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Original Article

Comparison of Diagnostic Accuracy of Bedside Thoracic Ultrasonography and Portable Chest Radiography in the Evaluation of Critically Ill Patients at Intensive Care Unit

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Abstract:
Background: Bedside thoracic ultrasound is increasingly used in patient with acute respiratory distress syndrome as it is a better option than bedside CXR. The present study was aimed at to find out and compare the diagnostic accuracy of bedside thoracic ultrasound over bedside thoracic ultrasound. **Methods:** This cross sectional study was conducted on 58 subjects aged 42-76 years in the department of radiology and imaging in collaboration with Department of intensive Care Unit(ICU), BIRDEM from July 2013 to June 2014 to find out and compare the diagnostic accuracy of bedside thoracic ultrasonography and portable chest radiography in mechanically ventilated clinically ill patients using computed tomography (CT) as a gold standard. Four pathologic entities were evaluated by each imaging method. 1. Pleural effusion, 2. collase-consolidation, 3. Pneumothorax, 4. Interstitial syndrome. The examinations were performed first by the investigator himself and subsequently confirmed by radiologist in the department of radiology and imaging, BIRDEM, who did not know the subjects condition to eliminate bias. **Results:** In this study lung ultrasound has a diagnostic accuracy of 79-100% in identifying pneumothorax, consolidation, interstitial syndrome and pleural effusion. **Conclusion:** Bedside thoracic ultrasound may therefore be considered as the first modality of choice than bedside CXR.

Key words: Bedside chest radiography, Thoracic computed tomography (CT), Portable chest radiography.

Introduction:
Imaging of the lung in critically ill patients is performed either by bedside chest radiography or thoracic computed tomography (CT)[1]. 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 a routine basis. In addition difficulty of transportation of critically ill patients to the radiology department combined with the radiation exposure carries a measurable risk. On the other hand, bedside chest X-ray lead to poor-quality X-ray films with low sensitivity[2,3,4]. It has been shown that even under carefully controlled exposure conditions more than 30% of the X-ray films are considered suboptimal [5]. Finally, there is poor correlation between chest X-ray and chest CT findings[6]. Nevertheless, despite these limitations bedside chest X-ray remains the daily reference for lung imaging.
Nowadays bedside thoracic ultrasound is increasingly used in patients managed in intensive care units (ICUs)[7,8,9]. It has been shown in patients with acute respiratory distress syndrome (ARDS) that compared to bedside CXR; thoracic ultrasound has a higher diagnostic accuracy for pleural effusion, collapse-

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consolidation, and interstitial syndrome. Here we will compare the diagnostic performance of thoracic ultrasound and bedside chest X-ray for the detection of several pathologic abnormalities in unselected critically ill patients, using thoracic CT as a gold standard.

Bedside thoracic ultrasonography has several advantages: (1) high sensitivity in detecting pleural lesions and differentiating pleural disease from parenchymal lesions (consolidation, abscess, or tumor), (2) consolidation can be used as a sonographic window to visualize some centrally located lesions more clearly, (3) sonographically guided aspiration biopsy and thoracentesis can be performed accurately and easily, (4) lower cost, (5) it is easily performed at bedside, (6) flexibility and short examination time as compared with compound scans[14-15].

So aim of the present study was to find out and compare the diagnostic accuracy of bedside thoracic ultrasonography and portable chest radiography in clinically ill patients using computed tomography as a gold standard.

Methods:

This cross-sectional study was conducted on 58 subjects aged 42-76 years in the department of Radiology and Imaging in collaboration with Department of Intensive Care Unit (I.C.U), BIRDEM from July 2013 to June 2014. Mechanically ventilated critically ill patients were selected for the study according to inclusion criteria. Patients were enrolled in the study when a thoracic CT scan was ordered by the primary physician. Prior to CT scan a portable chest radiograph was obtained and bedside thoracic ultrasound was performed at I.C.U. Ventilator settings were kept unchanged throughout the study. Four pathologic entities were evaluated by each imaging method: (1) pleural effusion, (2) collapse-consolidation, (3) pneumothorax, and (4) interstitial syndrome.

Each lung region was evaluated and characterized as positive or negative for each abnormality. Findings of ultrasonography and portable chest X-ray were compiled and compared with findings of CT scan. Considering findings of CT scan as gold standard, sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy were calculated using standard formulas.

Findings of the study was calculated and analyzed by standard statistical method and was presented in forms of tables and graphs. Data were expressed as mean ± SD.

Results:

The mean age was 56.38 ± 9.455 years and their age ranged from 42 to 76 years. Maximum numbers of patients were in the age group of 51-60 years (44.8%). Out of 58 patients 44 (76%) were male and rest 14 (24%) were female.

58 patients were examined with different modalities as CXR, LU and Chest CT. 42 findings were identified in CXR, out of which 20 were consolidation, 14 were pleural effusion, 2 were pneumothorax and 6 were interstitial syndrome. Similarly, a total of 57 findings were identified on LU out of which 19 were consolidation, 27 were pleural effusion, 4 were pneumothorax and 7 were interstitial syndrome. A total of 68 findings were identified in Chest CT scan out of which 22 were consolidation,34 were pleural effusion, 5 were pneumothorax and 7 were interstitial syndrome. Here, the number of findings in CT had exceeded the number of cases since some patients had more than one finding i.e. multiple responses were considered (Table I)

Table I: Portable chest radiography (CXR), lung ultrasonography and non contrast chest CT findings in study subjects (n=58)

	Chest radiography	lung ultrasonography	Chest CT
Consolidation	20	19	22
Pleural effusion	14	27	34
pneumothorax	2	4	5
interstitial syndrome	6	7	7
Total findings	42	57	68

Diagnostic characteristics of lung ultrasound in case of consolidation (n=58)

A total of 58 critically ill patients with mechanical ventilation and scheduled for CT scan were selected for the study. The effectiveness of lung ultrasound (LU) to rule in or rule out consolidation was assessed against the gold standard of CT scan. It was found that LU was 86% sensitive to diagnose consolidation correctly while it showed 100% specificity to rule out the condition. The diagnostic accuracy of LU was found to be 95% (Table II).

Table II Sensitivity, specificity, positive and negative predictive values, and diagnostic accuracy of lung ultrasound (LU) for consolidation using CT scan as a gold standard

Pathology	LU	CT+	CT-	Sn[a] (%)	Sp[b] (%)	PPV[c] (%)	NPV[d] (%)	DA[e] (%)
Consolidation	LU+	19	0	86	100	100	92	95
	LU-	3	36					

Lung was characterized as positive (+) or negative (-) for the abnormality by the presence or absence of a single positive region, respectively
TP true positive, *TN* true negative, *FP* false positive, *FN* false negative
[a]Sn=Sensitivity = [TP/(TP + FN)] X 100
[b]Sp=Specificity = [TN/(TN + FP)] X 100
[c]Positive predictive value (PPV) = [TP/(TP + FP)] X 100
[d]Negative predictive value (NPV) = [TN/(TN + FN)] X 100
[e]Diagnostic accuracy (DA) = [(TP+TN)/(TP+TN+FP+FN)] X10

Diagnostic characteristics of chest radiograph in case of consolidation (n=58)
A total of 58 critically ill patients with mechanical ventilation and who were scheduled for CT scan were selected for the study. The effectiveness of chest radiograph (CXR) was assessed against the gold standard of CT scan. It showed 91% sensitivity, 100% specificity and positive predictive value, 95% negative predictive values, and 96% diagnostic accuracy (Table III).

Table III: Sensitivity, specificity, positive and negative predictive values, and diagnostic accuracy of chest radiography (CXR) for consolidation using CT scan as a gold standard.

Pathology	CXR	CT+	CT-	Sn[a] (%)	Sp[b] (%)	PPV[c] (%)	NPV[d] (%)	DA[e] (%)
Consolidation	CXR+	20	0	91	100	100	95	96
	CXR-	2	36					

Lung was characterized as positive (+) or negative (-) for the abnormality by the presence or absence of a single positive region, respectively
TP true positive, *TN* true negative, *FP* false positive, *FN* false negative
[a]Sn=Sensitivity = [TP/(TP + FN)] X 100
[b]Sp=Specificity = [TN/(TN + FP)] X 100
[c]Positive predictive value (PPV) = [TP/(TP + FP)] X 100
[d]Negative predictive value (NPV) = [TN/(TN + FN)] X 100
[e]Diagnostic accuracy (DA) = [(TP+TN)/(TP+TN+FP+FN)] X100

Diagnostic characteristics of lung ultrasound in case of pneumothorax (n=58)
A total of 58 critically ill patients with mechanical ventilation and who were scheduled for CT scan were selected for the study. The effectiveness of the lung ultrasound (LU) was assessed against the gold standard of CT scan. It was found that LU was 80% sensitive to diagnose pneumothorax correctly while it showed 100% specificity to rule out the condition. The diagnostic accuracy of LU was found to be 98 %.

Diagnostic characteristics of chest radiograph in case of pneumothorax (n=58)
A total of 58 critically ill patients with mechanical ventilation who were scheduled for CT scan were selected for the study. The effectiveness of chest radiograph (CXR) was assessed against the gold standard of CT scan. It was found that CXR was 40% sensitive to diagnose pneumothorax while it showed 100% specificity to rule out the condition. The diagnostic accuracy of CXR was found to be as 95.

Diagnostic characteristics of lung ultrasound in case of pleural effusion (n=58)
A total of 58 critically ill patients with mechanical ventilation and scheduled for CT scan were selected for the study. The effectiveness of lung ultrasound (LU) to rule in or rule out pleural effusion was assessed against the gold standard of CT scan. It was found that LU was 79% sensitive to diagnose pleural effusion correctly while it showed 100% specificity to rule out the condition. The diagnostic accuracy of LU was found to be as 88%.

Diagnostic characteristics of chest radiograph in case of pleural effusion (n=58)
A total of 58 critically ill patients with mechanical ventilation and scheduled for CT scan were selected for the study. The effectiveness of chest radiograph (CXR) to rule in or rule out pleural effusion was assessed against the gold standard of CT scan. It was found that CXR was only 41% sensitive to diagnose pleural effusion correctly while it showed 100% specificity to rule out the condition. The diagnostic accuracy of CXR was found to be as 66%.

Diagnostic characteristics of lung ultrasound in case of interstitial syndrome (n=58)
A total of 58 critically ill patients with mechanical ventilation and who were scheduled for CT scan were selected for the study. The effectiveness of the of lung ultrasound (LU) was assessed against the gold standard of CT scan. It was found that LU was cent percent identical to gold standard test to rule in or rule out the condition, i.e. it showed 100% sensitivity, specificity, positive and negative predictive values, and diagnostic accuracy.

Diagnostic characteristics of chest radiograph in case of interstitial syndrome (n=58)
A total of 58 critically ill patients with mechanical ventilation and scheduled for CT scan were selected for the study. The effectiveness of chest radiograph (CXR) to rule in or rule out interstitial syndrome was assessed against the gold standard of CT scan. It was found that CXR was only 86% sensitive to diagnose interstitial syndrome correctly while it showed 100% specificity to rule out the condition. The diagnostic accuracy of CXR was found to be as 98%.

Discussion:
The main finding of this study is that in an ICU population of mechanically ventilated patients, lung ultrasound identifies the most common pathologic abnormalities of the respiratory system encountered in these patients with high diagnostic accuracy. It is important to note that patients were enrolled in the study when a thoracic CT scan was ordered by the primary physician and no other selection criteria were applied. Four common abnormalities (pneumothorax, pleural effusions, consolidation, and interstitial syndrome) were evaluated that have important implications in patient management and decision making. In order to accurately characterize the diagnostic performance of the three imaging methods various lung regions were analyzed in each patient. .

Interstitial syndrome
This disorder is very important for diagnosing acute respiratory failure, acute circulatory failure[9], and control of hemodialysis[17] among others. In the present study lung ultrasound had sensitivity, and diagnostic accuracy of 100% (due small number of patient), well comparable to those reported in patients with ARDS or respiratory failure[8]. Lung ultrasound was able to identify all the cases confirmed by CT. In some international study, however false positive cases were reported because of time lag between LU and thoracic CT. Studies have shown that this interval is sufficient to modify the appearance of interstitial syndrome on CT, because this pathology is very sensitive to treatment[17,18]. On the other hand bedside CXR showed 86% sensitivity and 98% accuracy to spot the disease. This finding is also identical to other study observation.

Consolidation
The sensitivity of lung ultrasound for the detection of consolidation in critically ill patients has been reported to be around 90%[8,17-19]. In our study lung ultrasound had a sensitivity of 86% and a diagnostic accuracy of 95% in identifying this abnormality. CXR had 91% sensitivity and 96% diagnostic accuracy. The lung ultrasound had 3 false negative cases, resulting in a reduced sensitivity, somewhat comparable to other finding that reported in the literature[19]. From our study findings it was observed that bedside CXR is relatively more effective to diagnose consolidation than LU. However, further study with bigger sample size is necessary to establish this hypothesis.

Pleural effusion
Lung ultrasound has long been used for identification of pleural effusions having sensitivity above 90%[20]. In our study the sensitivity and diagnostic accuracy were 79% & 88% respectively. Our analysis showed 7 false negative cases resulting in the decrease in sensitivity rate. CXR performed very poorly (sensitivity 41%, diagnostic accuracy 66%)

indicating that this technique is less useful compared to ultrasonography in diagnosis and evaluation of pleural effusion.

Pneumothorax

The bedside diagnosis of pneumothorax is extremely important in ICU patients. It is known that supine CXR is not sensitive for diagnosis of pneumothorax[21,22]. Lung ultrasound has been successfully used for identification of pneumothorax in a variety of patients[23,24,25,26]. These studies report a sensitivity of 81–100%. In our study lung ultrasound identified four cases of pneumothorax, giving a sensitivity of 80%. CXR was 40% sensitive. If the pneumothorax is small the chance of its identification by supine CXR is more reduced. We can draw inference that LU can be a reliable tool for bedside diagnosis of this abnormality compared to CXR.

Conclusion:

In conclusion, in a general ICU population lung ultrasound has a considerably better diagnostic performance than bedside chest radiography for the diagnosis of most common pathologies. Lung ultrasound has a diagnostic accuracy of 88–100% in identifying pneumothorax, consolidation, interstitial syndrome, and pleural effusion, and may therefore be considered as the first modality of choice. Therefore in this study, it can be proposed that ultrasonography is reliable, radiation free technique, has clinical significance for early, quick and accurate detection of common lung pathology than portable chest x-ray in critically ill patients at I.C.U and thus preventing the development of complications. To the best our knowledge no such prior study was undertaken in our country.

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