The accuracy of pleural ultrasonography in diagnosing complicated parapneumonic pleural effusions

ABSTRACT
We compared the accuracy of pleural ultrasound versus chest CT versus chest radiograph (CXR) to determine radiographic complexity in predicting a complicated parapneumonic effusion (CPPE) defined by pleural fluid analysis. 66 patients with parapneumonic effusions were identified with complete data. Pleural ultrasound had a sensitivity of 69.2% (95% CI 48.2% to 85.7%) and specificity of 90.0% (95% CI 76.3% to 97.2%). Chest CT had a sensitivity of 76.9% (95% CI 56.3% to 91.0%) and specificity of 65.0% (95% CI 48.3% to 79.4%). CXR had a sensitivity of 61.5% (95% CI 40.6% to 79.8%) and specificity of 60.0% (95% CI 43.3% to 75.1%). Pleural ultrasound appears to be a superior modality to rule in a CPPE when compared with chest CT and CXR.

INTRODUCTION
Approximately 60% of patients with pneumonia develop parapneumonic effusions, with some developing serious complications if the effusions are not adequately drained.[1] Thoracentesis with pleural fluid analysis (PFA) is essential in the diagnosis of a 'complicated parapneumonic effusion' (CPPE).[2] Pleural ultrasound may have a role in identifying a CPPE; however, its accuracy in identifying a CPPE based on the PFA is limited.[3–5] The goal of this study was to determine the accuracy of pleural ultrasound, chest CT and chest radiography (CXR) to identify complexity when the results of the PFA establish a CPPE.

METHODS
We designed a retrospective chart review of patients with parapneumonic pleural effusions who underwent thoracentesis. All patients had a clinical history and PFA consistent with pneumonia, which were adjudicated by three attending pulmonologists. Inclusion criteria required that the preprocedure ultrasound data, chest CT and CXR images were all available.

We compared the ultrasound, CT and CXR descriptions of the pleural fluid and their predictive values for determining a CPPE based on the PFA. The PFA was defined as complicated if it met at least one of the following criteria: pH<7.20, glucose <60 mg/dL or organisms noted on Gram stain or culture. Ultrasound was performed using a generic portable ultrasound machine (M-turbo, SonoSite, Bothell, Washington, USA, equipped with a phase array 5–1 MHz transducer). The proceduralist interpreted the ultrasound image prior to the thoracentesis using one of the following descriptors: anechoic, complex non-septate, complex septate or homogeneously complex.

The CXRs included both anterior–posterior and posterior–anterior images. The CTs included images obtained either with or without contrast. One chest radiologist blinded to the results of the PFA and outcomes interpreted the CXR and CT as complex or not complex. Effusions were considered not complex if they had a concave meniscus with the chest wall on radiograph or layered dependently with a smooth contour of the visceral pleura interface on CT. Effusions that had a lenticular shape on radiograph or demonstrated focal convexity, loculations or septations on CT were considered complex.

Two by two contingency tables were constructed to determine the relationship between complexity seen on imaging and the PFA's determination of a CPPE. Diagnostic test characteristics (sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratio (LR) positive and LR negative) were calculated for each modality (US, chest CT and CXR), along with their 95% CIs. Bootstrap resampling techniques were used to determine whether any of the observed differences between the modalities' test characteristics were statistically significant (p<0.05).[6] All analyses were conducted using SAS V.9.4 (Cary, North Carolina, USA).

RESULTS
Of the 1245 patients who underwent thoracentesis, 1097 were excluded due to an alternative diagnosis. Of the 148 patients with parapneumonic effusions, 82 patients were excluded because of a lack of complete data. Sixty-six patients were analysed having received all three radiographic tests. Twenty-six (39.4%) of 66 patients had a PFA consistent with a CPPE. Thirty-six patients were described as having an anechoic pleural effusion when the PFA was classified as simple or not complicated, whereas the other eight patients with anechoic effusions had a PFA that was considered complicated. Eighteen patients' effusions were identified as complex by ultrasound when their PFA was classified as complicated and only four patients had complexity on ultrasound when their PFA was considered simple.

Pleural ultrasound had a sensitivity of 69.2% (95% CI 48.2% to 85.7%), specificity of 90.0% 95% CI 76.3% to 97.2%), PPV of 81.8% (95% CI 59.7% to 94.8%), NPV of 81.8% (95% CI 67.3% to 91.8%), a positive LR of 6.92 (95% CI 3.18 to 28.1) and a negative LR of 0.34 (95% CI 0.15 to 0.55). Chest CT had a sensitivity of 76.9% (95% CI 56.3% to 91.0%), specificity of 65.0% (95% CI 48.3% to 79.4%), PPV of 58.8% (95% CI 40.7% to 75.3%), NPV of 81.3% (95% CI 63.6% to 92.8%), a positive LR of 2.20 (95% CI 1.42 to 3.75) and a negative LR of 0.36 (95% CI 0.12 to 0.66). CXR had a sensitivity of 61.5% (95% CI 40.6% to 79.8%), specificity of 60.0% (95% CI 43.3% to 75.1%), PPV of 50.0% (95% CI 31.9% to 68.1%), NPV of 70.6% (95% CI 52.5% to 84.9%), a positive LR of 1.54 (95% CI 0.94 to 2.63) and a negative LR of 0.64 (95% CI 0.32 to 1.05) (table 1). When comparing chest CT versus CXR, none of the differences in the test characteristics were statistically

Table 1 Estimates of the diagnostic test characteristics for ultrasound, chest CT and CXR, along with their 95% CIs

	Ultrasound (n=66)	Chest CT (n=66)	CXR (n=66)
Sensitivity % (95% CI)	69.2% (48.2 to 85.7%)	76.9% (56.3 to 91.0%)	61.5% (40.6 to 79.8%)
Specificity % (95% CI)	90.0%* (76.3 to 97.2%)	65.0% (48.3 to 79.4%)	60.0% (43.3 to 75.1%)
PPV % (95% CI)	81.8%* (59.7 to 94.8%)	58.8% (40.7 to 75.3%)	50% (31.9 to 68.1%)
NPV % (95% CI)	81.8% (67.3 to 91.8%)	81.3% (63.6 to 92.8%)	70.6% (52.5 to 84.9%
LR+ estimate (95% CI)	6.92* (3.18 to 28.1)	2.20 (1.42 to 3.75)	1.54 (0.94 to 2.63)
LR− estimate (95% CI)	0.34 (0.15 to 0.55)	0.36 (0.12 to 0.66)	0.64 (0.32 to 1.05)

*p<0.05 when compared with chest CT and when compared with CXR.
CXR, chest radiograph; LR−, negative likelihood ratio; LR+, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value.

significant. However, certain diagnostic test characteristics as measured via ultrasound, including specificity, PPV and positive LR, were significantly better than when measured using chest CT or CXR.

DISCUSSION

Based on our findings, pleural ultrasound could be considered the best test to rule in the presence of a CPPE. We propose that pleural ultrasound can be used to make an immediate decision for placement of tube thoracotomy when complexity is seen in a patient with a clinical suspicion for a CPPE. Due to the high specificity, PPV and positive LR, few patients may be subjected to the placement of a small bore chest tube when one may not be clinically indicated.

When pleural ultrasound detected an anechoic effusion, the PFA was noted to be biochemically complex; this may be a result of the timing of thoracentesis relative to the evolution of the infection. These effusions are easily drained and typically do not require further interventions besides antibiotic therapy. The small number of false positives was due to the appearance of sonographic complexity when the PFA was non-complicated. It is possible these cases could represent: (1) sampling done within a loculation that was not as biochemically inflammatory or (2) pre-existing pleural stranding as a result of prior insults.

The major limitation of this study was the retrospective design and original ultrasound images were not independently reviewed. In addition, there may be variability in image acquisition and technique. Other limitations would include: (1) the potential to introduce bias if CXR and chest CT were viewed first and (2) no standardisation for the CXR and chest CT. Lastly, to include patients with all three imaging modalities, we excluded 82 patients.

A randomised study could validate if early versus delayed chest tube placement improves outcomes in patients with suspected CPPE based on pleural ultrasound characteristics. We speculate that pleural ultrasound can drive clinical decisions regarding chest tube placement in patients with suspected CPPE prior to the PFA.

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