Validity Of Lung Ultrasound in Diagnosis of Acute Respiratory Distress Syndrome and Prediction of Successful Weaning from Mechanical Ventilation

Mohammed Essam Ali Hussein[1], Mona Abdelhameed El-Harrisi[1], Neven Mohamed Gamil [1], Sameh Saber Bayoumi [2], Marwa Mohamed Medhat Abd Elwahab[1]

1 Anesthesia, Intensive care and Pain Management Department, Faculty of Medicine, Zagazig University, Egypt

2 Radiology Department, Faculty of Medicine, Zagazig University, Egypt

Article History: Received 10th June, Accepted 5th July, published online 10th July 2023

Email: yassinmohammed522021@gmail.com, mohessam@zu.edu.eg, mohamedessam2023.me@gmail.com

Abstract

Background: The possibility of exploring the lung using ultrasound, at the bedside and noninvasively, is going popularity among intensivists.

Aim: to evaluate the validity of lung ultrasound compared to CT chest for diagnosis of ARDS and prediction of successful weaning from mechanical ventilation in those patients compared to traditional methods. (spontaneous breathing trial (SBT), arterial blood gases (ABG) and standard parameters of weaning).

Methods: This cohort study was conducted in surgical and emergency Intensive Care Units, Zagazig university hospitals. 57 patients with suspicious criteria of ARDS were diagnosed by CT chest and clinical criteria, then were compared between the findings by lung ultrasound and CT chest to detect the sensitivity of imaging to CT chest as gold standard in diagnosis of ARDS patients .Then used US on lung and diaphragm compared to traditional methods as a prediction for weaning.

Results: lung US diagnosed ARDS in (22.8%) of cases while CT confirmed ARDS in (26.3%) of cases. The Validity of lung US versus CT in diagnosis of ARDS, revealed that the Sensitivity was (86.4%), specificity= (69.2%), predictive value for positive (PVP) of = (90.5%), predictive valuefor negative (PVN) = (60%) and the accuracy was (82.5%). The Validity of LUS at cut off value <13 in predicting weaning illustrated that the Sensitivity was (78.1%), specificity= (24%), predictive value for positive (PVP) of = (56.8%), predictive value for negative (PVN) = (46.2%) and the accuracy was (54.3%).Lung US diagnosis at cut off value <13 indicating successful weaning in only 23 cases and it shows poor agreement of US diagnosis at cut off <13 in assessing successful weaning as kappa coefficient was -0.001, the Validity of Modified LUS at cut off value < 9.5 in predicting successful weaning, revealed that the Sensitivity was (84%), specificity= (68.7%), predictive value for positive (PVP) of = (77.1%), predictive value for negative (PVN) = (77.3%) and the accuracy was(77.2%)

Conclusion: Lung ultrasound can be a robust and effective tool for the rapid and accurate evaluation of ARDS at the bedside in intensive care units. Thus it can help the physicians initiateearly, life-saving interventions, resulting in improved outcomes for the patients. All critical care physicians should have point-of-care ultrasound training to use this novel, potential diagnostic tooleffectively with Sensitivity was (86.4%)the accuracy was (82.5%). LUSm and TI are sensitive non- invasive bed side sonographic indices that can predict weaning out come in mechanically ventilated patients. DRSBI should be added to lung aeration (LUSm) in the weaning process evaluation. In this study the DRSBI is the best diagnostic accuracy than diaphragmatic thickness index, and LUSm, sensitivity 100% and accuracy 98.3%.

Keywords: Lung Ultrasound, Acute Respiratory Distress Syndrome, Weaning, Mechanical ventilation

Introduction

Lung imaging in critically ill patients is performed traditionally either by bedside chest radiography (CXR) or thoracic computed tomography (CT).Both techniques have limitations which constrain their usefulness .Although thoracic CT is the gold standard for lung imaging ,it is expensive and cannot be performed on routine basis .In addition the transportation of critically ill patients to radiology department combined with the radiation exposure carries a measurable risk .On the other hand, limitations of bedside CXR have will been described and lead poor-quality X-ray film with low sensitivity .Indeed it has been shown that even under carefully controlled exposure conditions more than 30 % of the X-ray films are considered suboptimal .Finally, there is poor correlation between CXR findings and those of CT **(1).**

Critically ultrasound, apparently a recent fields is in fact the outcome of a slow process, initiated since 1946 .The lung was traditionally not considered as a part of ultrasound, now as apriority in the critical ultrasound .

The possibility of exploring the lung using ultrasound, at the bedside and noninvasively, is going popularity among intensivists. Lung ultrasound would be of minor interest if the usual tools (bedside radiography, CT) did not have drawbacks (irradiation, low information content for radiology, need for transportation) **(2)** .

The Bedside Lung Ultrasound in Emergency department (BLUE-protocol) is an exclusive diagnostic ultrasound approach intended to be combined with simple clinical data .It proposes a step-by-step analysis, which can be achieved in three minutes **(2).**

On the other side most, patients may be successfully weaned of mechanical ventilation after they have recovered, as long as they have adequate gas exchange, excellent neurological and muscle function, and hemodynamic stability. Weaning failure, on the other hand, is highly prevalent, and mechanical breathing may be necessary within 48 hours of weaning. Prolonged mechanical ventilation and ICU stay are linked to weaning failure **(3)**.

Weaning of a mechanical ventilator is delayed, which increases the risks of barotrauma, ventilator-associated infections, and ventilator-induced diaphragmatic atrophy and dysfunction **(3)**.

The diaphragm is the primary respiratory muscle. The diaphragm produces roughly 70 percent of resting pulmonary ventilation with an excursion of 1-2 cm, while its amplitude varies from 7 to 11 cm during forced breathing. Sepsis, hypotension, and hypoxia can all cause damage to the diaphragm. The use of mechanical ventilation can cause diaphragmatic dysfunction, which can lead to weaning failure and the need for long-term artificial ventilation. Weaning failure can be avoided if diaphragmatic dysfunction is diagnosed early before weaning **(4) .**

Diaphragm ultrasound (US) is a test that can be used to assess diaphragmatic dysfunction. Weaning failure can occur when a patient is shifted from mechanical ventilation (MV) to spontaneous breathing because of lung aeration loss (decruitment). Lung ultrasound is a new and increasingly used method for studying lung aeration during MV in both a semi-quantitative and quantitative manner **(5) .**

The aim of this study was to evaluate the validity of lung ultrasound compared to CT chest for diagnosis of ARDS and prediction of successful weaning from mechanical ventilation in those patients compared to traditional methods. (spontaneous breathing trial (SBT), arterial blood gas (ABG)and standard parameters of weaning).

Patients and Methods

This cohort study was conducted in surgical and emergency Intensive Care Units, Zagazig university hospitals. 57 patients with suspicious criteria of ARDS were diagnosed by CT chest and clinical criteria , then were compared between the findings by lung ultrasound and CT chest to detect the sensitivity of imaging to CT chest as gold standard in diagnosis of ARDS patients. Patients who were improved and predicted for weaning were examined by ultrasound to compare its sensitivity to traditional methods as a predictor for weaning .When patients admitted to ICU for different causes and highly suspected clinically for ARDS those patients under examination by lung ultrasound to evaluate the B and C lines in both hemi

-thorax then those patients transported to get CT chest (as a gold standard) to confirm the diagnosis of ARDS and compare this results with the results of the LUS . When those patients are weanable from mechanical ventilator according to traditional methods (ABG and RSBI) evaluate the scoring of the lung aeration and diaphragmatic thickness for weaning then compare between both methods success according to re-intubation or not for those patients within 48 hours later.

Inclusion criteria:

-Age >18 years.

-Patients or legal guardians consent.

- -All patients with suspicious criteria of acute respiratory distress syndrome according to Berlin criteria :
- lung injury of acute onset, within 1 week of an apparent clinical insult and with the progression of respiratory symptoms
- bilateral opacities on chest imaging (chest radiograph or CT) not explained by other lung pathology (e.g. effusion, lobar/lung collapse, or nodules)
- respiratory failure not explained by heart failure or volume overload
- decreased PaO_2/FiO_2 ratio (a decreased PaO_2/FiO_2 ratio indicates reduced arterial oxygenation from the available inhaled gas):
  - mild ARDS: 201 – 300 mmHg (≤ 39.9 kPa)
  - moderate ARDS: 101 – 200 mmHg (≤ 26.6 kPa)
  - severe ARDS: ≤ 100 mmHg (≤ 13.3 kPa)

-Hemodynamically stable in the absence or minimal of vasopressors.

Exclusion criteria:

-Pregnant women.

-patients with traumatic lung injury or pneumothorax.

-surgical dressings over the right lower rib cage which would preclude ultrasound examination.

-presence of ascites.

-presence of lung collapse, fibrosis or pleural effusion.

-presence of any mass or mechanical factor in the chest or the abdomen interfering with the diaphragmatic mobility.

After institutional ethics committee approval and an informed consent were taken from legal guardian of those patients, the presence of bilateral opacities in CT chest , not fully explained by pleural effusions, lobar/lung collapse, or nodules, was considered as the imaging criterion to detect ARDS. For 'LUS-based Berlin Definition', at least one region of each hemithorax had to be affected by multiple B lines (three B lines or more per rib space) on lung ultrasound to fulfill the imaging criterion.

All patients of study were subjected to:

a) Thorough medical history taking.

b) Complete clinical examination: Both general and local examination.

c) laboratory testing including :

-Routine laboratory investigations e.g complete blood count (CBC), kidney & liver functions tests and coagulation profile.

-Arterial blood gases (ABG).

-Sputum culture and sensitivity (when indicated).

-Serum procalcitonin and broncho-alveolar aspirate culture and sensitivity (when indicated).

d) Chest radiography:

Lung ultrasound and chest CT scan were done for each patient within a time limit of four hours for logistic reasons .

1) Chest ultrasound

Performance of the chest ultrasound:

Siemens Acuson x300 ultrasound will be used in this study using two probes (convex low frequency 3-5 MHZ and linear high frequency 7-10 MHZ). Patient position: supine position for anterior zones and lateral decubitus position for postero-lateral zones . Each lung was divided into 3 zones on each side delineated by a parasternal line, anterior axillary line, posterior axillary line, and paravertebral line. Examination was done on each side anteriorly and posteriorly using B-mode to assess the degree of lung aeration with total 12 zones to be examined .

The lung US score for detection of the degree of lung aeration for detection of ARDS

Points for each lung zone (12 zones)

Degree of lung aeration Pattern :

0 point: Normal aeration [Horizontal A-line (no more than two B-line)].

1 point: Moderate loss of aeration [Multiple B-line either regularly spaced or irregularly spaced].

2 points: Severe loss of aeration[Multiple coalescent B-lines].

3 points: Complete loss of aeration [Lung consolidation].

Total score from 0 to 36 .

Lung ultrasound as a predictor for weaning :

Four US aeration patterns was defined as:

Normal aeration is represented by the presence of lung sliding and horizontal A lines, or less than three vertical B lines; a score of 0 is assigned to a lung region if all of the intercostal spaces show normal aeration

A moderate loss of aeration is characterized by multiple regularly or irregularly spaced B lines that originate from pleural line or from small juxta-pleural consolidations; a score of 1 is assigned to a lung region if all of the intercostal spaces show a moderate loss of aeration.

Severe loss of aeration is characterized by the presence of coalescent B lines in several intercostal spaces, occupying the whole intercostal space;a score of 2 is assigned to the examined region .

Complete loss of lung aeration, as observed in lung consolidation is characterized by tissue echogenicity with static or dynamic air bronchograms; a score of 3 is assigned to the examined region.

The scores of the 12 examined regions range between 0 and 36.

The patients at a high risk of weaning failure [i.e., patients with a LUSm > 9.5 at the end of their spontaneous breathing trial] .

Diaphragmatic US :

Patient position: Semi-recumbent position.

Diaphragmatic thickness assessment: The linear US probe was placed intercostally perpendicular to the chest wall in the 8^{th} or 9^{th} intercostal space between the anterior and mid axillary line . The diaphragm appeared as three layered structure (two parallel echogenic lines representing the pleura and the peritoneum with central hypoechoic space representing the diaphragmatic muscle). The diaphragmatic thickness was measured from the middle of the pleural line to the middle of the peritoneal line. The thickness will be measured during the end of inspiration and the end of expiration (0.22 0.28 cm in healthy diaphragm and 0.13- 0.19 in paralyzed diaphragm). **Diaphragmatic thickness index (TI):** (Thickness at the end inspiration – thickness at the end expiration) / Thickness at the end expiration (normal TI 25 -40 %). **Diaphragmatic excursion (DE):** The convex probe was placed subcostally parallel to the inetrcostal space to measure the range of the diaphragmatic movement using M- mode method with the cursor crossing the diaphragm and assess the high and low peak points as indicator for the diaphragmatic mobility range (4-6 cm in healthy diaphragm). **DRSBI** was measured 30 minutes afterSBT using this equation; (respiratory rate/ diaphra-gmatic displacement in mm **(normally < 1.3)** .

Chest computed tomography (CT) :A low-dose CT scan without contrast medium using Toshiba prime Aquilion -64 slice high speed device was ordered for all patients to confirm diagnosis . CT scan wasdone using 120 kv,mA and reconstructed layer thickness of 4 mm and effective radiation dose of 0.4mSv.CT scan was done while the patient was in supine position from the apex of thorax to the lung bases,lung images were displayed in both lung and soft tissue window.

outcomes:

Primary outcome: to diagnose ARDS by detecting multiple B-lines on both lungs .

Secondary outcome: to evaluate and assess the value of lung and diaphragm ultrasound for predicting weaning outcome, using diaphragmatic thickening index "TI", modified lung ultrasound score (LUSm) and diaphragmatic rapid shallow breathing index (DRSBI) .

Statistical Analysis:

The collected data were organized ,tabulated and statistically analyzed, usig statistical package for social science (SPSS)version 19 (SPSS Inc, Chicago ,USA).Mean, standard deviation, frequency and percentage were used as descriptive. ROC Curve was estimated to determine the Sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of AUC as measurements of validity for chest and diaphragmatic ultrasonography results were compared to CT chest results and traditional methods of weaning .The latter was regarded as the standard reference.

Results

In this cohort study conducted on 85 patients were assessed for eligibility .Twenty eight patients were excluded for different causes and fifty seven patients completed the study . forty of them were males and seventeen were females .The mean age of the patients was 45.42±10.59 years .The causes of admission were eclampsia (post partum),post arrest, post exploration and trauma with percentage of 10.5 %,8.8%,17.6% and 63.2% respectively . Onset of ARDS after admission to ICU within 7 days35.08 % and after 7 days 64.92 %. Duration of MV up to 7 days 43.86% and more than 7 days 56.14 % .staying in ICU for 7 days 12.28 % and more than 7 days 87.72 % .

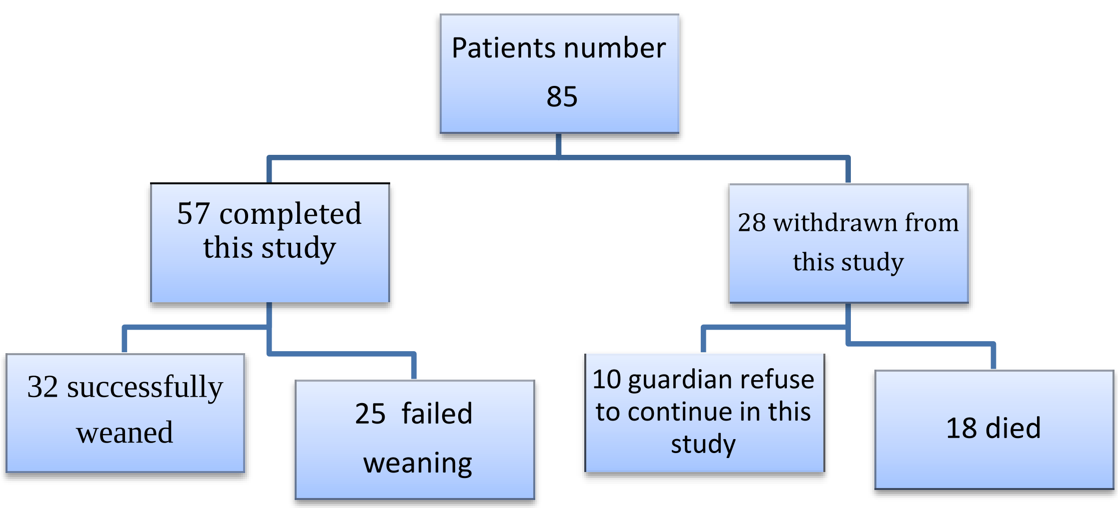

Figure (1): flow chart

Table (1): basic characteristic of the studied group (n=57):

Characteristic		**Study group (n=57)**	
Age **Mean ±SD** **Range**		45.42±10.59 (25-70)	
Category		**No.**	**%**
Sex	Female	17	29.8
	Male	40	70.2
Cause of admission	Eclampsia (post-partum)	6	10.5
	Post arrest	5	8.8
	Post exploration	10	17.6
	Trauma	36	63.2
Onset of ARDS after admission to ICU	**≤ 7 days**	20	35.08
	>7days	37	64.92
Duration of MV	**≤ 7 days**	25	43.86
	>7days	32	56.14
Stay in ICU	**≤ 7 days**	7	12.28
	>7days	50	87.72

ARDS (Acute respiratory distress syndrome).MV (mechanical ventilation).ICU (intensive care unit).

Table (2): kappa agreement between US and CT of diagnosis of ARDS in the studied group:

Category	**ARDS**				**P value**	**Kappa**
	Lung US		**CT**			
	N	**%**	**N**	**%**		
Positive	44	77.2	42	73.7	**<0.001***	0.527
Negative	13	22.8	15	26.3		

Kappa interpretation ≤ 0 = no agreement 0.01-0.20 =slight agreement 0.21-0.40 =fair agreement 0.41-0.60=moderate agreement 0.81-1.00 perfect agreement

As shown in table (2), lung US diagnosed ARDS in (22.8%) of cases while CT confirmed ARDS in (26.3%) of cases. It shows moderate agreement between US and CT in assessing ARDS as kappa coefficient was 0.527.

Table (3): Validity of lung US versus CT in diagnosis of ARDS

Category			**CT**			
			positive (n=42)		**Negative (n=15)**	
Lung US		**Positive (n=44)**	38		6	
		Negative (n=13)	4		9	
AUC	**95%CI**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
0.752	0.591-0.914	86.4%	69.2%	90.5%	60%	82.5%

Lung US (Lung ultrasound)

As shown in this table, the Validity of lung US and CT in predicting ARDS, revealed that the Sensitivity was (86.4%), specificity= (69.2%), positive predictive value (PVP) = (90.5%), negative predictive value (PVN) = (60%) and the accuracy was (82.5%).

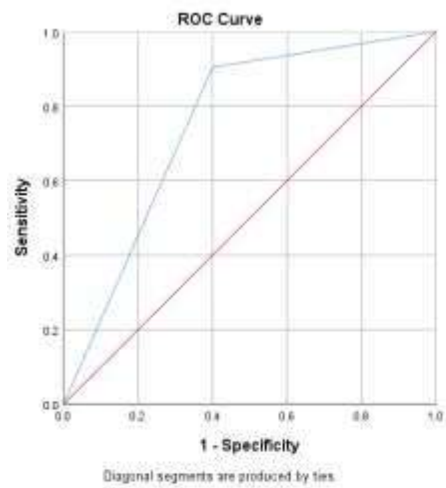

Figure (2): ROC curve illustrating Validity of lung US versus CT in diagnosis of ARDS

Table (4): diagnosis of readiness of the cases to weaning by US

Characteristic	**Category**	**Study group (n=57)**	
		No.	**%**
Lung US	**No**	16	28.1
	Yes	41	71.9
Modified LUS (LUSm) Mean ±SD Range		 10.28±4.87 (4-20)	
Diaphragmatic thickness index (TI) Mean ±SD Range		 0.96±0.35 (0.5-1.6)	
DRSBI Mean ±SD Range		 0.77±0.34 (0.6-2)	

Lung US (Lung ultrasound) LUSm (Modified lung ultrasound) TI (Diaphragmatic thickness index) DRSBI (Diaphragmatic rapid shallowbreath index)

As shown in table (4), lung US diagnosed readiness to weaning in (71.9%) of cases.
The mean **LUSm** was 10.28±4.87 ranging from 4 to 20 and the mean **TI** was 0.96±0.35 rangingfrom 0.5 to 1.6 and the mean **DRSBI** was 0.77±0.34 ranging from 0.6 to 2.

Table (5): outcome of weaning according to SBT (Spontaneous breathing trial)

Characteristic	Category	Study group (n=57)	
		No.	**%**
Weaning	**Failed**	25	43.9
	Successful	32	56.1

As shown in table (5), Weaning done successfully to more than half of cases (56.1%) of cases while it failed in (43.9%) of cases.

Table (6): relation between weaning and different parameters

Characteristic	Weaning		Test	P value
	Successful (n=32)	**Failed (n=25)**		
Age Mean ±SD	42.91±8.79	48.64±11.94	-2.088	**0.041***
LUSm 30 minafter SBT Mean ±SD	8.44±4.42	12.64±4.44	-3.554	**0.001***
TI 30 min afterSBT Mean ±SD	0.74±0.24	1.24±0.26	-7.421	**<0.001***
DRSBI 30 min after SBT Mean ±SD	0.53±0.1	1.07±0.03	-8.224	**<0.001***

Lung US (Lung ultrasound) LUSm (Modified lung ultrasound) TI (Diaphragmatic thickness index) DRSBI(Diaphragmatic rapid shallowbreath index)

This table shows that there were statistically significant differences (P < 0.05) between weaning and age as cases with lower mean age 42.91±8.79 years showed successful weaning. Also there were significant successful weaning associated with lower Modified US with mean 8.44±4.42.
The lower mean DT index score indicating significant successful weaning with value 0.74±0.24.
The lower mean DRSBI score indicating significant successful weaning with value 0.53±0.1.

Table (7): Kappa between lung us diagnosis of redness for weaning by us and the actual successful weaning and the validity of Lung US at cut off value <13 in predicting successful weaning

Category				**Weaning**		**P Value**	**Kappa**
				Successful (n=32)	**Failed (n=25)**		
Lung US		**Positive (n=41)**		23	18	0.992	-0.001
		Negative (n=16)		9	7		
AUC	**95%CI**	**Cutoff**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
0.501	0.348-0.653	<13	78.1%	24%	56.8%	46.2%	54.3%

The Validity of US at cut off value <13 in predicting weaning illustrated that the Sensitivity was (78.1%), specificity= (24%), positive predictive value (PVP) = (56.8%), negative predictive value (PVN) = (46.2%) and the accuracy was (54.3%).

Lung US diagnosis at cut off value <13 indicating successful weaning in only 23 cases and it shows poor agreement ofUS diagnosis at cut off value <13 in assessing successful weaning as kappa coefficient was -0.001.

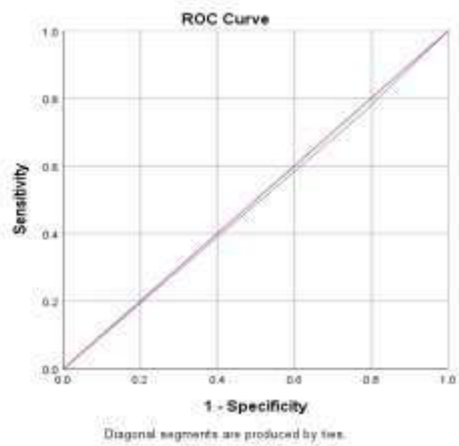

Figure (3): ROC curve illustrating Validity of Lung US at cut off vaue <13 in predicting successfulweaning

The standard of Validity of Lung US at cut off value <13 in predicting successful weaning
Show low accuracy (54.3%) . In this study according to the results the cut off value < 9.5 in predicting successfulweaning had more accuracy (77.2%) .

Table (8): Validity of modified US at cut off value < 9.5 in predicting successful weaning

Variables	AUC	95%CI	Cutoff	Sensitivity	Specificity	PPV	NPV	Accuracy
Modified US	0.732	0.598-0.866	9.5	84%	68.7%	77.1%	77.3%	77.2%

As shown in this table, the validity of modified LUS at cut off value < 9.5 in predicting successful weaning, revealed that the Sensitivity was (84%), specificity= (68.7%), positive predictive value (PVP) = (77.1%), negative predictive value (PVN) = (77.3%) and the accuracy was (77.2%)

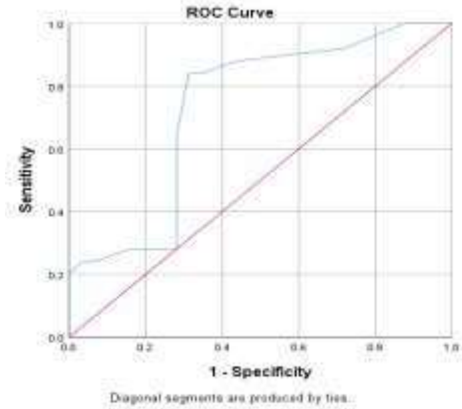

Figure (4): ROC curve illustrating validity of modified LUS at cut off value < 9.5 in predicting successful weaning

Table (9): Validity and kappa agreement of Diaphragmatic thickness in predicting successful weaning

Category			**Weaning**		**P value**	**Kappa**
			Successful (n=32)	**Failed (n=25)**		
Diaphragmatic thickness		**Positive (n=34)**	24	10	**0.014***	0.353
		Negative (n=23)	8	15		
AUC	**95%CI**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
0.657	0.531-0.819	75%	60%	70.6%	65.2%	68.4%

As shown in this table, the validity of diaphragmatic thickness in predicting weaning, the value of Sensitivity of were (75%), specificity= (60%), positive predictive value (PVP) = (70.6%), negative predictive value (PVN) = (65.2%) and the accuracy was (68.4%). Diaphragmatic thickness indicating successful weaning in 24 cases and it shows fair agreement of diaphragmatic thickness in assessing successful weaningas kappa coefficient was 0.353.

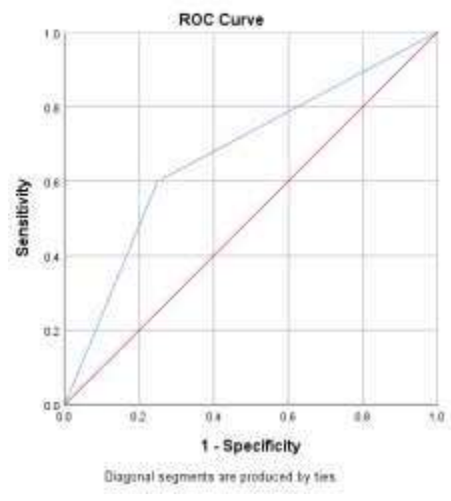

Figure (5): ROC curve illustrating validity of diaphragmatic thickness in predicting successful weaning

Table (10): Validity of IT at cut off value ≥ 25% in predicting successful weaning

Variables	AUC	95%CI	Cutoff	Sensitivity	Specificity	PPV	NPV	Accuracy
DT index	0.891	0.809-0.972	≥ 25%	89.33%	87.9%	81.1%	86.6%	88.7%

TI (diaphragmatic thickness index)

As shown in this table, the validity of TI in predicting successful weaning at cut off value ≥ 25%, revealed that the sensitivity was (89.33%), specificity= (87.9%), positive predictive value (PPV) = (88.1%), negative predictive value (NPV) = (86.6%) and the accuracy was (88.7%).

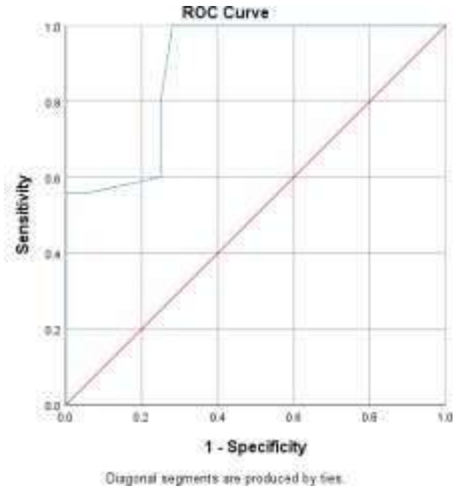

Figure (6): ROC curve illustrating Validity of TI at cut off value ≥ 25% in predicting successful weaning

Table (11): Validity and kappa agreement of Diaphragmatic motion in predicting successful weaning

Category			**Weaning**		**P value**	**Kappa**
			Successful (n=32)	**Failed (n=25)**		
Diaphragmatic motion		**Positive (n=33)**	28	5	**<0.001***	0.678
		Negative (n=24)	4	20		
AUC	**95%CI**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
0.838	0.724-0.951	87.5%	80%	84.8%	83.3%	84.2%

As shown in table, diaphragmatic motion indicating successful weaning in 28 cases and it shows good agreement of diaphragmatic motion in assessing successful weaning as kappa coefficient was 0.678.

Also, the validity of diaphragmatic motion in predicting weaning as shown in this table indicating that the value of Sensitivity was (87.5%), specificity= (80%), positive predictive value (PVP) = (84.8%), negative predictive value (PVN) = (83.3%) and the accuracy was (84.2%).

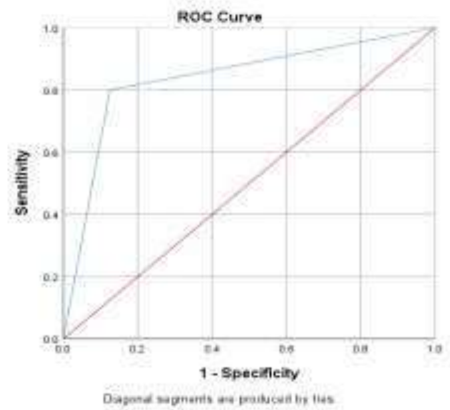

Figure (7): ROC curve illustrating Validity of Diaphragmatic motion in predicting successful weaning

Table (12): Validity of DRSBI at cut off value < 1.3 in predicting successful weaning

Variables	**AUC**	**95%CI**	**Cutoff**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
DRSBI	0.999	0.938-1	<1.3	100%	96.55%	96.9%	100%	98.3%

DRSBI (diaphragmatic rapid shallow breath index)

As shown in this table, the validity of DRSBI in predicting successful weaning at cut off value < 1.3 , revealed that the Sensitivity was (100%), specificity= (96.55%), positive predictive value (PVP) = (96.9%),negative predictive value (PVN) = (100%) and the accuracy was (98.3%)

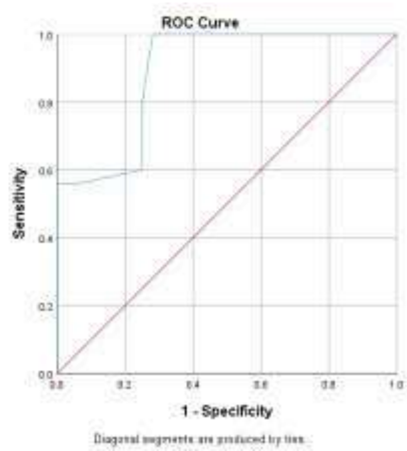

Figure (8): roc curve illustrating Validity of DRSBI at cut off value < 1.3 in predicting successful weaning

Discussion

ARDS is a common cause of mortality in ICU worldwide, warranting prompt diagnosis and management to reduce its potential morbidity, mortality, and economic burden on the patient and the healthcare system.
This study aimed to assess the role of lung ultrasound as a convenient imaging tool for the diagnosis of ARDS in critically ill patients.
At present, a lot of structured, comprehensive point-of-care ultrasound (POCUS) training courses (both online and offline) are accessible all over the world, through which physicians can orient themselves with knowledge of ultrasound and improve their expertise & skill to perform POCUS efficiently. This versatile tool enables clinicians to make real-time diagnoses with an accuracy superior to that of radiography and is time-saving in dyspneic patients.
This study showed better performance of Berlin criteria in the detection of ARDS in critically ill patients when lung ultrasound is used as the imaging modality in place of chest X-Ray. Routine use of lung ultrasound in critically ill ARDS patients should reduce the frequency, number, and radiation hazard of bedside chest radiography and thoracic CT, resulting in decreased cost of patient care in the ICU.
In this study, most of the patients were relatively young.Primary diagnosis at the time of assessment was eclampsia (post partum) (10.5%), Post arrest (8.8%), Post exploration (17.6%) &trauma (63.2%). The age distribution and primary diagnosis were almost similar to other studies of low-income countries. Studies of developed countries showed relatively older age predominance, with post trauma being the most frequent diagnosis. The majority of the ARDS patients (diagnosed by Berlin Definition) Onset of ARDS after admission to ICU after 7 days 64.92 % and within 7 days35.08 % . Duration of MV more than 7 days 56.14 % and up to 7 days 43.86% . staying in ICU more than 7 days 73.68 % and for 7 days 26.32 % .According to this study, the sensitivity, specificity, and accuracy of lung ultrasound assessments against the radiographic criteria of ARDS were 86.4%, 69.2%, and 82.5% respectively.

Bass et al. (6) showed a slightly higher sensitivity of LUS in detecting ARDS (86 %) and specificity was only 38 %9(89). In another similar study, **See et al. (7)** found lower sensitivity(69%) of LUS for ARDS diagnosis **Roshandel , et al 2021 (8)** showed that sensitivity (95% CI) and specificity (95% CI) of LUS for the diagnosis of parenchymal lesions were 90.5% and 50% respectively. **Similarly Nazerian , et al 2015 (9)** showed that LUS had sensitivity 82.8% and specificity 95.5% in diagnosis of lung consolidation of ARDS . **Tung-Chen , et al 2020 (10)** conducted that the presence of LUS findings was correlated with a positive CT scan suggestive of COVID-19 with a sensitivity of 100.0%, specificity of 78.6%, PPV 92.5% and NPV 100.0%. There was no missed diagnosis of COVID-19 with LUS compared with CT in their study.
On the contrary, On the other hand, **Vingon , et al 2016 (11)** reported that in patients with acute respiratory failure, the identification of B lines had a sensitivity of 94.4% and a specificity of 77.3% to predict cardiogenic pulmonary edema. Therefore, several patients with ARDS showing B lines on chest ultrasound might be mistakenly diagnosed as pulmonary edema.
Therefore, combining LUS findings with echocardiography has been reported to be more useful in this regard. This study had several strengths. Most of the studies assessed 'the ability of ultrasound to detect ARDS' in optimum conditions- imaging was done by expert sonographers and patients were positioned as required for better image acquisition. However, in this study, lung ultrasound was performed by a critical care resident, keeping the intubated patients mainly in the supine position.
This approach correlated with the reality of ICU where intensivists, not sonographers, perform bedside ultrasound assessment and movement of intubated patients is not possible as required, all the time. In this study, critically ill medical and surgical patients, at risk for ARDS in a large referral center, were methodicallyevaluated, which suggests the external validity of the study in other busy critical care centers. Patients with various diseases and a range of different PaO2/FiO2 ratios were evaluated; thus, tests of diagnostic accuracy should apply to similar spectra of disease.

The two probes, found commonly in a resource-constrained setting, were a phased-array probe (for cardiac, intra-abdominal, and obstetric assessment) and a linear probe (for superficial assessments). Using the commonly found probe, this study showed almost the same or better results than many other studies that used a micro-convex probe.

The number of tools available for selecting the best time to wean and predicting the success of weaning is limited. Subjective decisions are frequently incorrect. The US is well-known as a noninvasive, widely available, and simple to use method that can be used by an intensivist to evaluate and manage mechanically ventilated patients, as well as guide weaning from it.

The lungs and diaphragm should be examined during a chest ultrasound. LUS can detect extravascular lung water and measure the degree of regional lung aeration loss with pinpoint accuracy . Because the diaphragm is the major muscle of breathing, accounting for roughly 70% of tidal volume during inspiration in healthy people, diaphragmatic dysfunction is not uncommon in patients with weaning problems

The results of the present study demonestrated that, 32 patients experienced successful weaning (56.1%), while 25 patients experienced failed weaning(43.9%) and re- intubated and mechanically ventilated within 48 hours.

There were statistically significant differences ($P < 0.05$) between weaning and age as cases with lower mean age 42.91±8.79 years showed successful weaning. Also there were significant successful weaning associated with lower Modified LUS with mean 8.44±4.42.

The validity of LUSm score at cut off value < 9.5 in predicting successful weaning, revealed that the sensitivity was (84%), specificity= (68.7%), (PPV) = (77.1%), (NPV) = (77.3%) and the accuracy (77.2%). This result was in agreement with **Laz , et al 2019 (12)**, who used LUSm at cut off value 8.5 for prediction of weaning failure with sensitivity 85% and specificity 100% and **Thabit , et al 2022 (13)** , who showed LUSm score with optimal cut off value ≤ 6, had sensitivity 83.9% and specificity 93.1%, PPV =92.9%, NPV =84.4% and accuracy =88.3%, indicated that patients had high incidence of successful weaning. In collaboration with this results **Bouhemad et al., 2020 (14)** who used combined cardiac and lung ultrasound to predict weaning failure in elderly high risk cardiac patients. They assess the lung aeration in 6 areas for each lung, the condition has been reported to be associated with weaning failure if the anterolateral LUSm score is ≥ 5 . In addition , **Gok et al., 2021(15)** found that for the success of weaning, the cut off value for LUSm score obtained during the T-tube stage was 6.5 as a total of eight areas. Also, **Tenza-lozano , et al., 2018 (5)** showed that when LUSm score > 7, the patient has a high risk of weaning failure.

A higher pre-established LUSm score at cut off value < 13 **Soliman , et al., 2019 (3)**had low sensitivity 70.0% and specificity 82.5 % and **Soummer , et al., 2012(16)** showed low sensitivity 69%, PPV = (56.8%) with low accuracy (54.3%).

In the current study, the validity of diaphragmatic thickness in predicting weaning, the value of sensitivity (75%), specificity= (60%), (PPV) = (70.6%), (NPV) = (65.2%) and the accuracy (68.4%). Diaphragmatic thickness indicating successful weaning in 24 cases showing fair agreement in assessing successful weaning as kappa coefficient was 0.353.

The validity of diaphragmatic thickness index (TI) in predicting successful weaning at cut off value ≥ 25 %, revealed that the sensitivity was (89.33%), specificity= (87.9%), (PPV) = (88.1%), (NPV) = (86.6%) and the accuracy (88.7%). This results were in agreement with **Thabit , et al 2022(13)**, that showed diaphragmatic thickening index (TI) 30 min after SBT with cut off value > 24% had a sensitivity 90.32%, specificity 89.88%, PPV 90.3% and NPV 89.7% in predicting successful weaning. This findings matched with **Tenza-lozano , et al., 2018(5)**, they evaluate (TI) 30 min after SBT and found that optimal cut off value of TI was > 24%, with a sensitivity 93%, specificity 58% in predicting successful weaning .

In addition, in the current study the diaphragmatic motion indicating successful weaning in 28 cases and it shows good agreement of diaphragmatic motion in assessing successful weaning as kappa coefficient was 0.678.

The validity of diaphragmatic motion in predicting weaning had sensitivity (87.5%), specificity= (80%), (PPV) = (84.8%), (NPV) = (83.3%) and the accuracy (84.2%).

In this study, the validity of DRSBI in predicting successful weaning at cut off value < 1.3, revealed that the sensitivity (100%), specificity= (96.55%), (PPV) = (96.9%), (NPV) = (100%) and the accuracy (98.3%).%). These results were in agreement with **Thabit , et al 2022(13)** , that showed (DRSBI) at cut off value ≤1.3 breath/min/mm with sensitivity 100%, specificity 96.55%, PPV 96.9, NPV 100%.In collaboration with these results **Spadaro , et al., 2016 (17)** investigated the role of (DRSBI) in predicting successful weaning during T-tube trials and discovered that DRSBI was the measure with the highest diagnostic accuracy. A cut off value of DRSBI ≤ 1.3 breaths/min/mm yielded 94.1% sensitivity, 64.7% specificity this was in accordance with our results. **Al Kadi , et al., 2021 (18)**, who studied the role of DRSBI and maximum inspiratory pressure in predicting outcome of weaning from mechanical ventilation sensitivity, 84.7% . They found that DRSBI less than 1.6 breaths/min/mm was a very good tool to predict successful weaning,. This study matched with Abbas , et al 2018 in predicting weaning failure during T-tube trials at cutoff value of D-RSBI >1.9 breaths/min/mm yielded 84.6% sensitivity, 100% specificity, 100% (PPV), 94.9% (NPV) and 96% accuracy.

On the other hand weaning outcome may be affected by several factors such as hemodynamic stability, muscle weakness, electrolyte imbalance, pulmonary function, cardiac condition, conscious level and the ability of the patient to generate a good cough and expectorate endotracheal secretions. As a consequence, single weaning index is insufficient to make an accurate decision about the prediction of the outcome. Multiple indices and parameters have been proposed as predictors of weaning but the prognostic accuracy of these indices is still questioned. Interestingly, **Abdelaleem , et al 2020 (19)** showed the modified burn wean assessment program (m-BWAP) score was higher in patients with successful weaning using a cut-off value ≥ 55 with sensitivity 73.77% and specificity 84.85% . Like any other scientific study, this study is notwithout limitations. It was a single-center study, conducted on a limited number of patients. Therefore, findings derived from this study cannot be generalized to the reference population. Further multicenter studies involving a large number of patients would confer greater applicability. Moreover, the inter observer agreement for ultrasound assessments was not taken in the study. Finally ,it is important to say that the lung ultrasound operator was not blind concerning clinical presentation of patients .Furthermore, the rule of LUS and diaphragmatic ultrasound will be mandatory in diagnosis of lung diseases and as a predictor for weaning

Conclusion

Lung ultrasound can be a robust and effective tool for the rapid and accurate evaluation of ARDS at the bedside in intensive care units. Thus it can help the physicians initiate early, life-saving interventions, resulting in improved outcomes for the patients. All critical care physicians should have point-of-care ultrasound training to use this novel, potential diagnostic tool effectively with Sensitivity was (86.4%)the accuracy was (82.5%).

Weaning from mechanical ventilation (MV) could be described as the process of suddenly or regularly removing ventilator support. Weaning from MV often implies 2 separate but closely linked views of care, elimination of MV of any artificial airway . The primary challenge is identifying whethera case is prepared to restart ventilatory support. Several studies have mentioned that a direct technique for evaluating the ability to preserve spontaneous breathing is by initiating a trial of unaided breathing.

DRSBI, diphragmatic thickness index should be added to lung aeration (LUSm) in the weaning process evaluation because the diaphragm is the major muscle of breathing, accounting for roughly 70% of tidal volume during inspiration in healthy people, diaphragmatic dysfunction is not uncommon in patients with weaning problems so when involved the diaphragmatic function improving success incidence of the weaning . In this study the DRSBI is the best diagnostic accuracy than diaphragmatic thickness index , and LUSm, sensitivity 100% and accuracy98.3%.

References

1. **Nektaria X , Eleftherios M, Katerina V, Eumorfia K, Maria P, Alexandros P, Evaggelia A, et al** : lung ultrasound in critically ill patients :comparison with bedside chest radiography .Int Care Med. 2011,37:1488-93.
2. **Lichtenstein DA :Classification of artifacts.** Whole body ultrasonography in critically ill, Springer Heidelberg Dordrecht London New York, 1 st edition. 2010, 185-88.
3. **Soliman SB, Ragab F, Soliman RA, Gaber A, Kamal A**. Chest ultrasound in predication of weaning failure. Open Access Maced J Med Sci. 2019;7(7): 1143–7.
4. **Kim WY, Suh HJ, Hong SB, Koh Y, Lim CM.** Diaphragm dysfunction assessed by ultrasonography: Influence on weaning from mechanical ventilation. Crit Care Med . 2011 Dec (30):7-9.
5. **Tenza-Lozano E, Llamas-Alvarez A, Jaimez-Navarro E, and Fernández-Sánchez J**. Lung and diaphragm ultrasound as pre-dictors of success in weaning from mechanical ventilation. Crit Ultrasound J. 2018 (36):4 -12.
6. **Bass CM, Sajed DR, Adedipe AA, and West, TE.** Pulmonary ultrasound and pulse oximetry versus chest radiography and arterial blood gas analysis for the diagnosis of acute respiratory distress syndrome : a pilot study. *Crit Care*. 2015; 19(282): 1–11.
7. **See KC, Ong V, Tan YL, Sahagun J, and Taculod J.** Chest radiography versus lung ultrasound for identification of acute respiratory distress syndrome: A retrospective observational study. *Crit Care.* 2018;22(1): 1–9.
8. **Roshandel J, Alahyari S, Khazaei M, Asgari R, Moharamzad Y, Zarei E., et al .**Diagnostic performance of lung ultrasound compared to CT scan in the diagnosis of pulmonary lesions of COVID-19 induced pneumonia: a preliminary study .Virus Dis. (October–December 2021) 32(4):674–80.
9. **Nazerian P, Volpicelli G, Vanni S, Gigli C, Betti L, Bartolucci M, et al.** Accuracy of lung ultrasound for the diagnosis of consolidations when compared to chest computed tomography. Am J Emerg Med. 2015;33:620–5.
10. **Tung-Chen, Y.; de Gracia, M.M.; Díez-Tascón, A.; Alonso-González, R.; Agudo-Fernández, S.; Parra, M.; et al.** Correlation between Chest Computed Tomography and Lung Ultrasonography in Patients with Coronavirus Disease 2019 (COVID-19). Ultrasound Med. Biol. 2020, 46, 2918–26.
11. **Vignon P, Repessé X, Vieillard-Baron A, Maury E.** Critical care ultrasonography in diagnosis of acute respiratory failure.Crit Care. 2016;20:228-38.
12. **Laz, N.I., Mohammad, M.F., Abdelsalam and Abdelwahab R M.** Sonographic measurement of lung aeration versus rapid shallow breathing index as a predictor of successful weaning from mechanical ventilation. Egypt J Bronchol (2019)13, 477–83.
13. **Thabit, E. H., Ali, N. S., Ahmed, M. A., and Kassim, A. H.** Ultrasound Evaluation of Lung and Diaphragm as Predictors of Liberation Success from Mechanical Ventilation. Minia Journal of Medical Research (2022)., 33(2), 213-9.
14. **Bouhemad B, Mojoli F, Nowobilski N, Hussain A, Rouquette I and Guinot PG, .** Use of combined cardiac and lung ultrasound to predict weaning failure in elderly, high-risk cardiac patients: a pilot study. Intensive Care Med 2020. :212:1010-55.
15. **Gok F, Mercan A, Kilicaslan A, Sarkilar G and Yosunkaya A**. Diaphragm and Lung Ultrasonography During Weaning From Mechanical Ventilation in Critically Ill Patients. Cureus. 2021. (2) :1320-44.
16. **Soummer A, Perbet S, Brisson H, Arbelot C, Constantin JM and Lu Q, Rouby JJ**; Lung Ultrasound Study Group. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. Crit Care Med. 2012;40(7):2064-71.
17. **Spadaro S, Grasso S, Mauri T, Dalla Corte F, Alvisi V and , Ragazzi R**. Can diaphragmatic ultrasonography performed during the T-tube trial predict weaning failure? The role of diaphragmatic rapid shallow breathing index. Crit Care. 20164 (2) ;324-40.
18. **Al Kadi A GM, Mostafa RH, Helwa OMM and , Abd-Allah AFA.** The Role of Diaphragmatic Rapid Shallow Breathing Index and Maximum Inspiratory Pressure in Predicting Outcome of Weaning From Mechanical Ventilation. QJM An Int J Med. 2021(3) :330 -43 .
19. **Abdelaleem N A, Mohamed S AA , Abd ElHafeez A S and Bayoumi H A.** Value of modified Burns Wean Assessment Program scores in the respiratory intensive care unit: an Egyptian study. 10.4081/mrm.2020.691-70