# Could chest ultrasonography replace chest radiography in outpatient chest clinic?

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**Objective**
Plain chest radiography is the commonest ordered investigation in chest outpatient clinic; however, it is time consuming and may be expensive in some settings. With the availability of chest ultrasonography (CUS) at bedside, CUS might be used instead of plain chest radiography in outpatient settings. Still there is controversy regarding CUS as the primary investigation in outpatient chest clinics.
**Patients and methods**
Consecutive patients referred to the outpatient chest clinic of Assiut University between March 2018 till June 2020 who were proposed to have computed tomography (CT) chest after plain chest radiography were asked to participate in the study. The included patients had CUS with a pulmonologist who was blind to the chest radiography and chest CT results. CUS was done using a convex probe of ultrasonography in all chest anatomical planes for any finding that may help in the diagnosis. The plain chest radiography results also were recorded. Both results were compared with chest CT results as the gold standard investigation.
**Result**
A total of 101 patients were included in the study. There were 18% female patients, with mean age of 49.4±17.9 years. The final diagnosis was lung malignancy, pneumonia, bronchiectasis, chronic obstructive lung diseases, pulmonary embolism, pleural effusion, interstitial lung disease, and other miscellaneous causes. CUS were normal in 14 cases, with a sensitivity of 89.5% and a specificity of 80%, whereas chest radiography was normal in 20 cases, with a positive finding in 81 cases, with a sensitivity of 83.3% and a specificity of 80%, in comparison with chest CT.
**Conclusion**
CUS may be the primary investigation in chest outpatient clinic with good accuracy and rapid patient diagnosis.

**Keywords:**
chest computed tomography, chest ultrasonography, outpatient chest clinic, plain chest radiography

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## Introduction

Since the discovery of radiography by Rotangen and its use for medical purposes by Edison 1896, standard chest radiograph has become the most preliminary investigation ordered by physicians to help diagnose different pulmonary diseases [1,2]. Pulmonologists consider plain chest radiography is vital for every patient with unexplained chest complaints before ending their outpatient clinic visit [3,4]. Although plain chest radiography has a beneficial diagnostic role [5], it has some limitations, such as it is time consuming, is cost intensive, had radiation exposure, and may lead to another visit in busy tertiary hospitals [6], together with occasional difficulty in interpretation and inadequate technique that accentuate its difficulty plus poor sensitivity and specificity [3,7,8]. With the emergence of chest ultrasonography (CUS) for pulmonary diagnosis [9], and its widespread use in wards, critical care, and emergency departments for diagnosis of effusion, consolidation, pneumothorax, and alveolar interstitial syndrome [10–13], especially with the introduction of ultrasonography BLUE protocol for assessing emergency patients [14,15], there has been an increase in CUS diagnostic value and has improved pulmonologists learning skills; especially with identification of the invaluable normal and abnormal CUS artifacts such as a horizontal artifact, B vertical hyperechoic artifact, pleural line with its sliding motions artifacts, seashore sign, diaphragmatic displacement and excursion, and consolidations with airbronchogram artifacts or fluid bronchogram artifacts while considering their

diagnostic value [16]. Pulmonologists in practice are ordering CUS usually as a secondary test after reviewing patient plain radiography to confirm certain radiological findings [17]. However, it is promising to use CUS as a preliminary pulmonary investigation in outpatient chest clinic instead of plain radiography; unfortunately, there is a lack of research studies to evidence the use of CUS in outpatients clinic as a preliminary investigation for assessing unexplained pulmonary complaints [18]. Our aim was to assess the feasibility of CUS as a preliminary imaging investigation in the outpatient chest clinic to improve and accelerate the diagnostic accuracy of chest diseases.

## Patients and methods

This prospective comparative study was conducted in consecutive patients referred to the tertiary pulmonary outpatient clinic of Assiut University Hospital for diagnosis or management in the period of March 2018 till June 2020. The university ethical committee approved the study, and an informed consent was obtained from the participants. After careful history taken and clinical examination by the attending pulmonologist, the patients who were proposed to have computed tomography (CT) chest after plain chest radiography were asked to participate in the study. The included patients had CUS with a pulmonologist who was blind to the plain chest radiography and chest CT results. The CUS was done using a convex probe of Aloka ultrasonography (IPC-1530). CUSs were done by expert consultants (M.K.A. and M.N.M.) with 10 years of experience in the Assiut University Chest ultrasonography unit. All chest anatomical CUS planes (including anterior and posterior mediastina sonographic views) were looked for to detect any findings that could help in the diagnosis and were recorded [19]. The CUS finding include chest wall finding (echogenic lesions); pleural findings, such as pleural effusion, pleural sliding, pleural thickening, and/or pleural interruptions [20]; parenchymal findings, such as consolidations, vertical B lines (hyperechoic vertical artifact rays arise from the pleural line and extend vertically to the end of screen with synchronous motion with pleural sliding) [21], and horizontal A lines (horizontal lines with a regular vertical spacing down the image), either normal profile or abnormally increased, and echogenic lesions (hypoechoic, hyperechoic, and anechoic); assessment of diaphragmatic displacement; and rapid visual cardiac size and function [22]. The plain chest radiography results were recorded and included pleura, lung zones, cardiac size, and mediastina position. Plain chest radiography was also interpreted blindly of the patient data and recorded. CUS and chest plain radiography results were compared with chest CT results (chest wall, pleura, lung parenchyma, lung vasculature, and mediastinum finding) as the gold standard investigation. The patients' final diagnosis was obtained from patient record sheets.

### Statistical analysis

Statistical analysis was performed using SPSS (version 19.0; SPSS Inc., Chicago, Illinois, USA). Continuous variables were presented as means±SD and categorical variables were presented as percentages. Mann–Whitney test was used to compare quantitative variables between groups. Receiver operating characteristic analysis was used to identify the sensitivity, specificity, and accuracy of CUS in comparison with plain radiography. A *P* value less than 0.05 was considered statistically significant.

## Result

A total of 101 patients are included in this study. There were 18% female patients. Their mean age was 49.4 ±17.9 years, with BMI of 21.1±3.5. Overall, 12% were diabetic and hypertensive. The patients' final diagnosis is presented in Table 1. All of the patients had traditional plain radiography, CT chest, and CUS. A total of 20 patients had normal plain radiography and 81 patients had abnormal plain radiography findings (27 patients had suspected pleural lesions, 51 had suspected parenchymal zonal lesions, seven low flat diaphragms, and 10 cases had cardiomegaly) (Table 2). On the contrary, CUS was normal in 14 patients, whereas 32 patients had CUS pleural effusion either unilateral or bilateral, 78 patients had CUS parenchymal finding, 18 patients had suspected cardiac enlargement or impaired function that was

**Table 1 Patients' final diagnosis**

| Final diagnosis | *n* (%) |
|---|---|
| Pneumonia | 31 (30.9) |
| COPD | 7 (6.9) |
| Lung malignancy | 19 (18.8) |
| Isolated pleural effusion | 8 (7.9) |
| Pulmonary embolism | 7 (6.9) |
| Pulmonary hypertension | 1 (1) |
| ILD | 6 (5.9) |
| Bronchiectasis | 8 (7.9) |
| Congestive heart failure | 4 (3.9) |
| Pulmonary nodule | 1 (1) |
| Bronchial asthma | 2 (1.9) |
| Miscellaneous | 4 (3.8) |

Miscellaneous diagnoses include lung abscess, mediastinal ganglioma, pulmonary aspergilloma, lung collapse. COPD, chronic obstructive lung diseases; ILD, interstitial lung disease.

**Table 2 Plain chest radiography finding**

| Plain chest radiography finding | *n* (%) |
|---|---|
| Obliteration of costophrenic angle | 27 (26.7) |
| Homogenous opacities and airbronchogram | 50 (49.7) |
| Reticular opacity | 14 (13.8) |
| Mediastinum abnormality | 13 (12.9) |
| Hyperinflation | 7 (6.9) |

Mediastinum abnormality include cardiomegaly, hilar, paracardiac or paratracheal opacity, and/or mediastinal shift.

**Table 3 Chest ultrasonography finding**

| Chest ultrasonography finding | *n* (%) |
|---|---|
| Consolidation | 44 (43.6) |
| Pleural effusion | 32 (31.7) |
| Pleural thickening | 3 (3) |
| Vertical lines | 20 (19.8) |
| Horizontal lines | 2 (2) |
| Hypoechoic lesion | 22 (21.8) |
| Isoechogenic lesion | 7 (6.9) |
| Decreased diaphragmatic displacement | 5 (5) |
| Normal view | 14 (13.8) |

confirmed with further echocardiography, and 10 cases had sluggish diaphragmatic motion. Eleven cases had sonography-related interventions (aspiration, CUS-guided biopsy, or both) in the same sonographic session that shortened the diagnostic time (Table 3). CT chest were normal in four cases, 27 patients had CT pleural finding, 67 patients had CT parenchymal lesions, and 16 patients had CT cardiac abnormality (Table 4).

Regarding the CUS patterns of our cohort, community-acquired pneumonia was the most common noted diagnosis and presented as consolidations, consolidations with parapneumonic effusions, predominant vertical B lines unilateral or bilateral, patches of consolidation dispersed all over both the lungs, or less common hypoechoic lesions. Thoracic malignancy was the second most common malignancy identified among cases, which presented on ultrasonography as hypoechoic lung lesions, echogenic lung or mediastinal lesions, pleural effusions, or two cases presented as CUS consolidations. Pulmonary embolism cases presented as hypoechoic lesions, pleural effusion whether unilateral or bilateral consolidation, vertical lines, or normal sonographic appearance, as in one patient; chronic obstructive lung diseases (COPD) were found to have normal CUS, as well as predominant horizontal A lines with or without sluggish diaphragmatic motions; bronchiectasis presented as normal CUS in four cases, with presence of minimal bilateral consolidations or hypoechoic lesions with or without minimal pleural effusions in the remaining

**Table 4 Computed tomography chest finding**

| CT finding | *n* (%) |
|---|---|
| Consolidation | 52 (51.4) |
| Pleural effusion | 27 (26.7) |
| Mass | 20 (19.8) |
| Interstitial infiltrate | 12 (11.8) |
| Bronchiectasis | 10 (9.9) |
| Pulmonary embolism | 7 (6.9) |
| Cardiomegaly | 10 (9.9) |
| Cavitations | 11 (10.8) |
| Fibrosis | 6 (5.9) |
| Mediastinal lymphadenopathy | 5 (4.9) |
| Nodules | 8 (7.9) |
| Emphysema | 8 (7.9) |
| Collapse | 7 (6.9) |
| Ground glass | 8 (7.9) |
| Pneumothorax | 1 (1) |
| Empyema | 2 (2) |

CT, computed tomography.

**Table 5 Sensitivity, specificity, and accuracy of chest ultrasonography versus plain chest radiography in comparison with chest computed tomography**

| | Sensitivity (%) | Specificity (%) | PPV (%) | NPP (%) | Accuracy (%) |
|---|---|---|---|---|---|
| Chest US | 89.58 | 80.00 | 98.85 | 28.57 | 89.11 |
| Plain chest radiography | 83.33 | 80.00 | 98.77 | 20.00 | 83.17 |

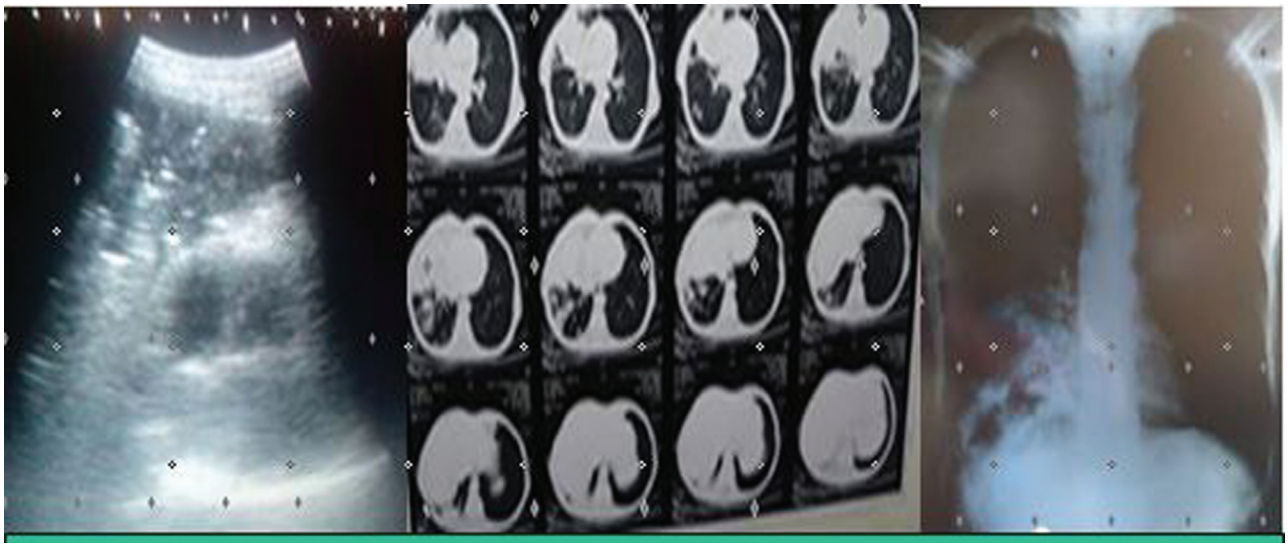
NPV, negative predictive value; PPV, positive predictive value; US, ultrasonography.

bronchiectasis cases; interstitial lung disease (ILD) was found to have vertical lines bilateral with thickened interrupted pleural line in all cases except one that had normal CUS; and congestive heart failure cases were found to have bilateral mild to moderate pleural effusion, predominant vertical lines in front CUS view with little vertical lines in the CUS back view, with sluggish cardiac contractility in rapid visual cardiac view. Sensitivity, specificity, and accuracy of CUS are presented in Table 5 and Fig. 3.

## Discussion

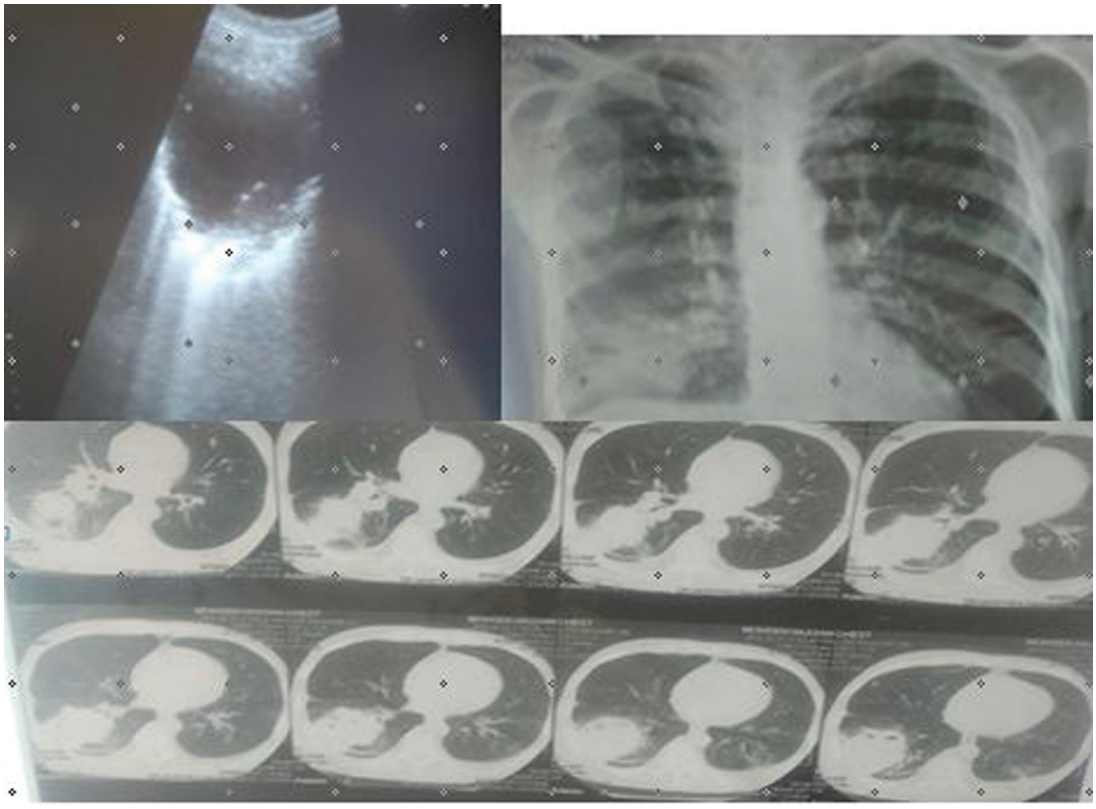
The present study encourages the practice of CUS in the outpatient chest clinic for proper and fast patient management [13]. Our finding ensures the invaluable participation of CUS in managing patients at the outpatient clinics, especially in busy referral hospitals with expert CUS pulmonologists. Patients with pneumonia, pleural effusion, peripheral lung lesions, peripheral pulmonary embolism, and congestive heart failure could be diagnosed rapidly when CUS was performed early [9,23]. The accuracy of CUS image reached 90% when compared with chest CT in the present study, which was higher than plain radiography. Many authors identified similar results

**Figure 1**



Middle lobe pneumonia in 59 male patient with different imaging views; Chest ultrasonography, Computed Tomography and plain, radiography respectively.

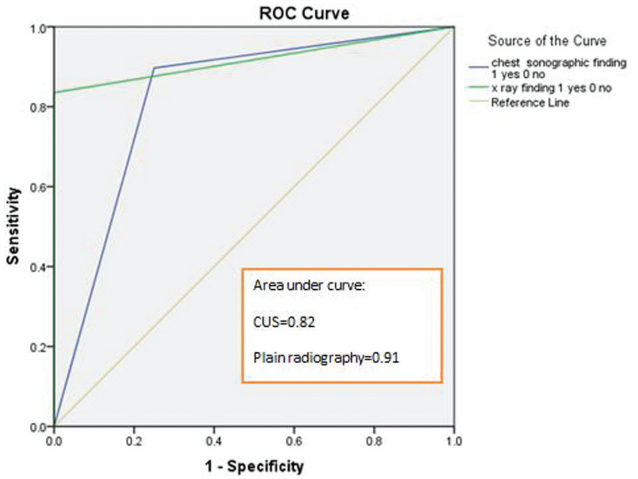
**Figure 2**



Right lower lobe lung abscess in 65 years male patient, images are showing different views; chest ultrasonography, plain radiography and computed tomography.

in emergency and critical care settings [23]. Many pulmonary diseases are peripherally located and might be easily ultrasonographically recognized [21]. Many authors recommend the use of CUS as a complementary investigation in managing patients with pulmonary diseases [18,24,25]. Although this principle is still working in most chest departments, it is time to include CUS as a preliminary pulmonary investigation adjunct to stethoscope instead of chest plain radiography in outpatient setting [26]. CUS has superiority over plain radiography in assessing the pleura lesions as effusion, septation, and thickening,

**Figure 3**




ROC cure analysis of chest ultasonography versus plain chest radiography in comparison with Chest Computed Tomography.

while giving rapid potential diagnosis and treatment, and also it is recommended before any pleural procedures [27]. This was observed in our study in the outpatient setting, as pleural diseases were diagnosed early and confidently and pleural procedures (aspiration, biopsies) were done in the same setting where the use of plain radiography imaging was further wanted [26–28]. An interesting finding in our study was that CUS could identify pleural lesions in a few cases that could not be identified with chest radiography, even CT; moreover, CUS could differentiate between pleural thickening and effusion [28,29]. Plain radiography has a limitation in assessing the nature of the pleural diseases. CUS has high efficacy and is even preferred over chest CT. CUS echogenicity of pleural effusion could diagnose, differentiate and give accurate impression regard fluid nature as in empyema, hemorrhage, or suspicious of malignancy [30]. All of these findings might be difficult to conclude with radiography, making CUS superior in managing pleural diseases even in outpatient setting as our findings noted [28,30]. Despite the benefit of CUS in diagnosing pneumothorax with identification of absence pleural gliding sign, barcode sign, and lung point sign, still patients with pneumothorax in outpatient settings need radiography for proper patient care [11,28]. Pneumonia, parapneumonic effusion, and empyema might be displayed easily with the use of CUS. This is identified in our study of diagnosis of pneumonia in third of our cohort and empyema in two cases as complex septated effusion [26]. We noted 44 patients had consolidations with CUS, where three of them have pulmonary embolism, three have lung malignancy, and the remainder were diagnosed as pneumonia. This might guide physicians to proper management. On the contrary, with plain chest radiography, it is difficult some time to differentiate between consolidations and other opacities. CUS is recommended in follow-up of empyema, pneumonia, and parapneumonic effusions by many authors [31,32].

ILDs carry challenges in diagnosis and management in the respiratory field. Chest radiograph is still very limited in its assessment, and many impressive findings are obtained after undergoing high-resolution CT [33]. The accuracy of plain radiography finding related to ILD diseases is questionable [34]. With CUS, the patients' diagnoses differ, as CUS patterns in ILD are characteristics, with predominant vertical B lines, brown rings artifacts, and thickened interrupted pleural lines, making it easy for the pulmonologists to consider alveolar interstitial syndrome in their differential diagnoses [24,25,35,36]. The CUS finding in ILD reflects lung parenchymal acoustic impedance properties related to the pathological parenchymal changes with increases in lung water volume [36]. We noted in our study that all ILD cases (six cases), apart from one, have CUS findings that might guide the pulmonologist for further investigation to identify the etiological ILD diagnosis.

In our study, we noted that patients with decompensated congestive heart failure who presented to the chest clinic had characteristic CUS pattern that might differentiate these patients from patients with interstitial pulmonary diseases or other pulmonary diseases, as having bilateral pleural effusion, with little vertical lines in basal CUS view, while predominant B lines in front CUS views; these findings were used to evaluate alveolar interstitial syndrome in emergency conditions [17,21,37]. Many studies had identified the accuracy of CUS plus natriuretic peptide to differentiate heart failure from other pulmonary diseases [38]. Neesse *et al.* [39] identified similar findings as our; all patients with congestive heart failure presented with pleural effusion with vertical lines.Obstructive lung diseases either bronchial asthma, COPD, or bronchiectasis are difficult diagnose with CUS and frequently show normal lung sonographic patters; however, CUS might identify objective CUS signs as predominant bilateral horizontal line profile with emphysema cases, sluggish diaphragmatic displacement, or decreased sonographic M mode index of obstructions that could correlate with spirometric obstructive parameters [40,41]. Our study noted that four cases

of patients with COPD presented with bilateral sluggish diaphragm, two COPD patients presented with predominant horizontal A-line, whereas three with normal sonographic view; on the contrary, patients with bronchiectasis were difficult to suspected with sonographic appearance only, as three patients presented with normal CUS appearance and the other cases were noted to have peripheral tiny consolidations with few hypoechoic and echogenic lesions. However, with chest CT, the diagnosis was perfect and easy. Figs 1 and 2 represent two of our patients' images, showing how CUS can easily help us rapidly reach final diagnosis. Our study has limitation, such as heterogeneity of the cohort sample; however, it represents the actual daily outpatient clinic data, with the strength of all of the patients undergoing chest CT. This lends power to our comparison and makes it strong, which may lead to generalization of the results.

## Conclusion

CUS is strong weapon to help the pulmonologist to diagnose different diseases easily and rapidly. It is time to start the substitution of chest radiography with CUS in outpatient settings.

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### Conflicts of interest

There are no conflicts of interest.

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