lines). The lung water content score ranged from 0 to 32. The study included 94 males and 26 females, with a mean participant age of 36.88 ± 14.82 years.

El Naggar et al. (2022) explored the relationship between the PU grading system and clinical metrics to identify the causes of acute respiratory failure (ARF) and assess treatment response. The study involved 50 patients, with a mean age of 58.34 (SD: 15.13) years. Of these, 22 (44%) were female and 28 (56%) were male.

The goal of Chen et al. (2022) was to provide an overview of the impact of bedside ultrasound on ARDS dynamic assessment and early diagnosis.

Regarding gender, our study differed from Sun et al. (2021) in that the latter found 192 (47.8%) male individuals and 210 (52.2%) female participants. The use of a random technique for sample collection may be the cause of the disparity in demographic data.

According to co-morbidities, the patients in this study were divided into 26 (86.7%) who had diabetes, 25 (83.5%) who had hypertension, and 21 (70%) who smoked.

According to Tian et al. (2021), among all recruited patients, sepsis (including pneumonia) is the most often diagnosed illness category (n = 991, 15.5%). In terms of the patients' range of illnesses, metastatic cancer, distributive shock, and cardiac arrest are highly prevalent in both the survival and non-survival categories. The most frequent problem among patients is hypertension (26.5%), which is followed by diabetes (14.2%) and heart failure (20.5%).

Regarding comorbidities, our findings differed from those of de Alencar et al. (2021) since the majority of comorbidities were caused by hypertension, which was followed by diabetes and CHF (98 (55%), 69 (39%), and 25 (14%), respectively. Selection bias is also probably to blame for the discrepancy between their results and ours.

The APACHE II score increased statistically significantly during the course of the day, rising from 13.66±2.58 on day one to 13.98±2.42 on day three, 15.07±2.25, and 16.78±3.46 on day four ($p<0.001$).

As the illness worsens, APACHE II scores rise over the course of many days in ARDS patients in the intensive care unit. ARDS is a serious respiratory condition that often becomes worse with time. A decrease in the patient's physiological state and an aggravation of their sickness are indicated by an increase in the APACHE II score (Hsu et al., 2022).

According to Tian et al. (2021), the APACHE II scores of survivors and non-survivors were as follows: 18.0 ± 6.3 vs. 19.8 ± 6.1, 14.5 ± 5.4 vs. 19.6 ± 5.7, 14.5 ± 5.2 vs. 20.2 ± 5.8, 14.9 ± 4.9 vs. 20.6 ± 5.7, 15.0 ± 5.1 vs. 21.6 ± 5.9, 14.2 ± 4.8 vs. 22.4 ± 5.8, and 12.4 ± 4.4 vs. 23.2 ± 5.6, respectively. **According to Tian et al. (2021),** the APACHE II scores differed significantly between survivors and non-survivors. The APACHE II scores for survivors were consistently lower at each time point compared to non-survivors. For example, survivors had lower scores on day one, with a gradual decrease through day 28, while non-survivors had higher scores, indicating more severe illness and an increased risk of death. Mortality rates were notably higher in the non-survivor group, with ICU mortality reaching 82.3% and overall hospital mortality at 100%. Additionally, the length of stay in the hospital and ICU was slightly longer for survivors compared to non-survivors.

Beigmohammadi et al. (2022) studied critically ill COVID-19 patients and found that the non-survivor group had notably higher APACHE II scores compared to survivors, suggesting a higher severity of illness in non-survivors.

Similarly, Carbonell et al. (2021) compared death patterns in critically ill COVID-19 patients during different waves of the pandemic. Their findings indicated that patients in the second and third waves had lower APACHE II scores, reflecting less severe disease than those in the first wave. On the other hand, **Kim et al. (2013)** studied ICU patients in Korea and observed that the APACHE II score in the first 24 hours after ICU admission had poor calibration when it came to predicting hospital mortality.

In a large-scale study by **Harrison et al. (2006)** involving 141,106 ICU patients in the U.K., the APACHE II score showed good discrimination but lacked sufficient calibration for accurately predicting hospital mortality. **Similarly, Yoon et al. (2018)** found that the APACHE II score on day 3 was the best predictor of poor neurologic outcomes in survivors of hospital cardiac arrest. Their analysis revealed an area under the curve of 0.793, with a cut-off score of 20, providing a sensitivity of 43.75%, specificity of 94.12%, a positive predictive value of 94.59%, and a negative predictive value of 41.56%.

In a different study, hospital mortality among intensive care unit patients was assessed using the APACHE II scores at various time periods. Yoon's research involves a variety of subjects with varying objectives and outcomes.

Another study by **Donnino et al. (2013)** found that the APACHE Score II discrimination was best 72 hours after cardiac arrest and noted the same thing in the cardiac arrest population. Donnino's study, like Yoon's, used the APACHE II score to assess the scoring system's ability to distinguish between cardiac arrest and post-cardiac arrest in individuals. Therefore, to reliably forecast the mortality of ICU patients, a stronger prognostic biomarker is required.

Therefore, to reliably forecast the mortality of ICU patients, a stronger prognostic biomarker is required.

Fika et al. (2018) have created a number of innovative models in recent years to forecast the mortality of intensive care unit patients, which have demonstrated specific values in clinical practice. Still, the most extensively used model for estimating the mortality of critically ill patients is the APACHE II score. Therefore, it is still possible to increase the accuracy of the APACHE II system by further developing the model, such as by thoroughly examining multicenter and large-scale research to choose an ideal time point other than 24 hours for computing the score.

This study documented changes in respiratory parameters over time, with VT, Pao2/Fio2, Pco2, and peak inspiratory pressure all showing statistically significant declines over time ($p<0.001$). Day one's VT was 419.73±26.45; day two's was 412.00±24.23; day three's was 411.83±25.68; and day four's was 406.67±31.22; Pao2/Fio2 was 171±35 on day one, 166±34 on day two, 163±35 on day three, and 163±42 on day four; Pco2 was 33.03±6.93 on day one, 31.37±4.75 on day two, 29.83±5.07 on day three, and 30.13±6.88 on day four. Peak inspiratory pressure was 33.17±1.82 on day two, 33.30±1.80 on day three, 33.67±2.14, and 29.90±10.89 on day four.

According to Gattupalli et al. (2019), the Pao2/Fio2 ratio was 419.43±62.23 for patients with EVLW and 293.62±82.89 for those without (Mean± SD).

According to Bratton et al. (1997), patients with isolated TBI who have lower Pao2/Fio2 also have a higher global degree of head damage (low GCS).

According to Bilotta et al. (2013), patients receiving neurocritical care who have B lines have lower Pao2/Fio2.

The mean p/f ratio of the patients under study was 172.14 (SD: 37.38), the mean number of days of intubation was 6.42 (SD: 1.32), and the mean length of stay in the intensive care unit was 10.06 (SD: 3.12), according to El Naggar et al. (2022). The hospital stay mean was 12.6 (SD: 2.32), and the death rate was 68%.

According to Wang et al. (2016), our study disagreed with their findings regarding PEEP.

Regarding PEEP, our study disagreed with Wang et al. (2016) since he found a greater beginning PEEP of 9 ± 2.

This study demonstrated how the Lap data changed over time, showing a statistically significant rise in TLC and CRP as well as a decline in albumin with time ($p<0.001$). Day 1 TLC was 11.83±2.13, Day 2 was 15.00±2.10, Day 3 was 14.93±1.98, and Day 4 was 16.27±3.11. Day 1 CRP was 47.27±21.20, Day 2 was 67.27±24.07, Day 3 was 67.77±26.03, and Day 4 was 73.00±26.91. Day 1 albumin was 3.70±0.11, Day 2 was 3.64±0.12, Day 3 was 3.63±0.14, and Day 4 was 3.58±0.08.

Regarding creatinine and urea, there was no statistically significant variation between the days.

Beigmohammadi et al. (2022) identified significant differences between the two groups in several laboratory results, including WBC count, neutrophil and lymphocyte counts, platelet count, urea, creatinine, direct bilirubin, albumin, calcium level, pH, and base excess.

According to Gattupalli et al. (2019), S. albumin levels were 3.46±0.48 (Mean ± SD) in patients with excess EVLW and 3.87±0.45 (Mean ± SD) in patients without excess EVLW.

According to El Naggar et al. (2022), 58% of the patients in the study had elevated TLC, with a mean of 15.32 (SD: 2.632) in their laboratory results. With a mean of 64.5 (SD: 14.32) and a range of 23 to 250, only 48% of patients had elevated urea levels. The creatinine level was elevated in only 44% of patients, with a mean of 2.35 (SD: 0.34) mg/dl and a range of 0.7 to 9 mg/dl.

According to El Naggar et al. (2022), 58% of the patients in the study had elevated TLC, with a mean of 15.32 (SD: 2.632) in their laboratory results. With a mean of 64.5 (SD: 14.32) and a range of 23 to 250, only 48% of patients had elevated urea levels. The creatinine level was elevated in only 44% of patients, with a mean of 2.35 (SD: 0.34) mg/dl and a range of 0.7 to 9 mg/dl.

The development or progression of lung diseases, such as the accumulation of fluid or gas in the lungs, which results in reduced lung function, may be the cause of the increase in lung ultrasonography scores. According to Mojoli et al. (2019), a rise in the LUS score may potentially be a sign that the patient is not responding to treatment or that there are other underlying factors causing the ARDS to worsen.

According to Gattupalli et al. (2019), 61.66% of patients had elevated EVLW using lung USG during their ICU stay (74/120), however only 40.83% of patients had raised EVLW utilizing chest x-rays over the same time period (49/120).

Two diagnostic methods demonstrated a statistically significant difference in occurrence. Lung ultrasound grading classified pulmonary fluid burden as low in 13.51% of patients (score 0–10), moderate in 60.81% (score 11–20), and high in 24.32% (score 21–32). In contrast, chest X-rays revealed increased extravascular lung water (EVLW) in only 6 patients (8.11%) at ICU admission, whereas 32 patients (43.24%) showed this condition on lung ultrasound, indicating a significant difference in the detection rates between the two diagnostic approaches.

El Naggar et al. (2022) found no significant difference between parenchymal and non-parenchymal diseases when categorized based on lung ultrasound scores, which were classified clinically for the first time. The mean initial lung ultrasound score in their study was 18.1 (SD: 3.15), with a range of 7 to 28, and the second score, taken after 48 hours, was 17.54 (SD: 4.51), ranging from 3 to 28. Among the patients, 68% did not survive. The study showed no significant difference in lung ultrasound scores between the initial and follow-up measurements for various diagnoses.

Right ultrasonography was significantly correlated with TLC, Pao2/Fio2, PEEP, and APACHE II score. On the first day, there was a strong association between Pao2/Fio2 and left ultrasonography.

On the first day, there was a strong association between Pao2/Fio2 and left ultrasonography. Right ultrasonography was significantly correlated with fluid balance (CC), TLC, Pao2/Fio2, and PEEP. Pao2/Fio2, peak inspiratory pressure, and fluid balance (CC) on day two were significantly correlated with left ultrasonography. Significant relationships were found between right ultrasonography and fluid balance (CC), TLC, and Pao2/Fio2. On day three, there was a noteworthy association between Pao2/Fio2, Urea, and left ultrasonography. Pao2/Fio2, RR, and TLC were significantly correlated with right ultrasonography. On day four, there was a noteworthy association between Pao2/Fio2 and left ultrasonography.

Zhou et al. (2018) conducted a review of the latest studies on the use and validation of lung ultrasonography (LUS) in critically ill ARDS patients. LUS has been shown to effectively predict the outcomes of lung recruitment therapies, assist in prognosis evaluation for ARDS, and support the early detection and diagnosis of concurrent pulmonary conditions. Despite its usefulness, there is inconsistent evidence regarding its ability to predict responses to prone positioning and oxygenation in ARDS patients.

In a study focused on PaO2/FiO2 ratios, **Gargani et al. (2007)** demonstrated that LUS could detect early signs of extravascular lung water accumulation in cases of oleic acid-induced lung injury. Similarly, **El Naggar et al. (2022**) found that patients with acute kidney injury (AKI) had significant differences between their initial and extubation ultrasound scores, while no major changes were observed in patients with conditions like COVID-19, pneumonia, bronchopneumonia, congestive heart failure, or post-cardiac arrest.

Tierney et al. (2017) found a notable positive correlation between the total lung ultrasound score and the parenchymal disease score in conditions such as pneumonia. **Bouhemad et al. (2011)** demonstrated that LUS is a reliable bedside method for assessing lung recruitment induced by positive end-expiratory pressure (PEEP) in ARDS patients. Their prospective trial involving 40 consecutive patients revealed a strong correlation between the ultrasonography reaeration score and pressure-volume curves used to reflect PEEP-induced recruitment. However, because LUS cannot measure PEEP-induced hyperinflation, the authors concluded that it is insufficient for titrating PEEP in isolation.

In 2010, Bouhemad and colleagues compared LUS with bedside chest radiography to assess lung reaeration in patients treated for ventilator-associated pneumonia. The study showed that chest radiography was inaccurate in predicting lung reaeration, while LUS offered a more precise estimate.

ARDS in children occurs at a rate of 12 cases per 100,000 person-years and often leads to under-recruited lungs and inflammatory edema. In situations where CT scans or pulmonary mechanics are challenging to obtain, pediatric intensivists often perform complex lung recruitment maneuvers **(Zimmerman et al., 2009).** Lung ultrasonography has become an invaluable tool in critical care for continuous, rapid, and accurate assessments. Santuz et al. (2010) reported the successful use of LUS in a 2-month-old infant with severe ARDS undergoing a lung recruitment maneuver, marking the first report of this procedure in pediatric ARDS. **Sameshima et al. (2014)** further argued that LUS-guided recruitment techniques in newborns are both practical and safe, following a case in which it was used for a baby with severe ARDS.

Sameshima et al. (2014) argued that LUS-guided recruitment techniques in newborns are both practical and safe, after describing a case of its use in a baby with severe ARDS.

Sameshima et al. (2014) argued that lung US-guided recruitment techniques in newborns are a practical and secure treatment after describing a case of the procedure used on a baby with severe ARDS.

Prone positional response in individuals with acute respiratory distress syndrome can be predicted by lung ultrasonography. PP has been acknowledged as one of the key treatment approaches for patients with ARDS. According to numerous studies, PP may enhance oxygenation, lessen lung damage brought on by breathing, and lower mortality. However, there is a chance that the procedure will cause hemodynamic disruption and unintentional extubation. It's critical to evaluate PP's efficacy in treating patients with severe acute respiratory distress syndrome and forecast if the operation would be beneficial for these patients **(Taccone et al., 2009).**

The usefulness of lung US in predicting PP oxygenation response in ARDS patients was evaluated by

Prat et al. (2016). In their prospective investigation, six distinct ultrasonography windows were used to evaluate 19 ARDS patients for a minimum of 12 hours.

Based on their response to prone positioning (PP) in terms of oxygenation, patients were categorized into two groups: responders and nonresponders. A significant correlation was found between the oxygenation response and the normal appearance of the anterobasal areas on lung ultrasound (LUS), with a positive predictive value of at least 100% (P = 0.0436).

In a multicenter study by **Haddam et al. (2016),** the oxygenation response to PP was evaluated using LUS in 51 patients with severe and moderate ARDS. LUS assessments were conducted at four time points: one hour before the prone position (baseline), one hour after positioning, and one hour before and after returning to the supine position. The study found no significant association between the oxygenation response and specific LUS patterns, as the changes in regional lung aeration did not correlate with improved oxygenation after PP.

Lung ultrasonography (LUS) has proven to be an effective tool for assessing the prognosis of ARDS. Timely evaluation of disease severity and the identification of coexisting conditions are critical for optimizing therapeutic interventions and improving patient outcomes. A study by Li et al. (2015) demonstrated a significant positive correlation between LUS findings and traditional clinical scoring systems such as the Acute Physiology and Chronic Health Evaluation II (APACHE II), the Sequential Organ Failure Assessment (SOFA), and the Clinical Pulmonary Infection Score (CPIS). These established scores are routinely utilized to gauge the severity and prognosis of ARDS. The study concluded that LUS offers an efficient approach to assess disease progression, predict mortality, and track changes in lung ventilation in ARDS patients.

Furthermore, LUS plays a critical role in early diagnosis and monitoring of ARDS, offering valuable insights into the extent of lung injury. The ability to detect specific ultrasound patterns, such as B-lines and consolidation, enables clinicians to assess lung aeration and fluid accumulation in real-time. This rapid assessment is essential for tailoring treatment plans, particularly in dynamic conditions like ARDS, where patient status can change quickly. A study by Mongodi et al. (2019) demonstrated that LUS could detect early changes in lung condition, offering a non-invasive alternative to traditional imaging methods for monitoring lung function. The study also highlighted the potential of LUS to predict patient outcomes, further establishing its role as a bedside diagnostic tool for ARDS management. **(Mongodi et al., 2019)**

It is commonly acknowledged that extravascular lung water indicators have a predictive value for ARDS patients. The prognosis is worse and the lung injury is more severe in patients with a high indexed EVLI. A recent prospective analysis demonstrated significant positive linear associations between LUS and EVLW. The authors came to the conclusion that LUS can be used as a diagnostic marker of ARDS and is a straightforward and cost-effective method of predicting the prognosis of ARDS patients **(Zhou et al., 2018).**

Limitations

Our study's limitation was that neurogenic edema cannot be identified as the exclusive cause of AIS; other factors may have also played a role. Although both groups' fluid balance was comparable, patients with EVLW needed more PEEP to achieve appropriate Pao2 values on blood gas measurement than patients without EVLW. Due to the lack of bedside CT in the intensive care unit, CT scans were not taken into account in our study. Better information about the sensitivity and specificity of lung ultrasonography may have been provided. Additional research is necessary to examine the different interventional strategies used to treat elevated lung water content.

Conclusion

In patients with ARDS, lung ultrasonography is being considered as a diagnostic and prognostic technique. It is an inexpensive, accessible, and user-friendly medical procedure that doesn't require ionizing radiation. It lessens the need for a CT scan and is a useful addition to bedside chest X-rays. LUS is a useful diagnostic, therapeutic, and prognostic technique for patients with ARDS.

Recommendation

1. We recommend using LUS in ARDS patients to diagnose and predict the prognosis.
2. Future studies needed to established the efficacy of LUS in ARDs.

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