Table 1 Patient demographics

	Pneumonia ($n = 44$)	No pneumonia ($n = 18$)
Age range, year		
30–39	3 (7)	2 (11)
40–49	9 (20)	3 (17)
50–59	10 (23)	3 (17)
60–69	13 (30)	4 (22)
70–79	6 (14)	2 (11)
≥ 80	3 (7)	4 (22)
Mean Age (SD)	58.5 (13.8)	61.2 (16.3)
Women	26 (59)	7 (39)
History of chronic obstructive pulmonary disease	18 (41)	11 (61)
History of tuberculosis	4 (9)	1 (6)

Values are presented as number (%)

with pneumonia, demonstrating a sensitivity of 91%. Chest X-ray was positive in 32 of the 44 patients with pneumonia, yielding a sensitivity of 73% (Table 2). The sensitivity of ultrasound was significantly better than chest X-ray ($p = 0.01$). Specificity of ultrasound and chest X-ray were similar at 61 and 50% respectively ($p = 0.62$). The positive predictive value of lung ultrasound was 85% and chest X-ray was 78%. The negative predictive value of ultrasound was 73% while chest X-ray was 43%. The positive likelihood ratio for diagnosing pneumonia with lung ultrasound was 2.34, while the negative likelihood ratio was 0.15. Chest X-ray had a positive and negative likelihood ratio of 1.45 and 0.55 respectively.

In patients with a false-positive ultrasound, CT diagnoses were the following: bronchiectasis with fibrosis ($n = 3$), interstitial lung disease ($n = 2$), tuberculosis ($n = 1$), and normal ($n = 1$). In the one patient with a normal CT scan, lung ultrasound was positive based on B lines in the posterior zone only.

Inter-rater reliability between ultrasound interpretations by the sonographer and expert reviewer was 0.79, demonstrating very good agreement.

Clinicians performed lung ultrasound in an average of 7 min 9 s (SD 1 min 57 s). The time it took for patients to get a chest X-ray was 117 min (SD 56 min). This time did not include the time required for film printing and pickup for clinician review.

Table 2 Results of chest X-ray and lung ultrasound compared with CT

	CT positive ($n = 44$)	CT negative ($n = 18$)
Chest X-ray		
Positive	32	9
Negative	12	9
Ultrasound		
Positive	40	7
Negative	4	11

Discussion

To our knowledge, this is the first study to provide evidence that the sensitivity of lung ultrasound is superior to chest X-ray for diagnosing pneumonia in a low-income country.

Lung ultrasound demonstrated a higher sensitivity for the diagnosis of pneumonia compared to chest X-ray. Previous studies have found similar results regarding the sensitivity of ultrasound for pneumonia. In recent meta-analyses, Long et al. found a pooled sensitivity of 88% for lung ultrasound and Ye et al. found a pooled sensitivity of 95% [7, 22]. However, in these meta-analyses, the majority of studies used biased reference standards such as chest X-ray and hospital discharge diagnoses, which may confound their results. Using similar methods to our study with CT as the reference standard, Liu et al.'s study in China found similar results with the sensitivity of lung ultrasound significantly outperforming chest X-ray (94.6 versus 77.7%, $p < 0.001$) [8].

Ultrasound missed pneumonia in four patients. These pneumonias were also missed by chest X-ray. In all four patients, the pneumonia was located in the middle of the lung parenchyma and did not extend to the pleura. This is similar to prior studies finding that lesions not extending to the pleura are missed by ultrasound [11]. Therefore, clinicians should continue to consider close follow-up for repeat evaluation in patients with continued high suspicion for pneumonia and negative lung ultrasound.

Specificities of lung ultrasound and chest X-ray for pneumonia were similar. Lung ultrasound specificity was significantly lower than previous studies, including the two meta-analyses previously mentioned. Long et al. found a pooled specificity of 86% while Ye et. Al found a pooled specificity of 91% [7, 22]. Using CT as the gold standard, Liu et al. found a specificity of lung ultrasound to be significantly better than chest X-ray (99 versus 61.1%, $p < 0.001$) for the diagnosis of pneumonia [8]. While this study was done in China, where there are also high rates of tuberculosis and chronic obstructive pulmonary disease, there were no patients with tuberculosis in the study and only 10% of patients had a diagnosis of chronic obstructive pulmonary disease, making it difficult to extrapolate these results to other areas of China and other middle- and low-income countries. The low specificity for ultrasound in our study is due to a higher prevalence of co-morbidities, including previous pulmonary tuberculosis, bronchiectasis, and chronic obstructive lung disease. Patients with history of tuberculosis often develop significant parenchymal scarring and fibrosis with bronchiectasis [23]. The CT findings