Journal of American Science

Websites:
http://www.jofamericanscience.org
http://www.sciencepub.net

Emails:
editor@sciencepub.net
sciencepub@gmail.com

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Lung Ultrasound in Rapid Diagnosis of Acute Respiratory Disorders in Critically Ill Children

Yomna Gaber Elfeky (MSc)[1], Khaled Talaat Abu-Eala (MD)[1], Omar Ahmed Hassanein (MD)[2] and Ahmed Mohamed Abd Elrazik (MD) [1]

[1] Pediatric Department, Faculty of Medicine, Tanta University, Egypt
[2] Radiology Department, Faculty of Medicine, Tanta University, Egypt
yomna199@yahoo.com

Abstract: Background: Lung ultrasound (LUS) has moved from its traditional role in diagnosing pleural effusions and masses, to diagnosing pulmonary parenchyma as a real time method used in emergency. The aim of the work was to evaluate the impact of LUS in rapid diagnosis of acute respiratory disorders in critically ill children. **Patients and Methods:** This prospective cohort study was carried out in pediatric intensive care unit on 120 critically ill children and equally divided into three groups (n=40); group I: suffered from acute respiratory disorders and ventilated, group II: suffered from acute respiratory disorders and not ventilated, group III: suffered from non-respiratory disorder. LUS was performed by a single operator then CXR in all studied cases. Multislice chest computed tomography (CT) was performed on only 80 cases (as the other cases couldn't be transferred). **Results**: There was insignificant difference among the three groups in mortality and length of stay. Regarding PRISM III score, there was a significant increase in groups I and III compared to group II. Regarding CPIS score, there was a significant increase in group I compared to group III, otherwise, there were insignificant differences among the three groups. Regarding SOFA score, there was a significant increase in group I compared to the groups II and III in the 1st, 2nd, 3rd and 4th day and in group III compared to group II in the 2nd, 3rd days. LUS showed 89.22% sensitivity and 66.67% specificity, while CXR showed 56.86% sensitivity and 72.22% specificity and chest CT showed 93.20%sensitivity and 44.44 %specificity. LUS was a good diagnostic tool which agrees well with the final diagnosis. **Conclusion:** LUS was superior to CXR and slightly inferior to CT chest in diagnosing acute chest disease but the hazards of mobilization of critically ill patients and of radiation exposure and time-consuming make LUS is the best diagnostic tool in emergency.

[Yomna Gaber Elfeky, Khaled Talaat Abu-Eala, Omar Ahmed Hassanein and Ahmed Mohamed Abd Elrazik. **Lung Ultrasound in Rapid Diagnosis of Acute Respiratory Disorders in Critically Ill Children.** *J Am Sci* 2020;16(1):7-14]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 2. doi:10.7537/marsjas160120.02.

Keywords: Lung ultrasound, acute respiratory disorders, critically ill children

1. Introduction

Chest X-ray (CXR) is done routinely in the pediatric intensive care (PICU) as it is feasible in it[1]. Chest CT is more accurate than CXR in diagnosing lung parenchymal and pleural diseases but with higher dose of radiation [2].

In the clinical practice, ultrasound (US) has appeared strongly in the last years. Lung ultrasound (LUS) has moved from its traditional evaluation of pleural effusions and masses, to evaluation of the pulmonary parenchyma as a real time technique used in emergency[3]. LUS is thought to be potentially helpful in the evaluation and detection of many different acute and chronic lung conditions, from cardiogenic pulmonary edema to acute lung injury, from pneumothorax to pneumonia, from interstitial lung disease to pulmonary infarctions[4].

LUS is fast, portable, repeatable, non-ionizing and independent from specific acoustic windows. It can be therefore used in various situations, both inpatient and outpatient, in both acute and chronic conditions[4].

Depending on different circumstances, the clinical strategy focused on LUS, adopting the main principles of what is regarded as "the point of care ultrasound" or POCUS. The full effectiveness of the procedure is reached by a clinically, focused evaluation[5].

The role of LUS as a diagnostic and prognostic tool in PICU needs to be studied further especially in compared to the established daily used CXR and chest CT. Therefore, the aim of this work was to evaluate the impact of LUS in rapid diagnosis of acute respiratory disorders in critically ill children.

2. Patients and Methods

The prospective cohort study was conducted from February 2016 to August 2018 at the Tanta

University Hospital's PICU on 120 critically ill patients aged between one month and 14 years. The study was approved by the ethical committee of the faculty of medicine, Tanta University.

An informed written consent was obtained from the guardians of the patients included in the study. The cases were classified into three groups (40 in each); **group I**: patients with acute respiratory disorders on mechanical ventilator (MV), **group II**: patients with acute respiratory disorders not on MV, **group III**: patients with non-respiratory disorder (MV or not). Exclusion criteria were: morbid obesity, massive surgical emphysema and multiple dressings on the chest.

All patients included in this study were subjected to the following: complete history, thorough clinical examination and routine investigations (complete blood count, liver and kidney function tests and arterial blood gases). The Pediatric Risk of Mortality (PRISM) III score was done for all cases at first 24 hours [7], Clinical Pulmonary Infection Scoring System (CPIS) score[8] and Sequential Organ Failure Assessment (SOFA) score[9] was done on 1st, 2nd, 3rd and 4th days.

Monitoring:

Oxygen saturation, systolic and diastolic blood pressure, heart rate and respiratory rate were monitored. Also, transcutaneous blood gases (Partial transcutaneous carbon dioxide tension ($P_{tc}CO_2$) and Partial transcutaneous oxygen tension ($P_{tc}O_2$) were done using [TCM4 series, Radiometer Medical Aps, Akandevej 21, 2700 Bronshoj, Denmark].

Table (1): Demographic data and clinical diagnoses of the studied groups

	Group I (n=40)	Group II (n=40)	Group III (n=40)	Test of Sig.	p
Age (months)					
Range	3 – 106	1 – 168	2 – 160	H=2.41	0.300
Median	12.0	8.50	13.0		
Sex					
Male	18 (45%)	19 (47.5%)	19 (47.5%)	χ^2=0.067	0.967
Female	22 (55%)	21 (52.5%)	21 (52.5%)		
Diagnosis					
Bronchopneumonia	21 (52%)	24 (52.5%)	----	----	----
ARDS	8 (20%)	----	----		
Acute bronchiolitis	----	7 (22.5%)	----		
Status asthmatics	----	4 (12.5%)	----		
Pleural effusion	4 (10%)	2 (5%)	----		
Near drowning	3 (7.5%)	1 (2.5%)	----		
Pneumothorax	3 (7.5%)	----	----		
Stridor	1 (2.5%)	----	----		
DKA	----	----	12 (30%)		
Status epileptics	----	----	10 (25%)		
Gastroenteritis	----	----	8 (20%)		
Post-operative +	----	----	7 (17.5%)		
AKI- CKD- HUS	----	----	4 (10%)		

AKD: acute kidney disease, ARDS: acute respiratory distress syndrome, CKD: chronic kidney disease, HUS: haemolytic uremic syndrome+ (Hirschsprung-intussusception - eventration of diaphragm-esophageal tear post corrosive- congenital diaphragmatic hernia), χ^2: Chi square test, H: Kruskal Wallis test.

Therapeutic interventions:

Circulatory support was done by intravenous fluids and or inotropes and or vasopressors. MV (either conventional or high frequency oscillatory ventilation HFOV) was done in the following cases: acute respiratory failure, acute respiratory distress syndrome (ARDS), cardiorespiratory compromise, Glasgow coma scale ≤ 8. Conventional ventilation was accomplished using a Raphael color ventilator, [Model X1, Hamillton medical, Hamilton Medical AG, CH-7403Rhazuns, Switzerland]. HFOV was accomplished using a [Fabian HFOV" "ACUTRONIC" Medical Systems AG Fabrik imSchiffli 8816 Hirzel / Switzerland] in patients requiring PaO_2/ FiO_2 < 300 with mean airway pressure (MAP) > 24 cmH_2O were considered for a trial of HFOV[11].

LUS was performed by a single experienced operator who was blinded to the clinical and radiological diagnosis using the portable US device (SONOSCAPE A5 SN 16226223) using the superficial linear transducer probe 12-MHz resolution. LUS was done on upper and lower parts of (anterior, lateral and posterior) areas of the lung (12 areas) using a standardized evaluation of lung aeration. LUS score for each hemi-thorax as follow (0 point if normal

aeration (lung sliding with A-lines or less than two isolated B-lines, 1 point if moderate loss of aeration (3 separated B-lines), 2 points if severe loss of aeration (coalescent B-lines) and 3 points if lung consolidation). The LUS score was calculated as the sum of points and ranged between 0 and 36 points[10].

CXR was performed for all studied cases in poster anterior view using the portable x-ray device (SIEMENS SN3312554).

Concomitant multislice chest CT was performed using the device (GE medical systems- optima CT 660, 128 slices). It was done in 80 cases only as the other cases couldn't be transferred. The timing of CT was according to the patient condition.

The collected data were tabulated and statistically analyzed using SPSS (IBM©, USA) version 25. Quantitative data were presented as range and median and were compared by Kruskal Wallis test with Post Hoc. Qualitative data were presented as number and percentage and were compared by chi-square test (X^2). LUS and CXR (as diagnostic tools) were assessed by sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy. The level of significance was adopted at a P value < 0.05.

3. Results

Demographic data, clinical diagnoses of the cases are shown in table (1). There was insignificant difference among the three groups in mortality and length of stay. Regarding PRISM III score, there was a significant increase in groups I and III as compared to group II. Regarding CPIS, there was a significant increase in group I as compared to group III, otherwise, there was insignificant differences between the three groups [Table (2)]. Regarding SOFA score, there was significant increase in group I as compared to the groups II and III in the 1st, 2nd, 3rd and 4th days and in group III compared to group II in the 2nd, 3rd days [Figure (1)].

LUS was more sensitive but less specific CXR in comparison to chest CT [Table (3)]. LUS was a good diagnostic tool which agrees well with the final diagnosis [Table (4)].

Table (2): Outcome of the studied groups

	Group I (n=40)		Group II (n=40)		Group III (n=40)		Test of Sig.	p
	No.	%	No.	%	No.	%		
Fate								
Dead	13	32.5	5	12.5	13	32.5	χ^2=5.567	0.062
Live	27	67.5	35	87.5	27	67.5		
PRISM III								
Min. – Max.	15.0 – 40.0		12.0 – 45.0		16.0 – 45.0		H=9.652*	0.008*
Median	24.50		19.50		23.0			
Significance between Groups	p_1=0.010*, p_2=0.830, p_3=0.005*							
Clinical Pulmonary infection score (CPIS)								
Min. – Max.	15.0 – 40.0		12.0 – 45.0		16.0 – 45.0		8.924*	0.012*
Median	8.0		6.50		5.50			
Significance between Groups	p_1=0.088, p_2=0.003*, p_3=0.204							
Length of stay (days)								
Min. – Max.	4.0 – 25.0		6.0 – 19.0		4.0 – 21.0		H=4.768	0.092
Median	9.0		9.0		8.0			

PRISM pediatric risk of mortality, χ^2: Chi square test, H: Kruskal Wallis test, p_1: p value for comparing between Group I and Group II, p_2: p value for comparing between Group I and Group III, p_3: p value for comparing between Group II and Group III, *: statistically significant at $p \leq 0.05$

Table (3): Diagnostic accuracy of lung ultrasound and chest X-ray to chest CT

	CT chest (n=80)				Sensitivity	Specificity	PPV	PV	Accuracy
	-ve (n = 6)		+ve (n = 74)						
	No.	%	No.	%					
LUS									
-ve	2	33.3	4	5.4	94.59	33.33	94.59	33.33	90.0
+ve	4	66.7	70	94.6					
X-ray chest									
-ve	5	83.3	18	24.3	75.68	83.33	98.25	21.74	76.25
+ve	1	16.7	56	75.7					

LUS: lung ultrasound, CT: computed tomography, NPV: Negative predictive value, PPV: Positive predictive value, US: ultrasonography

Table (4): Diagnostic accuracy of lung ultrasound to final diagnosis

LUS	Final diagnosis (n=120)				Sensitivity	Specificity	PPV	NPV	Accuracy
	-ve		+ve						
	No.	%	o.	%					
Bronchopneumonia (n = 45) (shred sign and C profile)	**(n = 3)**		**(n = 42)**						
-ve	2	57.1	3	14.3	85.71	57.14	90.91	44.4	80.95
+ve	1	42.9	38	85.7					
ARDS (n = 12) (bilateral B profile)	**(n = 1)**		**(n = 11)**						
-ve	1	100.0	1	9.0	92.31	100.0	100.0	50.0	92.86
+ve	0	0.0	10	90.3					
Pneumothorax (n = 4) (absent lung sliding and barcode sign)	**(n = 1)**		**(n = 3)**						
-ve	0	0.0	0	0.0	100.0	0.0	50.0	-	50.0
+ve	3	100.0	3	100.0					
Plural effusion (n = 13)	**(n = 0)**		**(n = 13)**						
-ve	0	0.0	1	9.1	90.91	-	100.0	0.0	90.91
+ve	0	0.0	12	90.9					
Acute bronchiolitis (n = 11)	**(n = 2)**		**(n = 9)**						
-ve	1	50.0	1	11.0	90.0	66.67	90.0	66.67	84.62
+ve	1	50.0	8	89.0					
No lung pathology (n = 35)	**(n = 4)**		**(n = 31)**						
-ve	3	83.3	2	6.5	89.47	83.33	94.44	71.43	88.0
+ve	1	6.7	9	93.5					
Total sample (n=120)	**(n = 11)**		**(n = 109)**						
-ve	12	66.7	11	10.8	89.22	66.67	93.81	52.17	85.83
+ve	6	33.3	91	89.2					

LUS: lung ultrasound, NPV: Negative predi

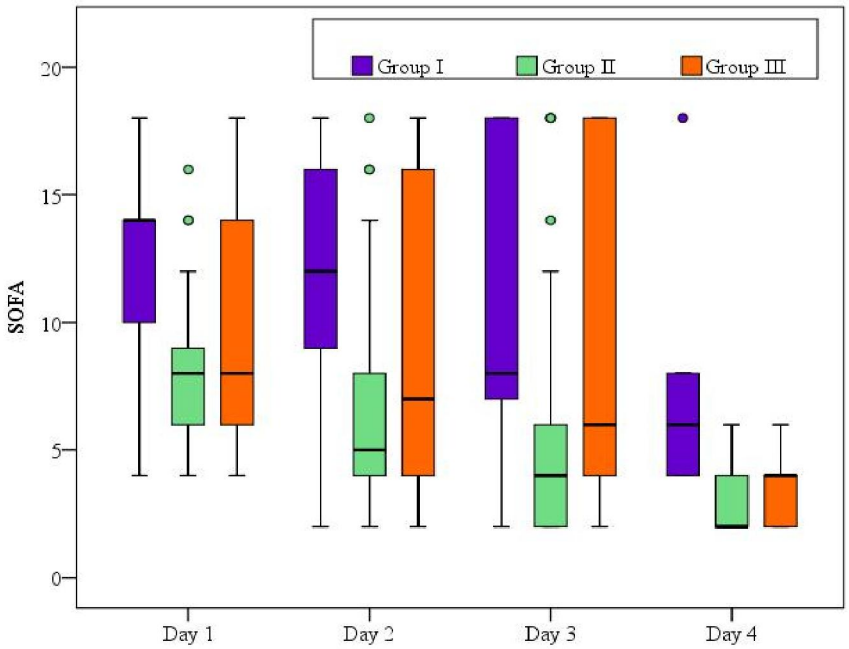

Figure (1): Comparison of Sequential Organ Failure Assessment (SOFA) Score among the Studied Groups

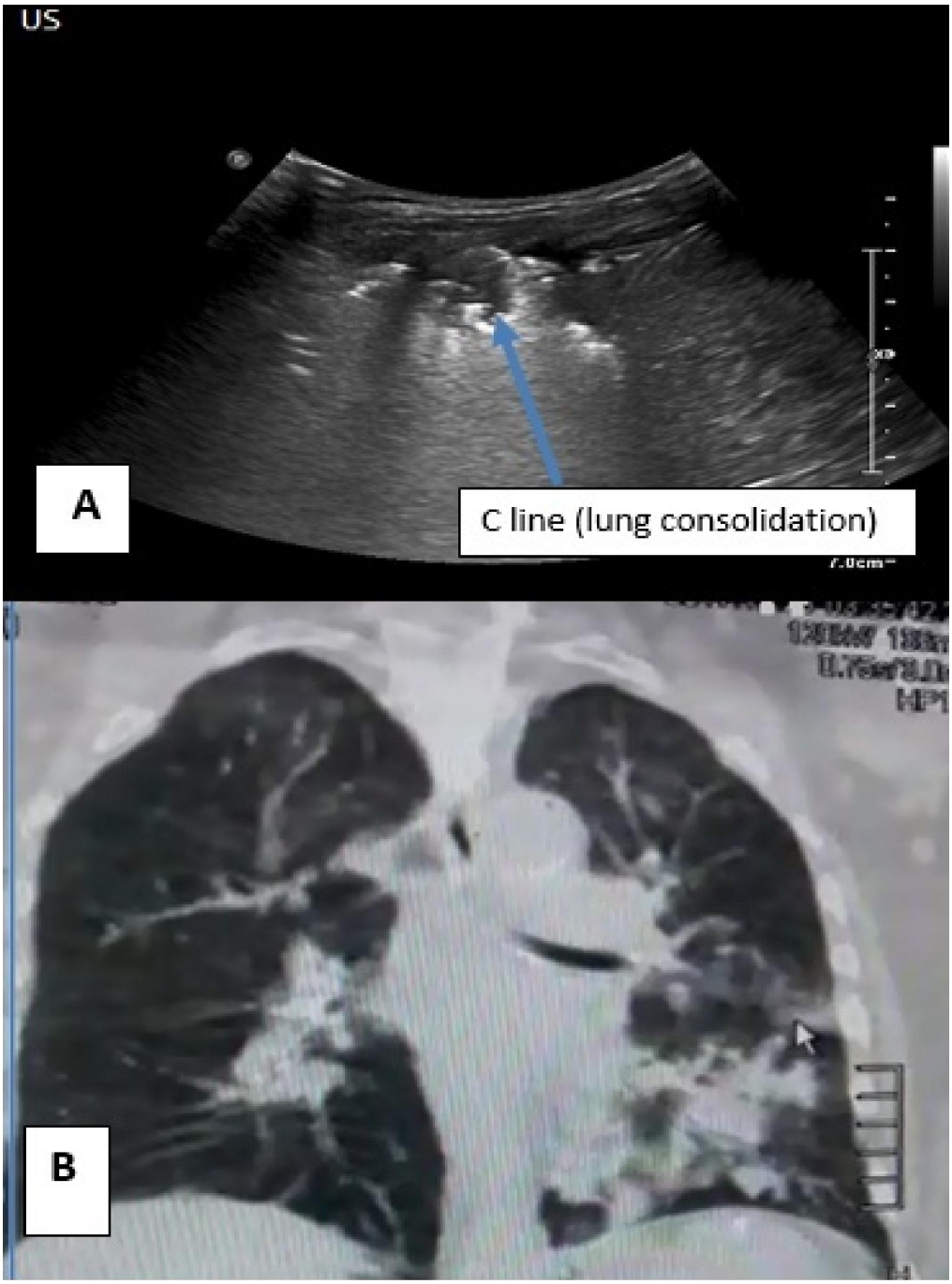

Figure (2): Bronchopneumonia (C line)

A): Pulmonary ultrasound of the patient showing alveolar consolidation with frank tissue pattern arising from the pleural line with highly irregular shredded border

B): CT chest coronal view showing consolidation in lower lobe of the left lung and the middle lobe of the right lung indicating pneumonia

4. Discussion

The aim of PICU is to encourage early intervention and quality care with the goal of achieving good results and improved prognosis[12].

LUS is a valuable screening and monitoring device that could become part of doctors' basic knowledge of the critically ill patient in the future [13].

LUS has developed significantly over the last decade as it is useful in diagnosing patients with acute respiratory failure, circulatory shock, or cardiac arrest. In fact, lung aeration can be measured at bedside and used in patients on MV to guide PEEP setting, to evaluate the efficacy of treatments, to monitor the evolution of the respiratory disorder, and to help the weaning process. Finally, LUS can be used for early detection and management of respiratory complications under MV, such as pneumothorax, ventilator-associated pneumonia, atelectasis and pleural effusions [13].

The primary goal of the present study was to introduce the rapid diagnostic action of LUS in PICU as a perfect tool to detect causes of acute respiratory problems and find rapid solutions for any acute chest problems with avoiding time waste and avoid recurrent exposure to radiation.

The present study showed that there was good agreement between LUS and CXR and CT chest in the studied groups. This was in accordance with Caiulo et al. [14] as they proved that LUS is a simple and reliable imaging tool, not inferior to CXR in identifying pleuro-pulmonary alterations in children with suspected pneumonia.

In the present study, LUS showed 89.22% sensitivity and66.67%specificity, while CXR showed 56.86% sensitivity and 72.22% specificity and chest CT showed 93.20%sensitivity and 44.44 %specificity.

In the present study, as compared to *chest CT in 80 cases*; LUS showed 94.59% sensitivity, 33.33% specificity, which in comparison to CXR 75.68% sensitivity, 83.33% specificity.

In the present study we found that *LUS* can diagnose *bronchopneumonia* with high accuracy by characteristics ultrasonographic signs of bronchopneumonia as (thick irregular pleural lines, air bronchograms, shred sign, lung consolidation and hepatization) C profile [Figure (2)]. Bronchopneumonia was diagnosed in 21 cases (52%) in group I and 24 cases (57.5%) in group II.

Is the present study, LUS showed 85.71% sensitivity, 57.14% specificity, while CXR showed 51.43%sensitivity, 71.43% specificity and chest CT showed 92.09%sensitivity, and 50%specificity?

This was in accordance with the meta-analysis done by *Hu et al.* [15] which showed that LUS for pneumonia diagnosis were as follows: sensitivity 97%, specificity 94%, PPV 15.62% NPV 0.03%. Also, *Reali et al.* [16]. who stated that LUS was accurate tool for the diagnosis of CAP in hospitalized children.

This was in agreement with *Alzahrani et al.* [17] systematic review and meta-analysis which confirmed that LUS is an accurate tool for the diagnosis of pneumonia considering being easy, readily availability, low cost, and free from radiological hazards, it can be considered as important diagnostic strategy in this condition. *Moreover Orso et al*. [18] meta-analysis found that LUS used for pneumonia diagnosis sensitivity and specificity were respectively 92%, and 93% and they concluded that LU was found to be a good tool in diagnosing CAP.

Regarding diagnosis of *pleural effusion*, sensitivity was higher with LUS then CT and CXR had equal sensitivity.

This was in accordance with *Steinmetz et al*., [19] who showed that the medical students' ability to detect the presence or absence of pleural effusion is superior when using LUS as an adjunct to the physical examination than when using the physical examination alone.

In this study regarding pneumothorax diagnosis, sensitivity and specificity were 100%, 0.0%, 50.0%, 50.0%, and CXR showed 66.67%, 100%, 100%, 50.0%, 75.0%, while CT chest 33.33%, 100%, 0%, 33.3% respectively, this could be explained by very early detection of pneumothorax by LUS.

This was in accordance with Husain et al., [20]who stated that LUS for detection of pneumothorax as a well-established modality in the acute care setting in the blunt or penetrating chest trauma patient, where the identification of a pneumothorax can prevent life-threatening consequences. Also, Cattarossi et al.,[21] demonstrated that LUS had optimal sensitivity and specificity in diagnosing Pneumothorax.

On the contrary Schroeder et al.,[22] had a different opinion after doing routine LUS in patients following lung transplantation, they noticed that it presented differently from what was expected, in one patient whose LUS did not show any movement of the pleural line (i. e., absence of lung sliding and B-lines on B-mode (not shown) as well as absence of the sea shore sign and lung pulse on M-mode on the right side of the chest, thus suggesting unilateral pneumothorax. The same day CT scan ruled out PTX on the right hemi-thorax. However, it did reveal a small anterior PTX on the left hemi-thorax.

Regarding diagnosis of ARDS, the higher sensitivity was for LUS then CXR then CT and the accuracy was higher in LUS then CXR then CT. The present study depended on presence of confluent B lines more than 3 in each lung zone to diagnose increased lung fluids which was followed up and accompanied with history and clinical examination we could diagnose ARDS.

This was in accordance with Riviello et al.[23]who stated that in Kigali modification of Berlin definition of ARDS, the use of LUS is very important in diagnosis of ARDS as the goal of the Kigali modification was to avoid the underestimation of

ARDS incidence. The main changes in Kigali modification of Berlin definition were due to the low availability of MV and ICU beds which led to "eliminate" the need of positive pressure ventilation in the Kigali modification and the scarcity of arterial blood gases and radiographs resulted in the use of P_aO_2/FiO_2 and LUS, respectively.

As regards to acute bronchiolitis, the present study showed that regarding sensitivity, Specificity and accuracy the higher was for LU then CXR.LU results were; sensitivity, specificity, PPV, NPV, and accuracy were respectively 90.0 %, 66.67 %, 90.0 %, 66.67 %, 84.62 %, while CXR sensitivity, specificity, PPV, NPV, accuracy was respectively 66.40%, 33.33%, 45.33%, 33.33%, 53.34%. CT was not done for cases diagnosed as acute bronchiolitis.

This was in accordance with Basile et al. [24] who concluded that LUS strictly correlated with the clinical evaluations in infants with bronchiolitis and permit the identification of infants who are in need of supplementary oxygen with high specificity. Scans of the posterior area are more indicative in ascertaining the severity of bronchiolitis. Taveira et al., [25] also concluded that the use of LUS to detect the number of pathological intercostal spaces correlated significantly with length of stay. Zoido et al., [26] found that there is positive correlation between early LUS findings with the severity of acute bronchiolitis and with the clinical progression. Furthermore Ramos-Fernández et al., [27] used LUS to estimate the severity of acute bronchiolitis regarding the need for PICU admission.

Which was in agreement with Elmahalawy et al., [28] who found that LUS showed a sensitivity 93%, specificity of 95%, PPV 98% and NPV 87% regarding pneumonia diagnosis while in diagnosing pleural effusion, LUS showed a sensitivity 94%, specificity 96%, PPV 97% and NPV 90% and also when diagnosing pulmonary edema, LUS showed a sensitivity 93%, specificity 93%, PPV 62% and NPV 99% while in diagnosing pneumothorax, the LUS sensitivity was 96%, specificity was 98%, PPV was 93% and NPV was 99%, so they concluded that the results and advantages of LUS make it a suitable diagnostic modality for evaluating lung and pleural pathologies in the ICU that will have the upper hand over CXR and chest CT in the following decades.

Furthermore Dexheimer Neto et al.,[29] concluded that, LUS accuracy was significantly higher than CXR (84% vs. 43%) when evaluating patients with atelectasis, pneumothorax, pneumonia, or acute respiratory distress syndrome.

From this study, it is recommended to introduce LUS as a corner stone in PICU. Get the benefits from LUS due to its non-invasiveness, and capacity to detect increases in extravascular lung water, might be useful in better managing postoperative patients and guide early therapeutic interventions.

There were difficulties like: special experience is needed as regard to physicians dealing with LUS, for obese patient's visualization of lung parenchyma could be difficult and it is a single centered study.

Conclusion:

LUS was superior to CXR and slightly inferior to CT chest in diagnosing acute chest disease but the hazards of mobilization of critically ill patients and of radiation exposure and time-consuming make LUS is the best diagnostic tool in emergency.

Conflicts of interest: Nil.

References:

1. Schulte-Baukloh H, Knispel H, Michael T. Botulinum-A toxin in the treatment of neurogenic bladder in children. Pediatrics. 2002;110:420-1.
2. Thomas KE, Owens CM, Britto J, Nadel S, Habibi P, Nicholson R. Efficacy of chest CT in a pediatric ICU: a prospective study. Chest. 2000;117:1697-705.
3. Gargani L, Volpicelli G. How I do it: lung ultrasound. Cardiovascular ultrasound. 2014;12:25.
4. Volpicelli G, Frascisco M. Lung ultrasound in the evaluation of patients with pleuritic pain in the emergency department. J Emerg Med. 2008;34:179-86.
5. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, et al. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med. 2012;38:577-91.
6. Vincent JL, Ince C, Bakker J. Clinical review: Circulatory shock--an update: a tribute to Professor Max Harry Weil. Crit Care. 2012;16:239.
7. Curley MA, Moloney-Harmon PA. Critical care nursing of infants and children. Miscellaneous Papers. 2001:4.
8. Zilberberg MD, Shorr AF. Ventilator-associated pneumonia: the clinical pulmonary infection score as a surrogate for diagnostics and outcome. Clin Infect Dis. 2010;51 Suppl 1:S131-5.
9. Ferreira FL, Bota DP, Bross A, Mélot C, Vincent J-L. Serial evaluation of the SOFA score to predict outcome in critically ill patients. Jama. 2001;286:1754-8.
10. Via G, Storti E, Gulati G, Neri L, Mojoli F, Braschi A. Lung ultrasound in the ICU: from diagnostic instrument to respiratory monitoring tool. Minerva Anestesiol. 2012;78:1282-96.

11. Wunsch H, Mapstone J. High-frequency ventilation versus conventional ventilation for the treatment of acute lung injury and acute respiratory distress syndrome: a systematic review and cochrane analysis. Anesth Analg. 2005;100:1765-72.
12. Jain S, Bhalke S, Srivastava A. A study of morbidity pattern in PICU at Tertiary Care Center.
13. Mojoli F, Bouhemad B, Mongodi S, Lichtenstein D. Lung Ultrasound for Critically Ill Patients. Am J Respir Crit Care Med. 2019;199:701-14.
14. Caiulo VA, Gargani L, Caiulo S, Fisicaro A, Moramarco F, Latini G, et al. Lung ultrasound characteristics of community-acquired pneumonia in hospitalized children. Pediatr Pulmonol. 2013;48:280-7.
15. Hu QJ, Shen YC, Jia LQ, Guo SJ, Long HY, Pang CS, et al. Diagnostic performance of lung ultrasound in the diagnosis of pneumonia: a bivariate meta-analysis. Int J Clin Exp Med. 2014;7:115-21.
16. Reali F, Sferrazza Papa GF, Carlucci P, Fracasso P, Di Marco F, Mandelli M, et al. Can lung ultrasound replace chest radiography for the diagnosis of pneumonia in hospitalized children? Respiration. 2014;88:112-5.
17. Alzahrani SA, Al-Salamah MA, Al-Madani WH, Elbarbary MA. Systematic review and meta-analysis for the use of ultrasound versus radiology in diagnosing of pneumonia. Crit Ultrasound J. 2017;9:6.
18. Orso D, Guglielmo N, Copetti R. Lung ultrasound in diagnosing pneumonia in the emergency department: a systematic review and meta-analysis. Eur J Emerg Med. 2018;25:312-21.
19. Steinmetz P, Oleskevich S, Dyachenko A, McCusker J, Lewis J. Accuracy of Medical Students in Detecting Pleural Effusion Using Lung Ultrasound as an Adjunct to the Physical Examination. J Ultrasound Med. 2018;37:2545-52.
20. Husain LF, Hagopian L, Wayman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. J Emerg Trauma Shock. 2012;5:76-81.
21. Cattarossi L, Copetti R, Brusa G, Pintaldi S. Lung Ultrasound Diagnostic Accuracy in Neonatal Pneumothorax. Can Respir J. 2016;2016:6515069.
22. Schroeder I, Weig T, Frey L, Scheiermann P. Lung Ultrasound for the Detection of Pneumothorax Might Be Misleading in Patients Following Lung Transplantation. Ultrasound Int Open. 2017;3:E128-e9.
23. Riviello ED, Kiviri W, Twagirumugabe T, Mueller A, Banner-Goodspeed VM, Officer L, et al. Hospital Incidence and Outcomes of the Acute Respiratory Distress Syndrome Using the Kigali Modification of the Berlin Definition. Am J Respir Crit Care Med. 2016;193:52-9.
24. Basile V, Di Mauro A, Scalini E, Comes P, Lofu I, Mostert M, et al. Lung ultrasound: a useful tool in diagnosis and management of bronchiolitis. BMC Pediatr. 2015;15:63.
25. Taveira M, Yousef N, Miatello J, Roy C, Claude C, Boutillier B, et al. [Can a simple lung ultrasound score predict length of ventilation for infants with severe acute viral bronchiolitis?]. Arch Pediatr. 2018;25:112-7.
26. Zoido Garrote E, Garcia Aparicio C, Camila Torrez Villarroel C, Pedro Vega Garcia A, Muniz Fontan M, Oulego Erroz I. [Usefulness of early lung ultrasound in acute mild-moderate acute bronchiolitis. A pilot study]. An Pediatr (Barc). 2019;90:10-8.
27. Ramos-Fernandez JM, Pinero-Dominguez P, Abollo-Lopez P, Moreno-Perez D, Cordon-Martinez AM, Milano-Manso G, et al. [Validation study of an acute bronchiolitis severity scale to determine admission to a Paediatric Intensive Care Unit]. An Pediatr (Barc). 2018;89:104-10.
28. Elmahalawy II, Doha NM, Ebeid OM, Abdel-Hady MA, Saied O. Role of thoracic ultrasound in diagnosis of pulmonary and pleural diseases in critically ill patients. Egyptian Journal of Chest Diseases and Tuberculosis. 2017;66:261-6.
29. Dexheimer Neto FL, Andrade JM, Raupp AC, Townsend Rda S, Beltrami FG, Brisson H, et al. Diagnostic accuracy of the Bedside Lung Ultrasound in Emergency protocol for the diagnosis of acute respiratory failure in spontaneously breathing patients. J Bras Pneumol. 2015;41:58-64.

11/22/2019