Annals of Neonatology Journal

OPEN ACCESS
ISSN: 2636-3596

Original Article

Comparative Study between Chest X-Ray and Lung Ultrasound in Neonatal Respiratory Distress

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DOI: 10.21608/ANJ.2021.137638
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Abstract

Background**:** In the past, ultrasound has not been widely used for neonatal chest imaging due to the obscuring artifact generated by normal air-filled lung. Aim of work: This study aimed to determine the value of chest ultrasonography in comparison to chest x-rays in diagnosis and follow up of neonates with respiratory distress. Methods**:** This prospective study has been conducted at Neonatal Intensive Care Unit (NICU), Al-Azhar Assiut University Hospital from 1st November 2019 to October 2020. The study was conducted to 50 neonates with moderate respiratory distress, 14 of them were females (28%) and 36 of them were males (72%). All newborns included in the study admitted to neonatal intensive care unit: 13 of them stabilized on nasal oxygen, 37 of them stabilized on Nasal Continuous Positive Airway Pressure (NCPAP) for 6 hours. 8 of them need mechanical ventilation based on clinical, arterial blood gases and lung ultrasonographic findings. Lung ultrasound was performed within 2 hours and repeated after 6 hours. Chest x-ray was performed and scored. Both Lung ultrasound score and chest x-ray score were used and compared for respiratory distress in neonates. Results: Lung ultrasound has important role in diagnosis and follow up of neonates with respiratory distress and considered higher than chest X-ray regarding its ability to detect different patterns of white lung in term of pulmonary oedema (B-Lines) (40%),consolidation(62%) and pleural effusion (8%). Conclusion: Lung ultrasound is a non-invasive, bedside and reproducible method that could improve the management of neonatal respiratory distress. After 6 hours of Nasal Continuous Positive Airway Pressure (NCPAP), neonatal lung ultrasound is a useful predictor of the need for intubation over chest x-ray. Respiratory distress syndrome was the main diagnosis of respiratory distressed infants followed by transient tachypnea of newborn, pneumonia, meconium aspiration syndrome (MAS), and finally pleural effusion.

Key words: Chest X-Ray; lung ultrasound, neonatal, respiratory distress

Introduction

Respiratory distress is the most frequent cause of neonatal intensive care unit (NICU) admission, and the individual management strategies should be the main task in NICUs for these infants [1]. Fifteen percent of term infants and twenty-nine percent of late preterm infants admitted to the NICU develop significant respiratory morbidity; this is even higher for infants born before 34 weeks' gestation. [2]. Respiratory distress is recognized as any signs of labored breathing in the neonate. Recognition of these signs and symptoms of increased work of breathing by careful inspection and auscultation are important, such as tachypnea, nasal flaring, retractions, bilateral and equal aireation of the lung and breath sounds, and the presence of cyanosis, should be evaluated. Non-invasive pulse oximetry is recommended by the American Heart Association (AHA) guideline for neonatal resuscitation [3]. Although chest X-Ray plays an important role in diagnosis of respiratory distressed neonates, it leads to their exposure to ionizing radiation due to their small size and the close proximity of radiosensitive tissues and organs are at greater risk from latent effects of chest X-Ray in comparison to other age groups [4]. Lung ultrasound (LUS) has emerged as a promising diagnostic tool with studies reporting accurate results in the diagnosis of neonatal respiratory distress syndrome (RDS) and other neonatal pulmonary diseases [6]. Use of ultrasonography (USG) in Emergency Department, Critical Care and Cardiac Care Units is becoming popular. It is considered as "third eye" of health care providers in these units. [5,7]. A systematic ultrasound has been validated across a wide span of ages using both chest anatomic structures (i.e, the ribs or the pleural line) and artifact images such as the B-lines that are discrete, laser like vertical hyperechogenic reverberations arising from the pleural line. Multiple diffuse bilateral B-lines are suggestive of

interstitial syndrome (pulmonary edema, interstitial pneumonia, diffuse parenchymal lung disease) [8].

In the neonate, one can accurately differentiate the aireated dry lung, appearing as uniform hypoechogenic pattern, sliding with respiration and often showing horizontal reverberations of the pleural image (the A-lines), from the hyperechogenic "white"pattern of the markedly "wet" or inflamed organ [8]. Non-invasive ventilation (NIV) is widely used for the treatment of moderate respiratory disease of the newborn to stabilize spontaneous breathing while avoiding the complications of invasive ventilation [9].

There is a need for reliable predictors of NIV failure that would spare the infant becoming exhausted from ineffective breathing. As clinics and chest radiographs are often discordant in grading the severity of neonatal respiratory distress syndrome, conventional radiology is often of little help. On the other hand, the persistence of a "white-lung" ultrasound image has been shown to correlate with clinical respiratory distress (RD) in preterm infants [10].

Aim of the work: To study the value of chest ultrasonography in comparison to chest x-rays in neonates with respiratory distress.

Methods

This prospective study has been conducted at Neonatal Intensive Care Unit (NICU) in Al-Azhar Assiut University Hospital from 1st November 2019 to 31th October 2020. The study was conducted to 50 neonates with moderate respiratory distress, 14 of them were females (28%) and 36 of them were males (72%). All newborns included in the study admitted to neonatal intensive care unit: 13 of them stabilized on nasal oxygen, 37 of them stabilized on Nasal Continuous Positive Airway Pressure (NCPAP) for 6 hours. 8 of them need mechanical ventilation based on clinical, arterial blood gases and lung

ultrasonographic findings. Lung ultrasound was performed within 2 hours and repeated after 6 hours. Chest x-ray also was performed and scored.

Both Lung ultrasound score and chest x-ray score were used and compared for respiratory distress syndrome neonates.

Inclusion criteria: Full term and preterm neonates in a clinical setting with signs and symptoms of moderate respiratory distress diagnosed using a combination of clinical indicators (presentation, vital signs and auscultation), chest x-ray and laboratory blood gas analysis.

Exclusion criteria: Neonates presented with respiratory distress due to extra pulmonary causes e.g.: Congenital heart diseases (CHD), renal failure, and electrolyte disturbances early severe sepsis….etc.

All neonates enrolled in this study were subjected to: Pre-natal history: pregnancy condition including (drug intake, smoking, seizures in pregnancy, hospitalization in early pregnancy, severe anemia , frequency of prenatal visits, prior fetal death, birth interval), Natal history: labour and delivery (spontaneous or induced onset of labour, duration of labour, methods of delivery, signs of fetal distress, problem during labour and delivery, medicines given to the mother e.g. pethidine and antenatal steroid , Post-natal history: Apgar score and any resuscitation needed, any abnormalities detected, birth weight and circumference, estimated gestational age and vitamin K given. Full clinical examination: General examination, systemic examination, chest examination. Investigations: CBC (Complete blood count), CRP (C-reactive protein), Blood gas analysis. A lung ultrasound (LUS) was performed at the bedside on respiratory distressed neonates 2 hours repeated after 6 hours immediately after admission by Transthoracic approach with longitudinal scans of the anterior and posterior chest walls, A high-resolution linear probe with a frequency of more than 7.5 MHz (GE Voluson i or E 6, USA) was used

and read by an independent radiologist. Chest X-Ray was performed at the bedside on respiratory distressed patients with low MA (Milliampere second) technique antero-posterior view in the supine position just following the lung ultrasound.

Chest Radiogram was considered in order to(0-4) score for all (19) neonates with respiratory syndrome (RDS) and it was graded in both lungs as follows:[0] normal radiolucent lung fields with sharp cardiac and diaphragmatic margins [1] slightly reduced radiolucency with still sharp cardiac and diaphragmatic margins [2] markedly reduced radiolucency with retained cardiac and diaphragmatic margins [3] severely reduced radiolucency with air bronchogram and blurred cardiac and diaphragmatic margins [4] completely white lung fields with or without air bronchogram and barely visible cardiac and diaphragmatic margin [19, 20].

Chest ultrasound was considered in order to (0-3) score for all (19) neonates with respiratory syndrome (RDS) and it was graded in both lungs as follows: Lung have been divided into three areas, upper anterior, lower anterior, and lateral. For each area, a score of 0-3 has been assigned. Score values correspond to different patterns. Scores were given as follows [0] presence of only A-lines [1] presence of A-lines in the upper part of the lung and coalescent B-lines in the lower part of the lung (pattern 1a) or at least 3 B-lines (pattern 1b) [2] presence of crowded and coalescent B lines with or without consolidations limited to sub-pleural space [3] presence of extended consolidation [19&20].

Ethical consideration: Oral and written consents were taken from parents or guardians of the patients and the aim of the study was explained to the parents before collection of the data. The privacy of all data collected was assured.

Statistical analysis

The collected data were revised, organized, tabulated and statistically analyzed using statistical package for social sciences (SPSS) version 25.0 for windows. Data are presented as the Mean ± standard deviation (SD), frequency, and percentage. McNemar test and McNemar-Bowker test were used for comparison between different diagnostic methods and findings. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of the tested findings were calculated. A 0.05 level was chosen as a level of significance in all statistical tests used in the study.

Results

During the study, 64 babies were considered eligible. 11 patients were excluded because of exclusion criteria (4 with complex malformation, 3 with congenital lung diseases and 4 with early severe sepsis) and 3 patients because consent was denied, leaving 50 in the study. The results of the present study were illustrated in the following tables and figures:

-Table (1): Characteristics of studied neonates with moderate respiratory distress.

-Table (2): Various etiological diagnoses of the 50 neonates with moderate respiratory distress by chest x-ray and lung ultrasound.

-Table (3): Chest ultrasonography findings in 50 neonates with moderate respiratory distress.

-Table (4): Concordance of ultrasound and Radiographic Results for 19 neonates with RDS.

-Table (5): Chest x rays versus chest ultrasonography in diagnosis of neonatal chest diseases.

-Figure (1): (A) Ultrasound picture of upper chest in RD patient shows multiple longitudinal white lines related to B lines with loss of A lines suggestive of mild interstitial lung edema (score 1). (B) Chest x-ray shows (Score 2) respiratory

distress syndrome of reduce radiolucency and preserved cardiac margins.

-Figure (2): (A) Ultrasound picture of upper chest in RD patient shows white lung picture due to multiple adjacent confluent longitudinal white lines related to B lines suggestive of sever form of interstitial lung edema (Score 2). (B) Chest x-ray shows (score 3) respiratory distress syndrome of marked reduced radiolucency and blurred cardiac margins.

-Figure (3): (A) Lung ultrasound shows a significant area of consolidation with air bronchograms in the left lung. (B) Chest x-ray shows (score 4) respiratory distress syndrome of marked reduced radiolucency and obscured cardiac margins.

Discussion

In the present study respiratory distress syndrome (RDS) represented the highest percentage of 50 neonates with moderate respiratory distress followed by transient tachypnea of newborn (TTN) and meconium aspiration syndrome (MAS) (38%), (32%) and (10%) respectively .These findings were found to be higher than the findings of Chen et al study [11].

On routine application of lung ultrasonography in NICU where their percentage were (19.3%), (11.4%)and (6.7%) respectively. However the reverse has been occurred in neonatal pneumonia which was the diagnosis in (17.5%) of our cases compared to (29.8%) in Chen et al study [11].

According to ultrasound indices used in this study , (Pleural line): is the regular echogenic line under the superficial layers of the thorax moving continuously during respiration, while abnormal pleural lines refer to pleural lines disappearance [13]. (A-line): a series of echogenic, horizontal, parallel lines equidistant from one another below the pleural line, which are the reverberation artifacts of the pleural line [14&15].(B-lines): also known as ultrasound lung comets, hyperechoic narrow-based artifacts spreading like laser rays from

the pleural line to the edge of the screen[16]. (Lung consolidation): defined as areas of hepatization with presence of air bronchograms or fluid bronchograms [15, 17]. (Pleural effusion): defined as anechoic-dependent collections limited by the diaphragm and the pleura [17]. (Interstitial syndrome): defined as the presence of more than 3 B-lines or the presence of areas of 'white lung' in every examined area [18]. (Bilateral white lung): defined as the presence of compact B-line in the 6areas without horizontal reverberation [13]. (Double lung point sign) refers to a sharp boundary found between relatively aireated superior lung fields and coalescent "B-lines" (representing interstitial edema) in the basal lung fields, with a reported sensitivity of 45.6-76.7% and a specificity of 94.8-100% in diagnosing transient tachypnea of the newborn [13,21].

In our study the total number of respiratory distress syndrome (RDS) diagnosed by lung ultrasound was 19 (38%), The abnormalities of the pleural line and A-line disappearance were found in 19 cases (100%) which matches with Chen et al. [11] and Liu et al. [12] while, interstitial syndrome, was present in 4 cases (21%) which was higher than that of Chen et al. [11] (14.8%) however lung consolidation could be found on Lung ultrasound in 18 cases (94.7%) which was less than that of Chen et al. [11] study (100%). Pulmonary oedema or white lung could be found on lung ultrasound in 15 cases (78.9%) which was less than that of Chen et al. [11] (85.2%).

The contradictory between our results and that of other studies might be attributed to differences of clinical severity of cases. The number of cases with RDS having pleural effusion was zero compared to that of Chen et al. [11] (31.7%). However double lung point was not found in our study and this matches with Chen et al. [11].

The sensitivity and specificity of combined lung consolidation, pleural line abnormalities and bilateral pulmonary edema finding by lung ultrasound in respiratory distress syndrome (RDS) was 96% and 63.3% respectively compared to 100% in studies of Liu et al. [12]. The sensitivity and specificity of combined lung consolidation, pleural line abnormalities and interstitial lung was 84.6 % and 77% respectively compared to 100% in studies of Liu et al. [12].

Based on lung ultrasound scan after 6 hours on NCPAP, Nine neonates were assigned score 3, five to score 2, and five to score 1. Eight newborns with score 3 were intubated after an average interval of 5-7 hours. No infant with score 1 or score 2 profile was intubated. In predicting failure of NIV, score 3 lung ultrasound had the following accuracy with 71.2% sensitivity and 80% specificity.

On the basis of the chest radiograph, no infant was assigned to grade 4 or 3,whereas five neonates were assigned to grade 2 and 14 to grade 1. The accuracy of grade 2 to predict intubation was as follows: 31.2% sensitivity and 62.3% specificity.

Lung ultrasound in transient tachypnea of newborn reported pleural line abnormality and absence A-line in 16 cases (100%) which was found to be in concordance with that of Chen et al. [11]. While interstitial lung was present in 12 (75%) of cases, it was higher than that of Chen et al. [11] (70.39%).

Pulmonary oedema was present in 5 cases of TTN (31.25%) which was higher than that of Chen et al. [11] (29.7%). This disagreement might be due to the severity of the disease. Double lung point was present in 12 cases (75%) which were higher than those found in Chen et al. [11] and their percent was (34.1%). Pleural effusion was not present in any case of transient tachypnea of newborn in comparison to (19.4%) in Chen et al. [11]. We found that there was

significant relation between double lung point and TTN in 12 cases (75%) was statistically significant (p value <0.001) with 52% sensitivity and 100% specificity.

The total number of pneumonia of diagnosed by Lung ultrasound was 8 (16%) and this was matched with the initial diagnosis made clinically. In our study the abnormalities of the pleural line were found in 7 cases of pneumonia (87.5%) which was less than Chen et al. [11] that was (90.9%). While A-line disappearance, and lung consolidation were found in 8 cases (100%) which matches with Chen et al. [11]. Double lung point couldn't be seen in pneumonia and this matches with Chen et al. [6] study. Pleural effusion was present in one case (12.5%) which was higher than Chen et al. [11] study which was (8.7%).

All cases diagnosed initially as MAS by chest x rays, their diagnosis confirmed by chest US by the presence of lung consolidation. Pleural line abnormalities was present in 4 cases (80%) less than those detected in Liu et al[12] which was 100% and Chen et al. [11] which was 88% . Lung consolidation and absence of A-line were present in (100%) which matches with Liu et al. [12] and Chen et al. [11] which were 100%. Pleural effusion was present in one case of meconium aspiration syndrome (MAS) (20%) which was higher than that of Liu et al. [12] study (13.7%) and those found in Chen et al. [11] which was (17.4%). Absence of lung sliding was present in 1case (20%) which was higher than Liu et al. [12] which was 16.2%. We found that the most specific finding in MAS is lung consolidation 5 (100%) (P value <0.05) statistically significant with 100% sensitivity and 40% specificity in comparison to 100% sensitivity and specificity and (p value <0.001) in prospective observational Liu et al study. [12].

However, there are some limitations in this study as follows: The number of respiratory distressed infants should be

increase in future studies as well as complicated respiratory distress with air leak syndrome such as (pneumothorax , interstitial emphysema) cannot easily be discovered by using ultrasound machine.

Based on this study, we recommended informing pediatricians to know the importance of learning ultrasound and the importance of follow up neonates with respiratory distress for detection of change of ultrasound finding in each disease during convalescent stage.

Conclusions

Lung ultrasound is a non-invasive, bedside and repeatable method that could improve the management of neonatal respiratory distress. After 6 hours of Nasal Continuous Positive Airway Pressure (NCPAP), neonatal lung ultrasound is a useful predictor of the need for intubation over chest x-ray. Combined lung consolidation, pleural line abnormalities and absence of A line findings were the most specific lung ultrasound findings in RDS which were present in 94.7% of cases (p value <0.001) statistically significant with 96% sensitivity and 63.3% specificity. Double lung point was found in 75% of cases which was statistically significant (p-value <0.001) with 52% sensitivity and 100% specificity. Combined lung consolidation, pleural line abnormalities and interstitial lung were found in 87.5% of cases of pneumonia which was statistically significant (p value < 0.001) with 84.6% sensitivity and 77% specificity. It is worth noting for ultrasonographic findings in MAS we found the most specific finding was lung consolidation that was found in 100% of cases statistically significant (p value <0.001) with 100% sensitivity and 40% specificity.

Acknowledgements

To all the staff members, assistant lecturers, residents and nursing team of the NICU and to every one helped to finish this study in the final form.

Author's contributions

HE, ME and HH equally contributed in the study concept, design, supervision,

methodology, statistical analysis and data collection. TM performed the investigations workup and wrote the first draft of the manuscript.

Conflict of interest

Authors declare they have no conflict of interest

Fund

The manuscript funded only from the authors.

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Date received: 16th December 2020, accepted 18th January 2021

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Table (1): Characteristics of studied 50 neonates with moderate respiratory distress.

Characteristic	
Gender n (%)	
Males Females	36 (72.0%) 14 (28.0%)
Weight(grams)	
Mean ±SD Median (range)	2001.5 ± 683.6 1900 (800-3600)
Gestational age(weeks)	
Mean ±SD Median (range)	33.76 ± 3.23 34 (28-41)
Previous NICU admission n (%)	
No Yes	39 (78.0%) 11 (22.0%)
Perinatal history n (%)	
Mode of delivery	
Normal vaginal delivery Caesarean section	11 (22.0%) 39(78.0%)
Premature rupture of membrane (PROM)	
No Yes	37 (74.0%) 13 (26.0%)
Antenatal steroid	
No Yes Unknown	14(28.0%) 15(30.0%) 21(42.0%)
Consanguinity	
Negative Positive	28(56.0%) 22(44.0%)
Signs of respiratory distress n (%)	
Cyanosis Chest retraction Grunting Tachypnea Cyanosis & chest retraction Tachypnea & chest retraction	16 (32.0%) 15 (30.0%) 12(24.0%) 5 (10.0%) 1 (2.0%) 1 (2.0%)

n=number %=percentage

Table (2): Various etiological diagnoses of the 50 neonates with moderate respiratory distress by chest x-ray and lung ultrasound.

Variable	n (%)
RDS Type I (white lung) Type II (predominance of b line)	19(38%) 14 (73.7%) 5(26.3%)
Pneumonia	8(16%)
Transient tachypnea of newborn (TTN)	16(32%)
Meconium aspiration (MAS)	5(10%)
Pleural effusion	2 (4%)

n=number %=percentage

Table (3): Chest ultrasonography findings in 50 neonates with moderate respiratory distress

Disorder	Chest ultrasonography findings	n (%)
RDS (19)	Pleural line abnormality Absence A line Interstitial lung Pulmonary oedema Lung consolidation	19 (100%) 19 (100%) 4 (19%) 15 (78.9%) 18 (94,7%)
TTN (16)	Pleural line abnormality Absence A line Interstitial lung Pulmonary oedema Double Lung point	16 (100%) 16 (100%) 12 (75%) 5 (31,25%) 12 (75%)
Pneumonia (8)	Pleural line abnormality Absence A line Interstitial lung Pleural effusion Lung consolidation Absence of lung sliding	7 (87.5%) 8 (100%) 8 (100%) 1 (12.5%) 8 (100%) 2 (25%)
Meconium aspiration syndrome(5)	Pleural line abnormality Absence A line Interstitial lung Pleural effusion Lung consolidation, Absence of lung sliding	4 (75%) 5 (100%) 4 (75%) 1 (12.5%) 5 (100%) 1 (12.5%)
Pleural effusion (2)	Pleural line abnormality Absence a line Pleural effusion, Lung collapse	2 (100%) 2 (100%) 2 (100%) 2 (100%)

n=number %=percentage

Table (4): Concordance of ultrasound and radiographic results for 19 neonates with respiratory distress syndrome.

Lung Ultrasound Result	**Chest Radiographic Result**			
	Grade 4	**Grade 3**	**Grade 2**	**Grade 1**
Score 3	0	0	1	8
Score 2	0	0	3	2
Score 1	0	0	1	4

Score 3 lung ultrasound in predicting failure of (NIV) had the following accuracy: sensitivity 71.2%, specificity 80%.While the accuracy of grade 2 chest x-ray to predict intubation was as follows: sensitivity 31.2% , specificity 62.3%.

Table (5): Chest x rays versus chest ultrasonography in diagnosis of neonatal chest diseases.

Diseases	**Chest X- Rays**	**Chest Ultrasonography**	**P-Value**
MAS	3 (6%)	2 (4%)	
Pleural effusion	1(2%)	1(2%)	
Pneumonia	4(8%)	4(8%)	0.12 NS
RDS	11 (22%)	8 (16%)	
TTN	7 (14%)	9 (18%)	

P-value was calculated by McNemar-Bowker Test, NS: No statically significant difference, P>0.05.

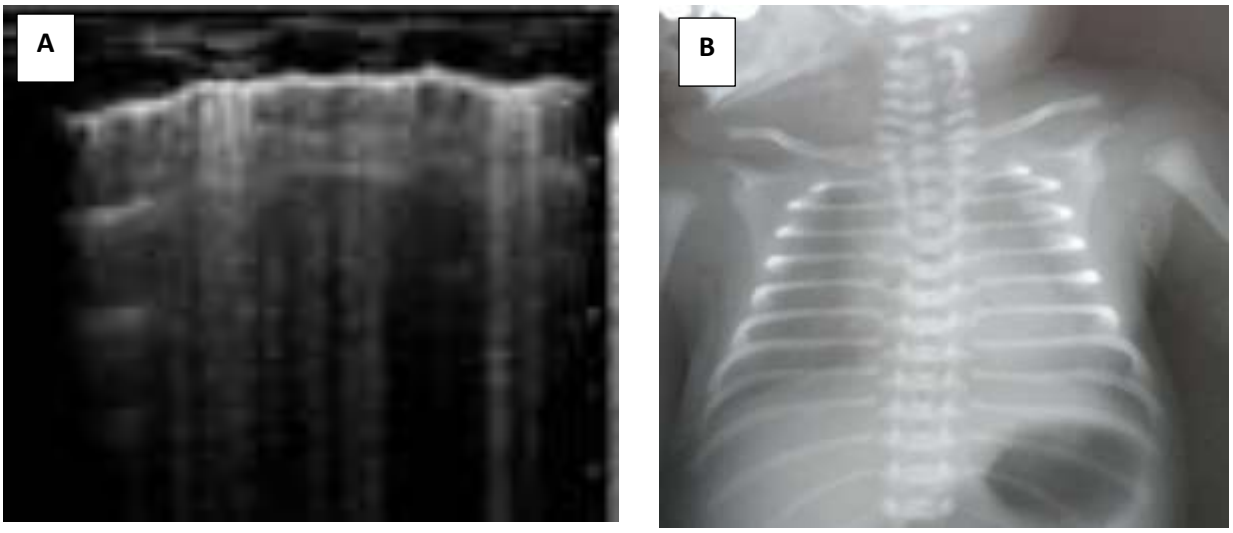

Fig. 1: A) Ultrasound picture of upper chest in RD patient shows multiple longitudinal white lines related to B lines with loss of A lines suggestive of mild interstitial lung edema (score 1). B) Chest x-ray shows (Score 2) respiratory distress syndrome of reduce radiolucency and preserved cardiac margins.

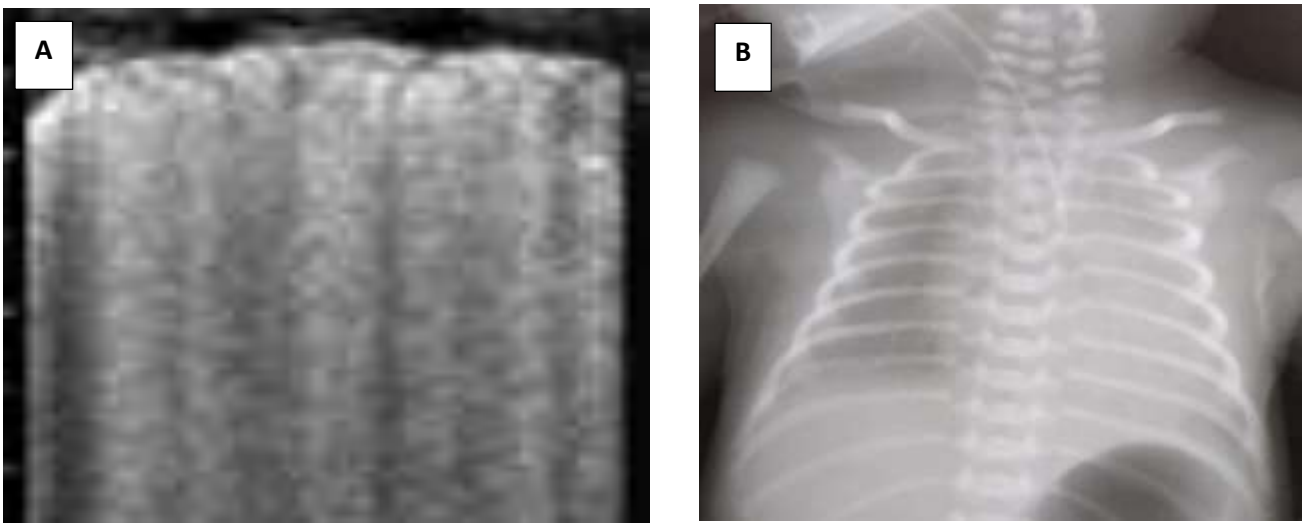

Fig. 2: A) Ultrasound picture of upper chest in RD patient shows white lung picture due to multiple adjacent confluent longitudinal white lines related to B lines suggestive of sever form of interstitial lung edema (Score 2), B) Chest x-ray shows (score 3) respiratory distress syndrome of marked reduced radiolucency and blurred cardiac margins.

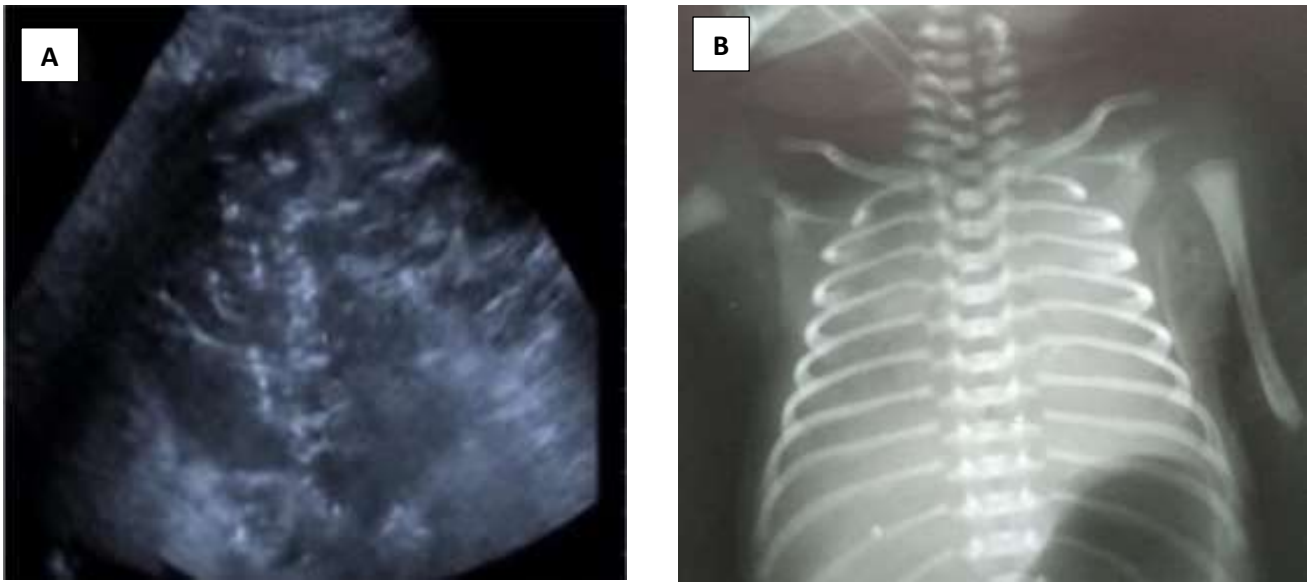

Fig. 3: A) Lung ultrasound shows a significant area of consolidation with air bronchograms in the left lung, B) Chest x-ray shows (score 4) respiratory distress syndrome of marked reduced radiolucency and obscured cardiac margins.

Citation: Hosny M. A. El-Masry, Mohammed A. Aladawy, Tarek M. Mansour and Hassan A. Hassan. "Comparative Study between Chest X-Ray and Lung Ultrasound in Neonatal Respiratory Distress". Annals of Neonatology Journal, 2021, 3(1):125-143 doi: 10.21608/ANJ.2021.137638