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Accuracy of Computed Tomography Attenuation Values in Differentiating Transudative from Exudative Pleural Effusion

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ABSTRACT

Introduction: Pleural effusion, the accumulation of fluid between the lungs and chest wall, arises from various diseases. Differentiating transudative from exudative effusions is essential for diagnosis and management. While thoracentesis is the standard, CT offers a non-invasive alternative. This study assesses the accuracy of CT attenuation values in distinguishing effusion types.

Methods: A single-center cross-sectional study was conducted at the Radiology Department, Patan Academy of Health Sciences, over one year. Patients with pleural effusion who underwent CT and thoracentesis within 48 hours were included. CT scans (Philips Ingenuity Core 128) measured attenuation values in Hounsfield Units (HU). Effusions were classified using Light's criteria, and diagnostic performance was evaluated with ROC analysis to determine optimal cut-off values.

Results: Among 137 patients, 41 (29.9%) had transudative and 96 (70.1%) had exudative effusions. Mean attenuation values were 7.66±3.22 HU for transudative and 10.75±3.80 HU for exudative effusions, with a significant difference (P=0.00001). ROC analysis identified 10.6 HU as the optimal cut-off, with 55.2% sensitivity, 87.8% specificity, 91.3% positive predictive value, and 45.5% negative predictive value. Features like pleural nodules, thickening, and loculations were not significantly differentiators (p>0.05).

Conclusions: CT attenuation values offer a significant, specific, non-invasive method for distinguishing effusion types, beneficial for patients contraindicated for thoracentesis. Sensitivity remains moderate, but CT is a valuable diagnostic tool.

Keywords: *Lung; Pleural Effusion; Thoracentesis*

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INTRODUCTION

Pleural effusion is the accumulation of fluid between the pleural membranes surrounding the lungs. It can be classified as a transudate or exudate, which differ in causes and require distinct treatments. Globally, common causes include heart failure, cirrhosis, parapneumonic effusions, and malignancy, while tuberculosis remains the leading cause in Nepal and neighboring countries. Accurate differentiation is vital for appropriate management.[1,2,3,4]

Thoracentesis, guided by Light's criteria, is the gold standard for distinguishing transudates from exudates by comparing protein and LDH levels in pleural fluid and serum. However, this invasive procedure carries risks like pneumothorax and bleeding, and may not always be feasible.

Computed tomography (CT) attenuation values offer a non-invasive alternative, with studies suggesting exudates generally have higher attenuation values than transudates. This study aims to determine optimal CT cut-off values for differentiating effusion types, benefiting patients where thoracentesis poses significant risks.[5,6,7,8]

METHODS

Pleural effusion is the accumulation of fluid between the pleural membranes surrounding the lungs. It can be classified as a transudate or exudate, which differ in causes and require distinct treatments. Globally, common causes include heart failure, cirrhosis, parapneumonic effusions, and malignancy, while tuberculosis remains the leading cause in Nepal and neighboring countries. Accurate differentiation is vital for appropriate management.[1,2,3,4]

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This study was a prospective observational analytical study conducted in the Department of Radiology at Patan Academy of Health Sciences (PAHS) over one year after obtaining approval from the Institutional Review Committee (IRC). Data collection followed a simple random sampling method, with a sample size of 137 patients. Inclusion criteria mandated that all patients with pleural effusion admitted to the medical or surgical wards and planned for a contrast-enhanced chest CT scan were eligible, provided they underwent thoracentesis. Exclusion criteria included patients with prior pleural tube placement, contraindications to thoracentesis, a history of traumatic pleural collection, or pleural effusion with a maximum dimension of less than 1 cm.

Thoracentesis was performed by the on-duty resident after obtaining informed consent. Under aseptic precautions, the procedure was carried out with the patient in a sitting position using a 10 mL syringe to aspirate pleural fluid from the side with the larger effusion. Ten milliliters of pleural fluid were collected and sent to the laboratory for analysis. Serum LDH and total protein levels were measured alongside pleural fluid analysis. All patients underwent CT scans of the chest within 48 hours of thoracentesis using the PHILIPS Multi-slice CT scanner Ingenuity Core 128. Scanning parameters included 120 kVp, automated mA, slice thickness of 1-10 mm, and a pitch of 1.

On CT, the attenuation values of pleural fluid were measured in Hounsfield Units (HU) on non-contrast images. Values were obtained by averaging measurements from three slices with the greatest fluid quantity, determined by the largest anteroposterior diameter of the pleural effusion. In cases of bilateral pleural effusions, measurements were taken from the side where thoracentesis was performed. Care was taken to exclude ribs, diaphragm, pleural thickening, and lung parenchyma from the region of interest. Each CT image was also assessed for features such as pleural nodules, thickening, and loculations.

Data were recorded in pre-designed proformas and analyzed using EPI Info V7.2.2.2 and EZ R software. The Shapiro-Wilk test was applied to assess data normality, revealing a normal distribution for CT attenuation values and a non-normal distribution for other variables. Mean CT attenuation values for transudates and exudates were expressed as mean ± SD. The variance of attenuation values between the two groups was tested using an F-test, confirming similar variances. An independent sample t-test was used to compare the attenuation values of transudates and exudates. Descriptive statistics, including frequencies and percentages, were calculated for variables such as age, sex, effusion type, and CT features like pleural nodules, thickening, and loculations.

Receiver Operating Characteristic (ROC) curve analysis was employed to evaluate the diagnostic performance of CT attenuation values in distinguishing transudates from exudates. Cut-off values were identified to optimize sensitivity and specificity for differentiation. The area under the curve (AUC), along with sensitivity, specificity, and p-values, was calculated for the chosen cut-off. A p-value <0.05 was considered statistically significant. The Chi-square test was used to compare categorical variables such as pleural nodules, thickening, and loculations between transudates and exudates. The findings aimed to determine the utility of CT attenuation values as a non-invasive diagnostic tool for pleural effusion classification.

Fig 1a

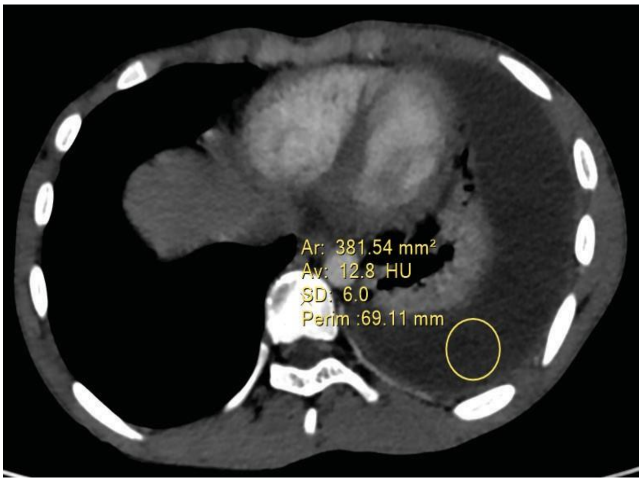

Fig 1b

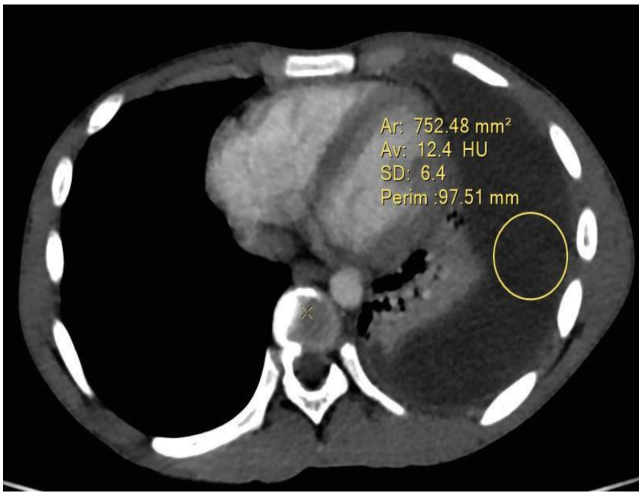

Fig 1c

Figure 1: *a, b, and c showing measurement of Hounsfield unit at the region of interest (ROI) at three different slices on the same side of the same patient*

RESULTS

In the biochemical analysis based on Light's criteria, 41 (29.9%) patients were classified as transudative, and 96 (70.1%) were classified as exudative. The median age±interquartile range of the patients with transudative effusion was 66.5±18.1years, and the median age±interquartile range of the patients with exudative pleural effusion (PE) was 55.5±34 years. Of the 41 (29.9%) patients with transudative PE, 18 (43.9%) were male and 23 (56.1%) were female (Figure 2). Of the 96 (70.1%) patients with exudative PE, 52 (54.1 %) were male and 44 (45.8%) were female (Figure 2).

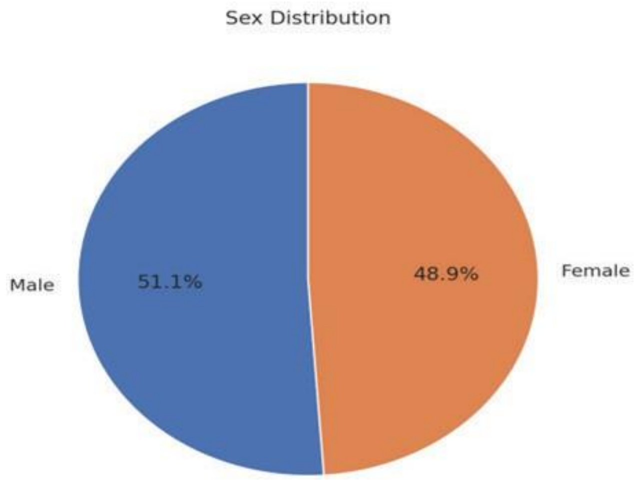

Figure 2: *Pie chart showing sex distribution*

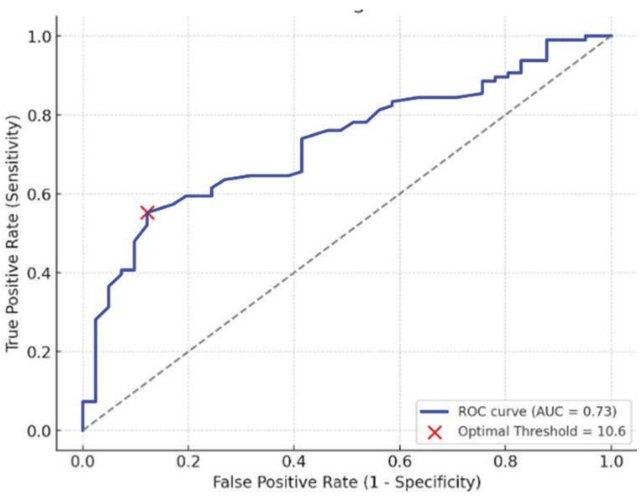

Figure 3: *Graph shows receiver operating characteristic (ROC) curve plotting 100-specificity (x axis) against sensitivity (y axis) with area under ROC curve of 0.729*

The mean attenuation ± standard deviation value for the patients with transudative PE was calculated as 7.66±3.22 HU, whereas the mean HU value for the patients with exudative PE was calculated as 10.75±3.80 HU (Table 2).

Table 1: Comparison of mean CT attenuation values in exudate and transudate

	Patients with transudate	Patients with exudate	P value
CT attenuation value (mean)	7.66 ± 3.22 HU	10.75 ± 3.80 HU	0.00001

The independent t-test made for the transudate-exudate differentiation revealed a statistically significant difference (p=0.00001) between the mean CT attenuation of exudative and transudative pleural effusions. In the ROC analysis carried out to determine the cut-off value of the attenuation value of pleural effusion in the transudate-exudate differentiation, the area under the curve was found to be 72.9% (Figure 3).

When the cut-off value was taken as 10.6 HU for the area under the curve, sensitivity was found to be 55.2%, specificity was 87.8%, positive predictive value was 91.3% and negative predictive value was 45.5%.

None of the additional CT features accurately differentiated exudates from transudates (P>0.05). Fluid loculation was found in 19% of exudates and in 29% of transudates. Pleural thickening was found in 41% of exudates and in 36% of transudates. Pleural nodule was found in 29% of exudates and in 24% of transudates. The p-values for all three features (Pleural Thickening, Pleural Nodule, and Septation) are greater than 0.05, indicating that there is no statistically significant difference between transudate and exudates based on the presence of these features (Table 2).

Table 2: Comparison of pleural characteristics between transudates and exudates

	Patient with exudate	Patient with transudate	P value
Pleural nodule	28(29%)	10(24%)	0.71
Pleural thickening	40(41%)	15(36%)	0.71
Loculations	18(19%)	12(29%)	0.25

DISCUSSION

In this study, we aimed to assess the utility of computed tomography (CT) attenuation values in distinguishing between transudative and exudative pleural effusions, offering an alternative to the more invasive thoracentesis. Our findings, when compared with other studies, provide a comprehensive insight into the effectiveness of CT in pleural effusion classification and highlight both the strengths and limitations of this approach.

Our findings align partially with those reported by Nandalur et al., who also found a statistically significant difference in mean attenuation values between exudates and transudates (17.1 HU vs. 12.5 HU, respectively). Their study had a higher sensitivity (83.2%) but a lower specificity (70.5%) when a threshold of 13.4 HU was applied. The AUC in their ROC analysis was 0.78, suggesting slightly better discriminatory power than our study. Sharma et al. similarly reported a higher mean attenuation for exudates (16.5 HU) compared to transudates (11.6 HU), with a sensitivity of 81.08% and specificity of 100% at a threshold of 15.3 HU. The slight discrepancy in the cut-off values between studies, including ours, suggests that there may be regional or population-based differences in pleural fluid characteristics. Variations in CT technology, like using dual energy CT for measuring attenuation value at different energy levels, can assist in differentiating exudative from transudative pleural effusion with specific thresholds. Different imaging protocols, such as the number of slices and regions of interest selected, can lead to discrepancies in HU measurements. Despite these minor variations, the overall agreement between these studies reinforces the diagnostic utility of CT attenuation values in distinguishing exudates from transudates.[5,9]

Our findings regarding the lack of significant differences in additional CT features such as pleural thickening, nodules, and loculation are consistent with those of Abramowitz et al., who reported that these features did not correlate significantly with effusion type (p>0.1). However, other studies have indicated a higher prevalence of these features in exudative effusions. For example, Sharma et al. found that pleural thickening, loculation, and nodules were more frequent in exudates, particularly in cases of malignancy and tuberculosis. They reported pleural thickening in 29.7% of exudates compared to 15.3% of transudates, and loculation in 35.13% of exudates versus 19.2% of transudates11. This suggests that while additional CT features may not be statistically significant in isolation, they could still provide supplementary diagnostic information in specific clinical contexts, such as infectious or malignant effusions.[10,11,12,13,14]

The lack of significant differentiation based on pleural morphology in our study suggests that fluid attenuation values, rather than pleural structural changes, should be prioritized when using CT to classify pleural effusions. Pleural thickening and loculations may develop in response to long-standing effusions of either type and, as such, are not reliable indicators of the underlying pathology. This is particularly important in cases where pleural fluid has been present for an extended period, leading to chronic changes that could obscure the true nature of the effusion.

While our study demonstrated a statistically significant difference in mean attenuation values between exudative and transudative effusions, the moderate sensitivity observed at our cut- off value of 10.6 HU (55.2%) suggests that CT attenuation alone may not be sufficient for reliable differentiation in all cases. The relatively high specificity (87.8%) indicates that when attenuation values exceed this threshold, the likelihood of exudative effusion is high, but lower values may not reliably indicate a transudative effusion. This is consistent with the findings of Abramowitz et al., who reported significant overlap in attenuation values between exudates and transudates, leading to an AUC of 0.582 and poor sensitivity (55.1%) at a cut-off of 8.5 HU. He also found that the mean CT attenuation value for exudate is significantly lower than that of transudate.[10]

Our findings are consistent with those of other studies, which also report significant variability in cut-off values and diagnostic accuracy. Additional CT features, though not statistically significant in our study, may play a complementary role in specific clinical scenarios.

CONCLUSION

CT attenuation values provide a specific and non-invasive approach to differentiating types of effusions, making them particularly useful for patients who cannot undergo thoracentesis. While the sensitivity is moderate, CT remains a valuable tool in the diagnostic process. Future studies should aim to enhance imaging protocols and combine CT results with other diagnostic methods to increase the accuracy of pleural effusion classification.

CONFLICT OF INTEREST

None

SOURCES OF FUNDING

None

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