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Comparison of Efficacy of Lung Ultrasound and Chest X-Ray in Diagnosing Pulmonary Edema and Pleural Effusion in ICU Patients: A Single Centre, Prospective, Observational Study

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Abstract

Background and Aims: While chest X-ray (CXR) has been a conventional tool in intensive care units (ICUs) to identify lung pathologies, computed tomography (CT) scan remains the gold standard. Use of lung ultrasound (LUS) in resource-rich ICUs is still under investigation. The present study compares the utility of LUS to that of CXR in identifying pulmonary edema and pleural effusion in ICU patients. In addition, consolidation and pneumothorax were analyzed as secondary outcome measures. Material and Methods: This is a prospective, single centric, observational study. Patients admitted in ICU were examined for lung pathologies, using LUS by a trained intensivist; and CXR done within 4 hours of each other. The final diagnosis was ascertained by an independent senior radiologist, based on the complete medical chart including clinical findings and the results of thoracic CT, if available. The results were compared and analyzed. Results: Sensitivity, specificity and diagnostic accuracy of LUS was 95%, 94.4%, 94.67% for pleural effusion; and 98.33%, 97.78%, 98.00% for pulmonary edema respectively. Corresponding values with CXR were 48.33%, 76.67%, 65.33% for pleural effusion; and 36.67%, 82.22% and 64.00% for pulmonary edema respectively. Sensitivity, specificity and diagnostic accuracy of LUS was 91.30%, 96.85%, 96.00% for consolidation; and 100.00%, 79.02%, 80.00% for pneumothorax respectively. Corresponding values with CXR were 60.87%, 81.10%, 78.00% for consolidation; and 71.3%, 97.20%, 96.00% for pneumothorax respectively. Conclusion: LUS

has better diagnostic accuracy in diagnosis of pleural effusion and pulmonary edema when compared with CXR and is thus recommended as an effective alternative for diagnosis of these conditions in acute care settings. Our study recommends that a thoracic CT scan can be avoided in most of such cases.

Keywords

Lung Ultrasound (LUS), Chest X Ray (CXR), Pleural Effusion, Pulmonaryedema, Consolidation, Pneumothorax

1. Introduction

Imaging has contributed immensely to the understanding of lung diseases in intensive care unit (ICU) patients, and currently serves as a vital tool in diagnosing lung pathologies, monitor their course, and guide the treating physicians towards apt clinical management. Although chest X ray (CXR) has conventionally been a popular imaging tool, its interpretation is influenced by the level of technical expertise of the radiologist and high inter-observer variability as well. Portable chest radiography is used as a bedside tool with relatively quicker access to results, but usually hindered by inadequate or improper patient positioning, the necessity for anteroposterior imaging and exposing patients to harmful radiations [1]. Computed tomography (CT) scan is being used as a more efficacious alternative, but has significant drawbacks too, such as issue of availability, cost, delay in treatment (while waiting for report), renal issues, anaphylactic shock, and radiation exposure, besides the logistics involved in intra-hospital shifting of patients [2]. Lung ultrasound (LUS) is a real time imaging modality and has a pivotal role as a handy and constantly evolving technique, which can be used as a bedside tool for chest imaging in critical care setting. It is already popular as a point of care test which is accurate, reproducible, flexible to use, easy to perform and safe (no radiation) when compared to that of chest radiograph [3] [4].

While the utility of LUS in the emergency setting is undebatable [5] [6], its potential role in the more complex and resource-rich intensive care environment is still under investigation. The aim of this study is to compare CXR and LUS to identify pulmonary edema and pleural effusion in a multidisciplinary ICU of a tertiary care hospital. While abundant literature is available on this subject, previous studies have smaller sample size and taken CT chest as a definitive diagnostic tool in their studies [3] [7] [8]. A prospective study with significant sample size, including well known pathologies without the need for CT scan as a "gold standard", is lacking. Rather, an expert radiologist's opinion has been taken as comparative reference, in order to establish more definitive diagnostic role of LUS and negate the need of routine CT chest scanning.

Primary objective is to compare sensitivity and specificity of CXR and LUS in diagnosing pleural effusion and pulmonary edema taking diagnosis of an inde-

pendent senior radiologist as reference. Diagnosis of pneumothorax and consolidation were taken as secondary objectives, considering their low prevalence in our ICU.

2. Material and Methods

This is a prospective, single centric, observational study, conducted in the department of anaesthesiology at our centre; a tertiary care, referral and teaching hospital from Aug 2021 till July 2022. The project was cleared by Institutional Ethics Committee of the institute and registered with Clinical Trials Registry-India (CTRI/2021//07/035282).

All patients above the age of 18 years who were admitted to the ICU of our hospital with any suspected or confirmed pulmonary pathology, or developed the same during the course of hospitalization were included in the study. Patients in whom consent could not be obtained, CXR couldn't be done within 4 hrs of LUS and in instances where radiologist was not able to form a definitive opinion of the diagnosis; were excluded from the study.

Consent for enrolment was obtained from each patient, or from the next of kin if the patient was incapable of giving consent; *i.e.* on mechanical ventilation (MV), or had altered sensorium. A standard proforma including the patient's baseline health status, reason for ICU admission, the patient's particulars (name, age, sex, identification number), presence of primary lung disorder, co-morbid conditions and status of ventilation (if on MV)was maintained. Bedside CXR and bedside LUS was done on the same day; within 4 hours of each other [7]. GE Vivid T8 machine and 5 - 9 MHz, curvilinear probe was used for visualization of lung fields. The scan was performed by an intensivist trained in LUS for more than 2 years, and was not part of the treating team. He was unaware of any other patient details (including CXR findings) till ultrasound was done. For LUS, each hemithorax was divided into three regions. Anterior region was defined by clavicle, parasternal, anterior axillary line and diaphragm; lateral region was defined by the anterior and posterior axillary lines; and posterior region was defined by the posterior axillary and the paravertebral lines. Each region was further divided into superior and inferior quadrants [7] [8]. Hence, a total of 12 areas were scanned for each patient. Supraclavicular space was used to scan the apex of lungs. Presence of anechoic or echoic collection in the dependent areas, fluctuating with respiration was taken as evidence of a pleural effusion. A volume of more than 10 ml was considered significant and included in the diagnosis. Comet tail shaped B-line artefacts (at least three per field), were used to define pulmonary edema. Consolidation was reported when areas of isoechoic tissue-like structure (*i.e.* liver), and air brochograms were seen. When the A-line sign (only A-lines visible) and stratosphere sign (complete abolition of lung sliding) were together seen, pneumothorax was diagnosed.

The final diagnosis was done by an independent senior expert faculty radiologist (with a post graduate degree in radiology, and more than 10 years of expe-

rience in clinical radiology practice), after correlation of LUS images/video recorded on machine by the intensivist with the findings on CXR image, assessment of complete medical charts (including clinical findings) and the results of thoracic CT, if available (12 cases). This analysis was done within 12 hours of patient arrival. The radiologist was unaware of the findings recorded by the intensivist. Positive findings of the bedside LUS and CXR were compared to that of the final diagnosis.

Assuming alpha as 5% and power of 80% with sensitivity and specificity obtained from previous studies [7] of the two modalities for pleural effusion and pulmonary edema; minimum required sample size calculated, was 58 positives for pulmonary edema and 41 positives for pleural effusion. All the data generated was collated in an excel data sheet and analyzed using SPSS ver. 23 software. Numerical variables were expressed as mean +/− standard deviation (SD) or median (range) as per data distribution pattern. The categorical variables were presented as absolute values or percentage/proportions. Two-sample t-test (student's t) was used for analyzing the quantitative variables with normal distribution. Chi (χ^2) square test was used where distribution was skewed and for categorical variables. For all tests of significance, p value < 0.05 was considered statistically significant.

3. Results

192 patients were assessed for eligibility for the study; out of which eight were excluded (three patients died before CXR could be done, in two patients the radiologist couldn't give a definitive diagnosis, and consent was refused in three patients). Of the remaining 184 enrolled patients, 150 were included in the study (34 were not further analyzed as none of the four pathologies was found either by the intensivist or by the radiologist). 60 patients with pulmonary effusion and edema each, 23 patients with consolidation/pneumonia and seven patients with pneumothorax were included in the study (**Figure 1**).

There were 93 male and 57 female (62% vs 38%) participants. Mean age of the participants was 48.2 ± 11.5 years, with comparable distribution among both genders. Age wise and weight wise distribution of the patients is noted in **Table 1**. Hypertension was the most prevalent comorbidity in the participants, followed by diabetes mellitus, ischemic heart disease, pulmonary kochs and malignancy in that order (**Figure 2**).

Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for each of the pathologies with LUS and CXR were compared and demonstrated in the bar diagram for easy comparison (**Figure 3**). Along with these values; the positive likelihood ratio, negative likelihood ratio, disease prevalence and their 95% confidence interval (CI) values were calculated to compare their diagnostic accuracy (**Table 2**). LUS was found to have better diagnostic accuracy than CXR in all the lung pathologies under study; except pneumothorax.

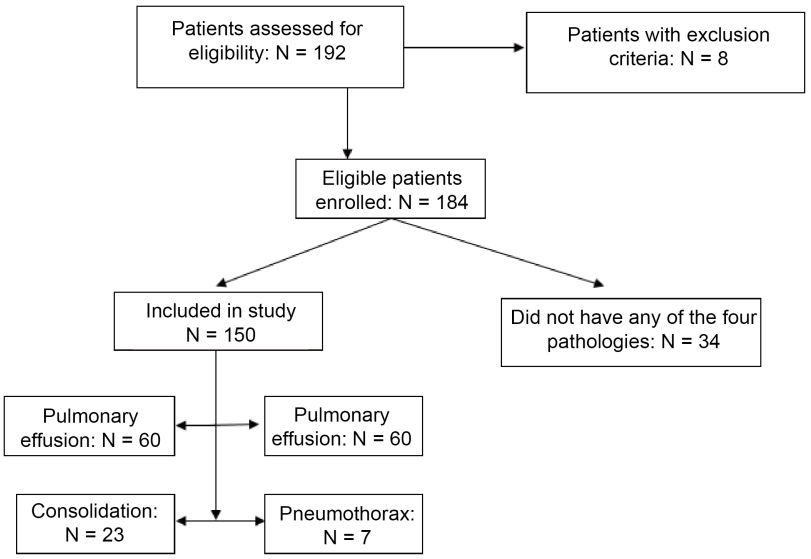

Figure 1. Flow of participants in the study.

Table 1. Age wise and weight wise distribution of participants: Male vs Female.

Age (years)	F	M	Total	Weight (kg)	F	M	Grand Total
21 - 30	4	3	7	**41 - 51**	1	4	5
31 - 40	21	11	32	**51 - 61**	15	27	42
41 - 50	16	32	48	**61 - 71**	34	36	70
51 - 60	12	32	44	**71 - 81**	7	24	31
61 - 70	4	11	15	**81 - 91**	0	2	2
71 - 80	0	3	3				
81 - 90	0	1	1				
Grand Total	57	93	150		57	93	150
Mean ± SD (kg)	48.2 ± 11.5				65.3 ± 7.7		
p-value (X^2)	0.008				0.07		

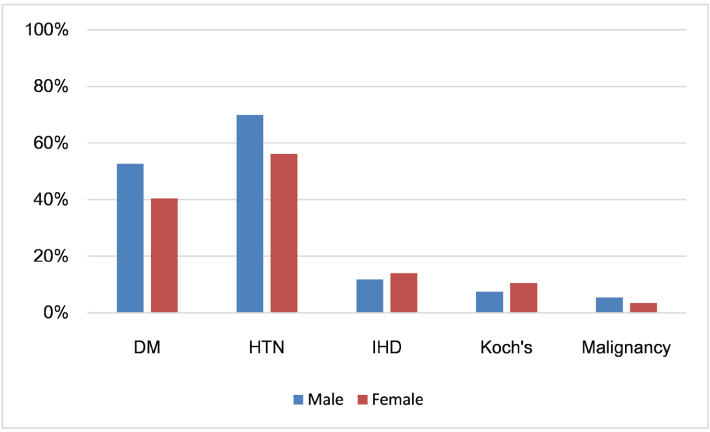

Figure 2. Comorbidities in patients (male vs female).

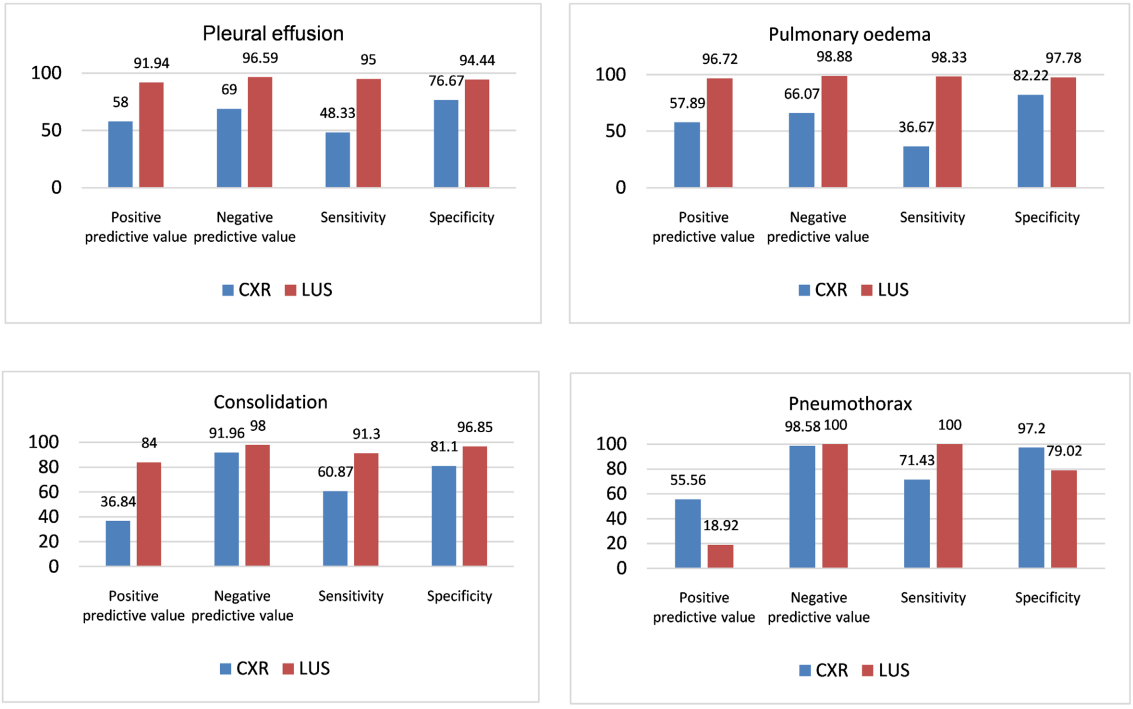

Figure 3. Comparison of lung pathologies (sensitivity, specificity, PPV, NPV): CXR vs LUS.

Table 2. Diagnostic accuracy {%, (95%CI)} of lung pathologies: CXR vs LUS.

	CXR	LUS
Pleural effusion	65.33 (57.14 - 72.91)	94.67 (89.76 - 97.67)
Pulmonary edema	64.00 (55.77 - 71.67)	98.00 (94.27 - 99.59)
Consolidation	78.00 (70.51 - 84.35)	96.00 (91.5 - 98.52)
Pneumothorax	96.00 (91.5 - 98.52)	80.00 (72.7 - 86.08)

4. Discussion

Imaging of the lung has been performed in critical care settings by bedside X-ray imaging or occasionally with the help of CT scan. Bedside CXR is usually inadequate and of poor quality due to multitude of reasons such as incorrect positioning, multiple layers of clothing and inability to remove parts of machineries attached to the patient. CT scans remain the gold standard of imaging. However, the patient needs to be transported to the CT suite which is difficult in most scenarios. LUS has emerged as an economical and viable option in acute care settings in diagnosis of pulmonary conditions.

The present study was done to assess the viability of LUS in detecting lung pathologies in acute care settings and determine its sensitivity and specificity patterns. Xirouchaki *et al.* compared the diagnostic performance of LUS and bedside CXR for the detection of various pathologic abnormalities in unselected critically ill patients, who were on MV using thoracic CT scan as a gold standard [7]. They derived lower values of sensitivity, specificity and diagnostic accuracy

for CXR (65%, 81%, 69% for pleural effusion; 38%, 89%, 49% for consolidation; 0%, 99%, 89% for pneumothorax respectively) and higher values for LUS (corresponding values were 100%, 100%, 100% for pleural effusion; 100%, 78%, 95% for consolidation; 75%, 93%, 92% for pneumothorax respectively) than our study. However, the authors have themselves admitted that besides having a smaller sample size (n = 42) in their study, patients were enrolled when a thoracic CTs can was already done and no other selection criteria were applied. Hence, a variety of conditions (*i.e.*, obesity, chest trauma, tissue edema) could have interfered with the results. Hansell *et al*. did a systemic review of seven studies to assess the accuracy of LUS for the diagnosis of pleural effusion, lung consolidation and lung collapse when compared with CXR and lung auscultation, with CT scan as reference standard in patients admitted in the adult ICU [9]. Five studies (with 253 participants) were included in the meta-analysis. It was found that LUS had a pooled sensitivity of 92% and 91% in the diagnosis of consolidation and pleural effusion, respectively; and pooled specificity of 92% for both pathologies. CXR had a pooled sensitivity of 53% and 42% and a pooled specificity of 78% and 81% in the diagnosis of consolidation and pleural effusion, respectively. The results of this meta-analysis are quite similar to our study. Only Agmy *et al*. has studied more patients (200 patients of consolidation, pleural effusion) than present study [10]. The authors noted that sensitivity, specificity, and diagnostic accuracy of CXR were 55%, 84%, and 65% for pleural effusion; 40%, 96%, and 88% for pneumothorax; and 40, 85, and 50% for consolidation respectively. The corresponding values for LUS were 100, 100, and 100% for pleural effusion; 100%, 100%, and 100% for pneumothorax; and 100%, 87%, and 95% for consolidation respectively. However, in contrast to our study, all the patients in their research were on MV, and they did a modified LUS (six points) protocol. Besides, they used CT scan as a gold standard in diagnosis.

Danish *et al*. (90 patients)while comparing the performance of LUS with CXR and CT scan established that LUS imaging protocol yielded greater sensitivity and diagnostic accuracy than CXR, as well as had >85% accuracy than CT thorax, in detecting common lung pathologies [11]. Lichtenstein *et al*., way back in 2004 analyzed 32 patients of ARDS and calculated almost equivalent values to our study of diagnostic accuracy (93% for pleural effusion, 97% for alveolar consolidation) [12]. Rocco *et al*. (15 patients of chest trauma) [8], Negm *et al*. (total 256 patients, although smaller number of 56 patients with pleural effusion and no cases of pulmonary edema) [13] and Wang *et al*. (78 patients, on MV) [14] have studied lesser number of patients; with similar results as in our study, nevertheless. This study is thus the largest prospective study for pleural effusion and pulmonary edema, without CT scan as a gold standard for diagnosis in a heterogenous group of patients. Our study had a lower diagnostic accuracy for pneumothorax (80%) than most of the cited studies. On analysis it was found that this is primarily because of very small sample size (n = 7); owing to low prevalence of disease in our ICU [15]. Besides, diagnosis of pneumothorax was not a primary objective in our study.

However, our study has certain limitations. CT scan was not used mandatorily for the final diagnosis in our study; and a thorough review of the patient's status by an expert radiologist was taken as a reference point for comparison. This is a unique study design, has not been adapted in previous studies. This method may have introduced some observer related oversight in diagnosis; but its effect is expected to be minimal on overall results, as the radiologist was looking at a comprehensive data (including history, examination, hematological and biochemical investigations and interpretation of CXR and LUS findings) of the patient rather than any individual diagnostic tool (such as CT scan).

A bedside point of care test with high diagnostic accuracy for patients with suspected lung pathology, which is conveniently reproducible, easily performed, rapid, cost effective and hazard free is required to be established as a gold standard to avoid the hazards of intra hospital transfer and reduce radiation hazard as well. The incidence of overall, as well as critical, adverse events during such transfers has been reported to be as high as 78% and 22%, respectively [16]. Although portable CT scanners are available for bedside scan, it is not widely available and is mostly used for neuroimaging [17]. Upto one-third of CXR images remain of suboptimal quality, especially in ICU setting [18] [19]. Emphasis on bedside LUS and to consider it a vital tool in diagnosis of lung pathologies is therefore justified.

5. Conclusion

With our robust study design, we have been able to conclude definitely, that in ICU patients, LUS has significantly better diagnostic accuracy than CXR in diagnosis of pleural effusion and pulmonary edema. CT scan can be avoided in most of the cases considering its limitations and hazards; and use of LUS should be encouraged. In diagnostic dilemmas, a review of LUS along with relevant medical records of the patient, by an expert radiologist may prove equally useful as an alternative to CT scan, if the CT scan is not feasible. For consolidation and pneumothorax, we recommend prospective studies of similar design with higher sample size to pronounce statistical significance.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Inglis, A.J., Nalos, M., Sue, K.H., Hruby, J., Campbell, D.M., Braham, R.M., *et al*. (2016) Bedside Lung Ultrasound, Mobile Radiography and Physical Examination: Acomparative Analysis of Diagnostic Tools in the Critically Ill. *Critical Care and Resuscitation*, **18**, 116-124. https://doi.org/10.1016/S1441-2772(23)01001-3

[2] Power, S.P., Moloney, F., Twomey, M., James, K., O'Connor, O.J. and Maher, M.M. (2016) Computed Tomography and Patient Risk: Facts, Perceptions and Uncertainties. *World Journal of Radiology*, **8**, 902-915. https://doi.org/10.4329/wjr.v8.i12.902

[3] Lichtenstein, D. (2014) Lung Ultrasound in the Critically Ill. *Current Opinion in Critical Care*, **20**, 315-322. https://doi.org/10.1097/MCC.0000000000000096

[4] Martindale, J.L., Noble, V.E. and Liteplo, A. (2013) Diagnosing Pulmonary Edema: Lung Ultrasound versus Chest Radiography. *European Journal of Emergency Medicine*, **20**, 356-360. https://doi.org/10.1097/MEJ.0b013e32835c2b88

[5] Volpicelli, G., Cardinale, L., Berchialla, P., Mussa, A., Bar, F. and Frascisco, M.F. (2012) A Comparison of Different Diagnostic Tests in the Bedside Evaluation of Pleuritic Pain in the ED. *The American Journal of Emergency Medicine*, **30**, 317-324. https://doi.org/10.1016/j.ajem.2010.11.035

[6] Cibinel, G.A., Casoli, G., Elia, F., Padoan, M., Pivetta, E., Lupia, E., *et al*. (2012) Diagnostic Accuracy and Reproducibility of Pleural and Lung Ultrasound in Discriminating Cardiogenic Causes of Acute Dyspnea in the Emergency Department. *Internal and Emergency Medicine*, **7**, 65-70. https://doi.org/10.1007/s11739-011-0709-1

[7] Xirouchaki, N., Magkanas, E., Vaporidi, K., Kondili, E., Plataki, M., Patrianakos, A., *et al*. (2011) Lung Ultrasound in Critically Ill Patients: Comparison with Bedside Chest Radiography. *Intensive Care Medicine*, **37**, 1488-1493. https://doi.org/10.1007/s00134-011-2317-y

[8] Rocco, M., Carbone, I., Morelli, A., Bertoletti, L., Rossi, S., Vitale, M., *et al*. (2008) Diagnostic Accuracy of Bedside Ultrasonography in the ICU: Feasibility of Detecting Pulmonary Effusion and Lung Contusion in Patients on Respiratory Support after Severe Blunt Thoracic Trauma. *Acta Anaesthesiologica Scandinavica*, **52**, 776-784. https://doi.org/10.1111/j.1399-6576.2008.01647.x

[9] Hansell, L., Milross, M., Delaney, A., Tian, D.H. and Ntoumenopoulos, G. (2021) Lung Ultrasound Has Greater Accuracy than Conventional Respiratory Assessment Tools for the Diagnosis of Pleural Effusion, Lung Consolidation and Collapse: A Systematic Review. *Journal of Physiotherapy*, **67**, 41-48. https://doi.org/10.1016/j.jphys.2020.12.002

[10] Agmy, G., Mohamed, S. and Gad, Y. (2014) Transthoracic Chest Ultrasound in Critically Ill Patients: Comparison with Bedside Chest Radiography. *Chest*, **146**, 570A. https://doi.org/10.1378/chest.1969292

[11] Danish, M., Agarwal, A., Goyal, P., Gupta, D., Lal, H., Prasad, R., *et al*. (2019) Diagnostic Performance of 6-Point Lung Ultrasound in ICU Patients: A Comparison with Chest X-Ray and CT Thorax. *Turkish Journal of Anaesthesiology and Reanimation*, **47**, 307-319. https://doi.org/10.5152/TJAR.2019.73603

[12] Lichtenstein, D., Goldstein, I., Mourgeon, E., Cluzel, P., Grenier, P. and Rouby, J.J. (2004) Comparative Diagnostic Performances of Auscultation, Chest Radiography, and Lung Ultrasonography in Acute Respiratory Distress Syndrome. *Anesthesiology*, **100**, 9-15. https://doi.org/10.1097/00000542-200401000-00006

[13] Negm, F.M., Kamela, M.H., Mohammad, O.I., Elsawy, R.E. and Khater, H.M. (2019) The Value of Chest Ultrasonography Applications in the Respiratory ICU.

Egyptian Journal of Bronchology, **13**, 323-327.
https://doi.org/10.4103/ejb.ejb_78_18

[14] Wang, X.T., Liu, D.W., Zhang, H.M., He, H.W., Liu, Y., Chai, W.Z., *et al*. (2012) The Value of Bedside Lung Ultrasound in Emergency-Plus Protocol for the Assessment of Lung Consolidation and Atelectasis in Critical Patients. *Chinese Journal of Internal Medicine*, **51**, 948-951.

[15] Simundic, A.M. (2009) Measures of Diagnostic Accuracy: Basic Definitions. *The Electronic Journal of the International Federation of Clinical Chemistry*, **19**, 203-211.

[16] Jia, L., Wang, H., Gao, Y., Liu, H. and Yu, K. (2016) High Incidence of Adverse Events during Intra-Hospital Transport of Critically Ill Patients and New Related Risk Factors: A Prospective, Multicenter Study in China. *Critical Care*, **20**, Article No. 12. https://doi.org/10.1186/s13054-016-1183-y

[17] Rumboldt, Z., Huda, W. and All, J.W. (2009) Review of Portable CT with Assessment of a Dedicated Head CT Scanner. *American Journal of Neuroradiology*, **30**, 1630-1636. https://doi.org/10.3174/ajnr.A1603

[18] Henschke, C.I., Yankelevitz, D.F., Wand, A., Davis, S.D. and Shiau, M. (1996) Accuracy and Efficacy of Chest Radiography in the Intensive Care Unit. *Radiologic Clinics of North America*, **34**, 21-31.
https://doi.org/10.1016/S0033-8389(22)00664-9

[19] Yu, C.J., Yang, P.C., Chang, D.B. and Luh, K.T. (1992) Diagnostic and Therapeutic Use of Chest Sonography: Value in Critically Ill Patients. *American Journal of Roentgenology*, **159**, 695-701. https://doi.org/10.2214/ajr.159.4.1529829