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Probing for answers: Is post-thoracentesis ultrasound as effective as chest x-ray for the evaluation of pleural fluid evacuation and lung re-expansion?

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The clinical question

In patients with moderate to large free-flowing simple pleural effusions undergoing therapeutic thoracentesis, is post-thoracentesis ultrasound as effective as chest x-ray (CXR) in assessing complete pleural space evacuation?

Take Home Message

The use of post-thoracentesis ultrasound, when performed by an experienced interventional pulmonologist, is equally as effective as CXR for the evaluation of complete effusion evacuation, with the benefit of reducing patient radiation exposure and offering a more immediate assessment of procedure efficacy and complications.

Background

Although CXR is typically obtained post thoracentesis to assess for complete pleural space evacuation and detect complications, it is limited by delayed availability, the potential need for patient transport to a different clinical location, additional radiation exposure, and suboptimal sensitivity for detecting residual effusion or trapped lung. Ultrasound offers a quick, bedside assessment that the proceduralist can perform without exposing the patient to radiation, and the ability to detect smaller volumes of fluid than CXR. Despite this, ultrasound has not been studied to assess for complete pleural drainage, representing a critical gap between current and potential best practices...

In the most updated 2018 ATS/STS/STR clinical practice guidelines in management of malignant pleural effusions, and the 2023 British Thoracic Society Guideline for pleural disease, they mention that ultrasound may be a valuable tool to assess malignant pleural effusions in the presence of adequate skills, however, no specific mention of ultrasound as a superior modality to assess for complete pleural fluid evacuation post-thoracentesis. CXR remains the standard of care for evaluation post-thoracentesis.

Study design

Type of trial: Prospective multicenter (6 academic U.S. centers) cohort study

Randomization, blinding, controls: Nonrandomized, single-blinded study. Two blinded pulmonologists reviewed all pre- and post-procedure ultrasound images, and two blinded thoracic radiologists reviewed all post-procedure CXR images. On ultrasound, effusion size was estimated based on the number of rib interspaces in which fluid was seen, as well as using the Goecke 2 formula. Two validated grading scales determined the presence or absence of pleural effusion on post-procedure CXR. A third blind radiologist resolved disparities regarding residual effusions on CXR. However, for ultrasound images, the assessments made by the proceduralist served as a third reviewer to resolve any discrepancies.
N: 147 patients
Study groups: Single group evaluated as pre- and post-procedure
Setting: 6 academic centers in the U.S.
Enrollment: 147 patients undergoing therapeutic thoracentesis for moderate to large, free flowing pleural effusions were enrolled in the 6 institutions and 2 were excluded for missing post-procedure ultrasound.
Treatment period: February 2021 to May 2022
Follow up: Index procedure with ultrasound immediately post-procedure and CXR within 4 hours post-procedure
Primary outcome:

- Concordance between ultrasound and CXR in determining complete pleural space evacuation.

Secondary outcomes:

- Ultrasound vs. CXR agreement by effusion size (small vs. large).
- Ultrasound vs. CXR-guided assessment of trapped lung (per a priori definition).
- Correlation of observed parenchymal abnormalities between ultrasound and CXR.
- Concordance of the identification of post-procedural complications by ultrasound and CXR.
- Inter-observer agreement among thoracic radiologists.
- Correlation between Body Mass Index (BMI) and the quality of ultrasound images.

Interventions: Pre-procedure ultrasound, post-procedure ultrasound immediately after thoracentesis and CXR within 4 hours post thoracentesis.

Population

Inclusion criteria:

- Patients >18 years old
- Symptomatic moderate or large free-flowing (non-septated) pleural effusions confirmed by ultrasound, CXR and CT when available.

Exclusion criteria:

- Presence of a disease or condition impeding study completion (e.g. coagulopathy or hemodynamic instability).
- History of ipsilateral pleurodesis.
- Presence of more than minimal thin septations (exceeding 3) and/or loculations on bedside pre-procedure ultrasound.
- Pleural effusion smaller than anticipated on pre-procedure ultrasound.
- Referral solely for diagnostic thoracentesis.

Baseline Characteristics:

- 145 patients underwent analysis.
- The median age was 64 years old (IQR 56-75).
- 52.8% of the population was female.
- The median number of prior thoracenteses was 1 (IQR 0-2)
- 103 patients (71%) had a right-sided pleural effusion.

Outcomes

Primary outcomes:

Overall agreement (ultrasound vs. CXR):

- High level of agreement
- *Gwet's AC1 = 0.93 (95% CI: 0.83–1.00)*

Secondary outcomes:

Agreement by effusion size (small vs. large):

- Substantial level of agreement
- *Kappa = 0.64 (95% CI: 0.51–0.77)*

Trapped lung (per a priori definition):

- Strong agreement between ultrasound and CXR
- *Kappa = 0.89 (95% CI: 0.81–0.96)*

Parenchymal abnormalities – pleural thickening:

- Strongest agreement between ultrasound and CXR
- *Gwet's AC1 = 0.89 (95% CI: 0.83–0.95)*

Pneumothorax detection:

- Slight to moderate agreement between ultrasound and CXR
- *Kappa = 0.30 (95% CI: 0.10–0.50)*

Inter-observer agreement among thoracic radiologists (CXR pneumothorax evaluation):

- Limited agreement
- *Kappa = 0.47 (95% CI: 0.23–0.71)*

Correlation between Body Mass Index (BMI) and the quality of ultrasound images:

- Blind reviewers were more likely to rate the image as suboptimal/poor in individuals with a higher BMI ($\rho = 0.194$, $p = 0.046$) on mid-axillary views, among the 106 participants with available BMI data.

Adverse events:

- Total pneumothoraces reported: 6. None required invasive intervention (i.e. chest tube placement).
- 3 patients: Small pneumothoraces identified by ultrasound and by the non-blinded radiologist at the recruiting institution. All discharged without need for additional intervention.
- 3 patients: Pneumothoraces detected by ultrasound. Not detected on CXR.

Commentary

Study Strengths

- Prospective study conducted across six academic centers.
- Two pulmonologists and two thoracic radiologists reviewed the ultrasound and CXR data, each blinded to patient and procedural information, with a third reviewer available to resolve any disagreements.
- Various statistical methods were used to evaluate agreement, showing robust results.
- The study addressed an evidence gap not discussed in previous studies, supporting a better approach in clinical practice using ultrasound for evaluation post-thoracentesis.

Study Limitations and Potential for Bias

- Small population size with only 145 patients enrolled.
- The inclusion criteria are narrow, only considering non-septated, free-flowing effusions and excluding complex loculated effusions, which limits generalizability...

- Lack of computed tomography in all patients to corroborate a gold standard for complete evacuation, which limits the validity of the results.
- The time discrepancy of both post-procedural studies (ultrasound performed immediately post-procedure, while CXR was done within 4 hours) could have introduced variability in fluid re-accumulation or lung re-expansion dynamics.
- All proceduralists were interventional pulmonologists, therefore, operator skill may not be generalizable to all practice settings.
- Despite being blinded, reviewers may have had prior preferences for one modality, subtly influencing interpretation.

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Suggested reading

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Article citation

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