Comparative Analysis of Thoracic Ultrasound and Contrast-Enhanced CT in Diagnosing Pleural Empyema: A Cross-Sectional Study

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Abstract

Background: Thoracic ultrasound (TUS) and contrast-enhanced CT (CECT) are integral in pleural empyema diagnosis.

Objective: To compare diagnostic yield, accuracy, and clinical utility of TUS vs CECT in confirmed empyema.

Methods: Cross-sectional study done on 80 adult patients with suspected empyema presenting to Saraswathi Institute of Medical Sciences, Hapur Casualty, IPD or OPD. Patients underwent TUS and CECT Thorax. Sensitivity/specificity for effusion, septation, loculation, and split-pleura sign were calculated. Procedural guidance, safety, cost, and time to intervention were evaluated.

Results: TUS detected effusions in 98%, septations in 85%, and loculations in 83%. CECT detected septations in 60% and split-pleura in 75%. Sensitivity of TUS vs CECT: effusion (98% vs 90%), septation (85% vs 60%), loculation (83% vs 65%). TUS enabled bedside drainage in 92% and avoided CECT in 60% of patients.

Conclusion: TUS demonstrated superior sensitivity for internal septations and loculations and provides real-time, radiation-free, cost-effective bedside guidance. CECT is complementary for anatomical delineation and surgical planning.

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Introduction

Pleural empyema continues to represent a significant global health burden, especially in developing countries where delayed diagnosis often leads to poor outcomes. Despite advances in imaging modalities and treatment techniques, the incidence of empyema has been steadily rising worldwide, particularly among elderly and immunocompromised populations.

Pleural empyema is defined as the accumulation of purulent material within the pleural space. It is a progressive, potentially life-threatening pleural infection. Clinically it is divided into Exudative, Fibrinopurulent and Organising types. Despite advances in antibiotics and drainage techniques, empyema continue to pose significant diagnostic and therapeutic challenges in both resource rich and resource limited settings. Traditional imaging modalities, such as chest X-rays, provide limited information, especially in differentiating uncomplicated parapneumonic effusions from complicated empyema requiring urgent intervention. This has led to increased reliance on thoracic ultrasound (TUS) and contrast-enhanced CT (CECT), which offer complementary diagnostic roles. While TUS provides rapid, bedside, real-time evaluation, CECT enables detailed anatomical assessment, particularly useful in surgical planning.

Chest Xray

Empyema can resemble a pleural effusion or mimic a peripheral pulmonary abscess a number of features usually enable distinction between the two. Generally, empyemas form an obtuse angle with the chest wall, and due to their lenticular shape are much larger in one projection.

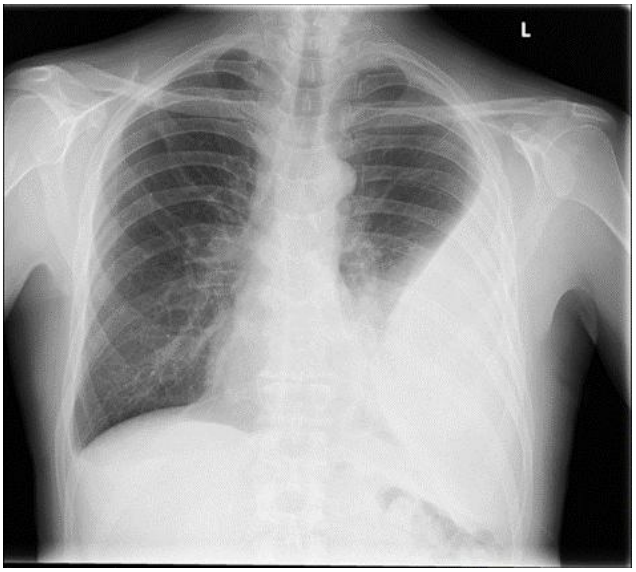

Fig 1

Ultrasound

The appearances of an empyema depend on the composition of the collection. Typically they are not uniformly anechoic and are often septated.

Fig 2

CT Thorax

Typically appears as a fluid density collection in the pleural space, sometimes with locules of gas due to gas-forming organisms or fistula. They form obtuse angles with the adjacent lung, which is displaced and compressed.

The pleura is thickened due to fibrin deposition and ingrowth of vessels with enhancement which is more obvious during portal venous phase.

At the margins of the empyema, the pleura can be seen dividing into parietal and visceral layers, the so-called Split Pleura Sign, which is the most sensitive and specific sign on CT and is helpful in distinguishing an empyema from a parapneumonic effusion or a peripheral lung abscess.

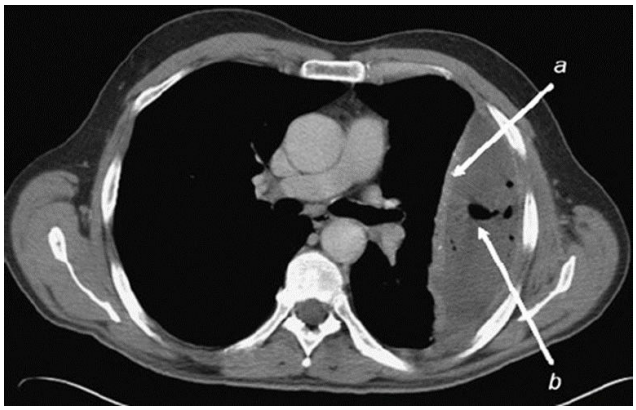

Fig 3

Approximately 20% to 40% of patients admitted for pneumonia experience associated parapneumonic effusion. Among these, 5% to 10% will develop empyema; 30% of these patients require surgical drainage, and the mortality rate for these patients is 15%. Less frequently, empyema can arise from conditions such as bronchogenic carcinoma, esophageal rupture, blunt or penetrating chest trauma, infectious mediastinitis spreading to the pleurae, infection crossing the diaphragm from abdominal sources, spinal infections, or postsurgical complications.

Methods

Study design & setting: Cross-sectional study at Saraswathi Institute of Medical Sciences, Hapur from November 2024 to May 2025.

Participants: Adults (>18 years) with suspected empyema based on clinical and chest X-ray findings.

Inclusion/exclusion criteria: Included clinical suspicion of empyema; excluded trauma, surgery. **Procedures:** All patients underwent bedside TUS (5–12 MHz probe) and contrast-enhanced CT thorax. TUS findings recorded: presence and volume of effusion, septations, free vs loculated fluid. CECT findings: pleural thickening, split-pleura sign, loculations.1, 2.

Outcome measures:

- Primary: sensitivity and specificity of modalities in empyema diagnosis (confirmed by thoracentesis or operative findings).
- Secondary: procedural guidance success, time to intervention, cost, radiation exposure.

Statistical analysis: Sensitivity, specificity, PPV, NPV calculated. Categorical comparisons by χ^2; $P<0.05$ significant.

Results

Effusion detection	TUS 98%, CECT 90%
Septation detection	TUS 85% VS CECT 60% (P<0.01)
Loculations	TUS 83% VS CECT 65%
Split-pleura sign	CECT POSITIVE IN 75%
Bedside chest tube placement	GUIDED BY TUS IN 92%

- Pleural effusion was detected in 98% of patients by using TUS as compared to 90% on CECT Thorax.
- Internal Septations were noted more precisely by using TUS (85%) as compared to CT thorax which helped in 60% cases only.
- Loculations were also seen more in TUS as compared to CT thorax which was 83% in TUS and 65% in CT.
- By using CECT Thorax, split pleura sign was seen in 75% of patients.

In 92% of patients TUS helped to do bedside chest tube placements.

Discussion

Ultrasound Sensitivity for Septations and Loculations

Our study demonstrated that TUS detected septations in 85% of patients, which is comparable to the findings of Qureshi *et al*. (2016) [3], who reported a sensitivity of 82.6% and specificity of 100% for ultrasound in identifying septated empyema compared to CT's 59.8% sensitivity.3 Similarly, Abdelrahman *et al*. (2022) [4]. found ultrasound superior to CT in detecting internal echoes and loculated collections, concluding that TUS is more sensitive in identifying empyema complexity, particularly in early fibrinopurulent stages.4

CT's Role in Detecting Split-Pleura and Adjacent Disease

CT was more effective in identifying split-pleura sign (75%) in our cohort, consistent with Chen *et al*. (2015) [5], who emphasized the specificity of this feature in differentiating empyema from lung abscess.5 While ultrasound cannot reliably visualize pleural thickening or enhancement, CT provides anatomic clarity, especially in complex or organizing empyemas.

Impact on Clinical Management and Intervention

Time-to-drainage is a critical determinant of empyema prognosis. Studies have shown that early drainage, particularly within 24–48 hours of diagnosis, correlates with shorter hospital stays and reduced morbidity.

Bedside ultrasound facilitated chest tube placement in 92% of cases in our study, which aligns with Lichtenstein *et al*. (2004) [6]. who reported TUS allowed for accurate, real-time, image-guided thoracentesis in over 95% of cases.6

In addition, a prospective trial by Reissig and Kroegel (2007) [7]. showed that TUS significantly reduced time to intervention and avoided unnecessary CT in more than 60% of patients with uncomplicated parapneumonic effusions.[7]

Operator Dependency and Limitations of Ultrasound

While TUS shows high accuracy, its operator dependency is a consistent limitation noted in literature. Koegelenberg *et al*. (2011) [8]. highlighted that TUS sensitivity for pleural disease may drop in obese patients or those with subcutaneous emphysema.8 This reinforces the need for standardized training and protocols to optimize diagnostic yield.

Radiation and Cost Considerations

Given the increasing awareness of cumulative radiation risks, particularly in younger patients and those requiring multiple follow-ups, TUS offers a radiation-free, low-cost modality, which is especially valuable in pediatrics, pregnancy, or repeated follow-up. A cost-benefit analysis by Miller *et al*. (2013) [9]. estimated that using TUS as a first-line tool in suspected pleural infections could reduce imaging- related costs by nearly 40%, supporting its adoption in resource-limited settings.9

Agreement with Current Guidelines

The findings of our study align with British Thoracic Society (BTS) and American Association for Thoracic Surgery (AATS) guidelines, both of which recommend initial use of ultrasound to confirm and characterize pleural effusions, reserving CT for uncertain or complex cases.10,11

Comparison to Other Imaging Modalities

Several recent studies have suggested that MRI can match or exceed CT in certain chronic empyema settings, particularly when assessing pleural fibrosis. However, MRI remains costlier and less accessible. Thus, ultrasound and CT together continue to represent the most pragmatic diagnostic pathway in routine clinical practice.12

Strengths & limitations:

Strengths

Direct, head-to-head comparison of TUS and CECT within the same patient cohort.

Evaluation of both diagnostic accuracy and clinical utility, providing a comprehensive perspective.

Inclusion of real-world procedural outcomes, such as bedside drainage success rates.

Limitations

Single-center design may limit generalizability.

Operator dependency of ultrasound could affect reproducibility across institutions. Lack of long-term follow-up to evaluate recurrence rates or complications.

Conclusion

Thoracic ultrasound (TUS) has emerged as a highly sensitive, radiation-free, and cost-effective first-line imaging tool for diagnosing pleural empyema. Its superiority in detecting internal septations, early loculations, and guiding bedside interventions makes it indispensable, especially in emergency and resource-limited settings. While contrast-enhanced CT retains value for detailed anatomical mapping, surgical planning, and differentiation from alternative diagnoses, a TUS-first strategy significantly streamlines patient management, and minimizes radiation exposure. In resource limited settings, availability of TUS is more and also TUS is much cheaper as compared to CECT Thorax which eventually reliefs some financial burden of patient's family which is an important factor for patients in developing countries like India.

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