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# Use of the Hounsfield unit scale in differentiating transudate and exudate in pleural effusion in the emergency department

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**Abstract**

Attenuation values in computed tomography (CT) are used as a diagnostic aid in certain clinical conditions. In our study, we investigated the effectiveness of attenuation values, obtained through the noninvasive method of CT, in determining the type of pleural effusions in the emergency department. Patients who presented to the emergency department with a diagnosis of pleural effusion and underwent thoracentesis within 48 hours between January 1, 2023, and January 1, 2024, were included in the study. Exclusion criteria were patients under 18 years of age, those without CT imaging, those presenting due to trauma, those with >48 hours between CT and thoracentesis, patients with chest tubes, a history of thoracic surgery/intervention within the last month, or incomplete data. Attenuation values measured on CT were compared with pleural fluid samples interpreted according to Light criteria. A total of 207 patients were evaluated. The mean age in the exudate group (66.00 ± 15.63) was significantly lower than in the transudate group (72.98 ± 10.38) ($P < .001$). The prevalence of malignancy was significantly higher in the exudate group (34.0%) compared to the transudate group (4.4%) ($P < .001$). Heart failure was more common in the transudate group (31.1%) ($P = .041$). The mean Hounsfield unit (HU) value was 16.64 ± 8.04 in the exudate group and 12.22 ± 7.01 in the transudate group, with a statistically significant difference between the groups ($P = .001$, 95% confidence interval [CI]: 1.79–7.05). At the cutoff point of 14.2, sensitivity was 62.73%, specificity was 75.00%, and the Youden index reached its highest value at 0.377. The area under the curve was 0.710 (95% CI: 0.626–0.794, $P < .001$), and the positive predictive value at the 14.2 cutoff point was 90.18%. In conclusion, our study demonstrated that the use of CT attenuation in managing pleural effusions in the emergency department can accurately detect exudative effusions as a noninvasive method. However, HU values should be evaluated alongside clinical parameters, and the varying cutoff values reported in different studies suggest that this method may not be sufficient on its own. In the emergency department setting, the use of the HU scale could improve patient management by avoiding complications associated with invasive procedures like diagnostic thoracentesis.

**Abbreviations:** AUC = area under the curve, CAD = coronary artery disease, CHF = congestive heart failure, CI = confidence interval, CKD = chronic kidney disease, COPD = chronic obstructive pulmonary disease, CT = computed tomography, HU = Hounsfield unit, IQ = Interquartile, NPV = negative predictive value, PPV = positive predictive value, SD = standard deviation

**Keywords:** emergency service, exudates and transudates, Hospital, Hounsfield units, pleural effusion, tomography, X-ray computed

## 1. Introduction

Pleural effusions result from imbalances between the production and absorption of pleural fluid. They can range from benign causes, such as viral pleuritis, to life-threatening conditions like heart failure and malignancy. Approximately 50% of patients diagnosed with malignant pleural effusion die within 1 year.[1] Therefore, the most crucial step in managing pleural effusion is determining whether the effusion is a transudate or an exudate, which requires sampling of the pleural fluid. Light criteria are used to classify the effusion as transudative or exudative.[2] Although thoracentesis is a relatively simple procedure, it carries risks of serious complications such as pneumothorax, chest wall hematoma, hemothorax, and infection. Pneumothorax can occur in up to 6% of cases following thoracentesis.[3] Additionally, performing chest wall procedures when performed by inexperienced operators can increase the complication rate.[4]

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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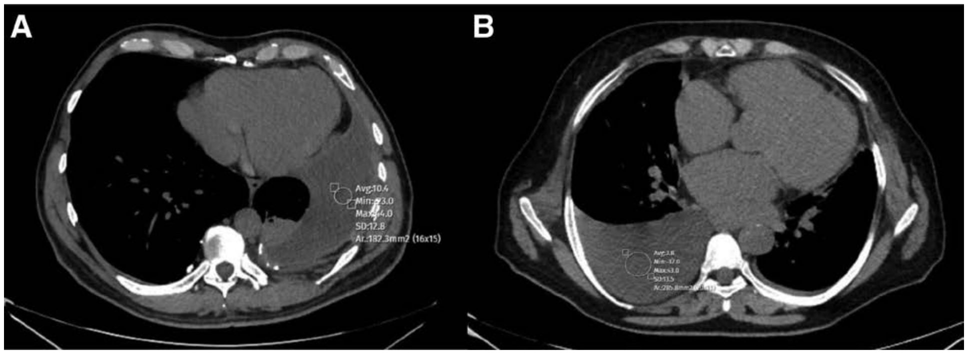


**Figure 1.** (A) In a 54-year-old male patient, unilateral pleural thickening, calcified pleural plaques, and a high-density pleural effusion were observed, with an average attenuation value measured at 10.4. (B) In a 67-year-old female patient with signs of congestive heart failure, minimal left-sided and massive right-sided pleural effusion were noted. The average attenuation value of the right pleural effusion was measured at 3.8.

Emergency departments are chaotic environments where rapid decision-making is essential. While therapeutic thoracentesis may be necessary in some cases, diagnostic thoracentesis is not an absolute indication in the emergency department but remains crucial for patient management and follow-up. Determining whether the effusion is a transudate or exudate guides further treatment and monitoring. In transudative cases, no further investigation is usually required, whereas exudative cases necessitate more specific tests and evaluations for targeted treatment.[5] Furthermore, it is recommended that patients be monitored for 4 hours postthoracentesis to detect complications, which can prolong emergency department waiting times.[1]

In nontraumatic chest pathologies, computed tomography (CT) is the most frequently used imaging method after chest X-rays in the emergency department. It is the preferred imaging modality for chest pathologies and suspected malignant pleural effusions, as indicated in the literature.[6,7] CT works by measuring the attenuation of X-rays, and the Hounsfield unit (HU) is a quantitative measure used in CT interpretation to assess radiodensity.[8] As tissue density increases, the HU value is expected to rise. Under normal conditions, water has an HU value of 0, air −1000, and dense bones 1000. While HU values are well established for certain diagnoses, there is no universally accepted approach for determining the nature of pleural effusions using HU, aside from some studies in the literature.[9–11]

When pleural effusions are detected, the most important step in management is to determine the type of effusion. Except for cases with significant dyspnea or empyema, there is generally no indication for emergency thoracentesis. Thoracentesis performed outside routine procedures has been associated with high complication rates.[12] In addition to their workload, emergency departments, especially in some countries, serve as areas for citizens' access to basic healthcare services.[13,14] Therefore, proper termination and referral of patients in the emergency department is critical.

Considering the potential risks of thoracentesis, the necessity for rapid decision-making in the emergency department, and the resulting overcrowding, there is a growing need for faster and noninvasive diagnostic tools. In our study, we aimed to determine the role of HU values in differentiating between transudates and exudates.

## 2. Methodology

Our study is a retrospective, observational, and descriptive analysis. Patients who were admitted to the emergency department, diagnosed with pleural effusion, and underwent thoracentesis within 48 hours were included in the study. The research was conducted at the Emergency Department of Ankara Etlik City Hospital. The study was initiated after obtaining ethical approval from the Ankara Etlik City Hospital Ethics Committee (Ethics Committee No.: AEŞH-BADEK-2024-147). Through the hospital's information system, patients who presented to the emergency department and underwent thoracentesis between January 1, 2023, and January 1, 2024, were identified. Patients under 18 years of age, those who did not have CT imaging performed in the emergency department, those who presented due to trauma, those with >48 hours between the thoracentesis and chest CT, those with a chest tube, those with a history of thoracic surgery or intervention within the last month, and patients with missing data were excluded from the study. Patient data, including age, gender, CT findings, final diagnoses, pleural fluid sampling results, and the classification of pleural fluids into transudate and exudate based on Light criteria, were collected.[2] The average HU value was recorded from measurements taken at 3 different points.

### 2.1. CT examinations

CT examinations were performed using a 128-detector General Electric Revolution EVO CT scanner. The scans were obtained without contrast material, with a section thickness of 0.625 mm and a section interval of 0.6 mm, covering the area from the lung apices to the costodiaphragmatic sinuses. Effusion thickness was measured at its deepest point in the posterior-anterior direction on axial sections. Measurements in HU were obtained using regions of interest in appropriate sections. At least 3 measurements were taken, and the average value was recorded. Care was taken to select areas distant from anatomical structures that could affect effusion density (such as lung parenchyma, ribs, and pleural thickening regions). Radiologists performed the measurements independently, blind to the patients' clinical information and each other's results, in a double-blind manner (Fig. 1).

### 2.2. Statistical analysis

In this study, data analysis was performed using IBM Statistics for macOS, version 28.0 (IBM Corp, Armonk, NY) and Jamovi for macOS software. The Shapiro–Wilk test, Q-Q plots, and histograms were used to assess the normal distribution of continuous variables. The independent sample $t$ test was applied for comparisons of normally distributed continuous variables between groups. For nominal variables, Pearson chi-square test or Fisher exact test was used to evaluate differences between groups. Statistical significance was set at $P < .05$ for comparisons between groups.

Normally distributed continuous variables were presented as mean ± standard deviation (mean ± SD), and differences between groups were reported with 95% confidence intervals (CI). Cutoff points were employed to assess the performance of different thresholds, and sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Youden indices were calculated. The overall performance of the model was evaluated using the area under the curve (AUC), and significance was determined by the *P* value.

## 3. Results

A total of 271 cases were identified through the system search, and after applying exclusion criteria, 207 patients were included in the final analysis (Fig. 2). The mean age of patients in the exudate group (66.00 ± 15.63) was significantly lower than that in the transudate group (72.98 ± 10.38) ($P < .001$). No significant difference was found in the gender distribution between the 2 groups ($P = .06$). No significant difference was observed between the groups in terms of effusion thickness ($P = .24$). Malignancy was more common in the exudate group (34.0%) compared to the transudate group (4.4%) ($P < .001$). Heart failure was more prevalent in the transudate group (31.1%) ($P = .041$). No significant differences were found between the groups for other factors (Table 1).

Significant biochemical differences were found between the exudate and transudate groups. The pleural lactate dehydrogenase levels were significantly higher in the exudate group (1165.47 ± 3787.47) compared to the transudate group (94.41 ± 31.23) ($P < .001$, 95% CI: 473.91–1668.21). Pleural total protein levels were also significantly higher in the exudate group (40.16 ± 12.86) compared to the transudate group (23.99 ± 8.25) ($P < .001$, 95% CI: 13.02–19.33). The mean HU value was 16.64 ± 8.04 in the exudate group and 12.22 ± 7.01 in the transudate group, with a statistically significant difference between the groups ($P = .001$, 95% CI: 1.79–7.05). No statistically significant difference was observed in serum lactate dehydrogenase and serum total protein levels ($P > .05$) (Table 2).

The performance of the model was evaluated for different cutoff points. At a cutoff point of 14.2, the sensitivity was 62.73%, and the specificity was 75.00%, with Youden index reaching its highest value of 0.377. This indicates that the model demonstrates its best performance at this cutoff point. The AUC value was 0.710 (95% CI: 0.626–0.794), with a *P* value of < 0.001. The positive predictive value at the cutoff point of 14.2 was found to be 90.18% (Table 3).

HU values showed significant efficacy in differentiating exudates from transudates in pleural effusions (Fig. 3).

## 4. Discussion

Our study demonstrated that the HU scale, when used as a noninvasive method with a cutoff value of 14.2 and combined with clinical correlation, achieved high accuracy in detecting exudates in the emergency department, with a 90% PPV and 75% specificity. Considering the complications of diagnostic thoracentesis and the limited resources of emergency departments, the use of the HU scale may facilitate faster referral of patients to advanced diagnostics and treatment, thereby accelerating emergency department processes. This can offer a significant advantage, especially when not all diagnostic tools are available in the emergency department.

Our study found that patients with exudates were significantly younger than those in the transudate group. Similarly, the literature indicates that the exudate group consists of younger patients.[9–11,15] Our study also shows that the rates of malignancy are higher in the exudate group. The higher average age in the transudate group may be due to conditions, such as heart

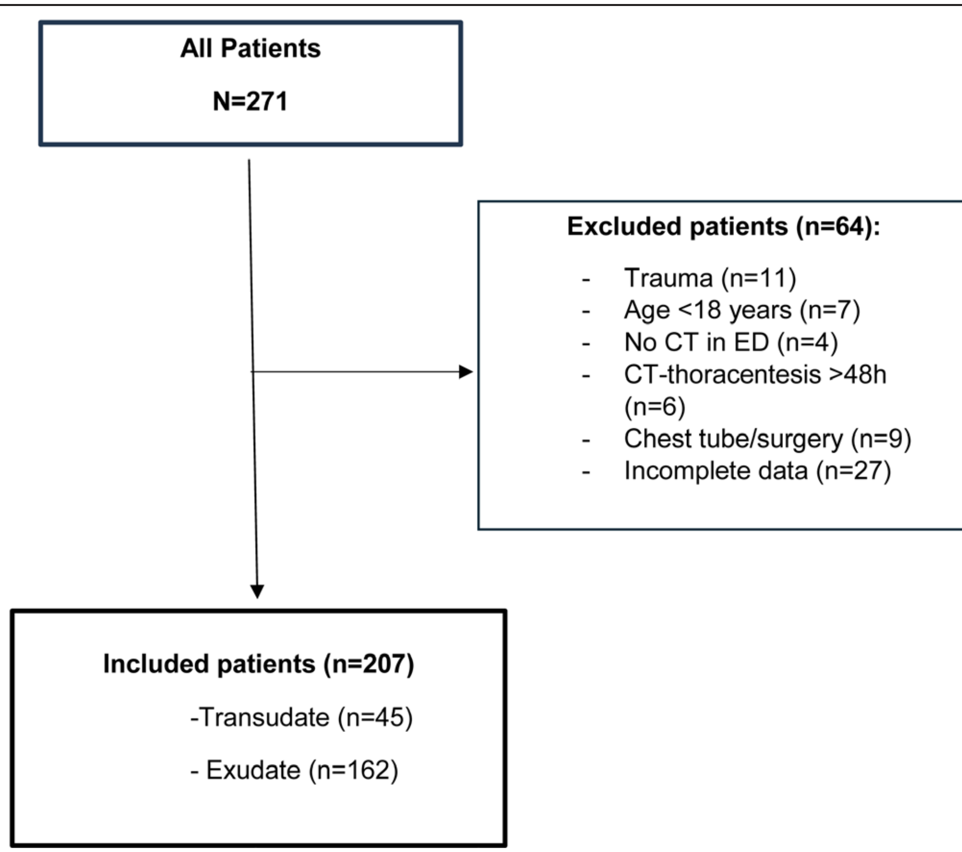


**Figure 2.** Flow diagram of patient inclusion and exclusion criteria. Out of 271 total patients, 64 were excluded due to trauma (n = 11), age < 18 years (n = 7), absence of computed tomography (CT) in the emergency department (ED; n = 4), CT-thoracentesis interval > 48h (n = 6), chest tube placement or surgery (n = 9), or incomplete data (n = 27). The final study population consisted of 207 patients, categorized as transudate (n = 45) and exudate (n = 162).

**Table 1**

**General characteristics of patients undergoing thoracentesis.**

| | | Exsuda | Transudate | *P* value | (95% CI) |
|---|---|---|---|---|---|
| Age, yr; median ± SD | | 66.00 ± 15.63 | 72.98 ± 10.38 | <.001* | −10.98 to −3.06 |
| Sex, n (%) | Male | 111 (68.5) | 24 (53.3) | .06† | |
| | Female | 51 (31.5) | 21 (46.7) | | |
| Effusion size (mm) | | 54.03 ± 31.87 | 47.86 ± 28.56 | .24* | −4.19 to 16.52 |
| Effusion side | Right | 76 (46.9) | 11 (24.4) | **<.001**† | |
| | Left | 41 (25.3) | 5 (11.1) | | |
| | Bilateral | 45 (27.8) | 29 (64.4) | | |
| Parenchymal nodule | Yes | 17 (710.5) | 2 (4.4) | .38‡ | |
| | No | 145 (89.5) | 43 (95.6) | | |
| Pleural thickening | Yes | 22 (13.6) | 3 (6.7) | .21† | |
| | No | 140 (86.4) | 42 (93.3) | | |
| Loculation | Yes | 30 (18.5) | 5 (11.1) | .24† | |
| | No | 132 (81.5) | 40 (88.9) | | |
| Empyema | Yes | 23 (14.2) | 3 (6.7) | .18† | |
| | No | 139 (85.8) | 42 (93.3) | | |
| Malignancy | Yes | 55 (34.0) | 2 (4.4) | **<.001**† | |
| | No | 107 (66.0) | 43 (95.6) | | |
| CHF | Yes | 28 (17.3) | 14 (31.1) | **.04**† | |
| | No | 134 (82.7) | 31 (68.9) | | |
| COPD | Yes | 31 (19.1) | 8 (17.8) | .84† | |
| | No | 131 (80.9) | 37 (82.2) | | |
| Others | Yes | 10 (6.2) | 4 (8.9) | .51‡ | |
| | No | 152 (93.8) | 41 (91.1) | | |

Bold values indicate statistically significant.
CHF = congestive heart failure, CI = confidence interval, COPD = chronic obstructive pulmonary disease.
* Independent sample t test.
†Pearson chi-square test.
‡ Fisher exact test.

**Table 2**

**Comparison of pleural sampling results by groups.**

| | Exsuda | Transudate | *P* value | (95% CI) |
|---|---|---|---|---|
| Pleural LDH (u/L) | 1165.47 ± 3787.47 | 94.41 ± 31.23 | <.001* | 473.91 to 1668.21 |
| Serum LDH (u/L) | 297.11 ± 377.43 | 255.88 ± 95.07 | .47* | −70.85 to 153.31 |
| Pleural protein (gr/L) | 40.16 ± 12.86 | 23.99 ± 8.25 | <.001* | 13.02 to 19.33 |
| Serum protein (gr/L) | 64.34 ± 8.19 | 63.31 ± 8.34 | .46* | −1.70 to 3.76 |
| CT attenuation (HU) | 16.64 ± 8.04 | 12.22 ± 7.01 | <.001* | 1.79 to 7.05 |

CI = confidence interval, CT = computed tomography, HU = Hounsfield unit, LDH = lactate dehydrogenase.
*Independent sample t test.

failure, that increase in frequency with age. Although the rate of malignancy increases with age for lung malignancies, most of the proposed and implemented screening models focus on patients under 75 years of age.[16] This may lead clinicians to investigate younger patients more thoroughly, potentially influencing our results.

In studies examining the efficacy of attenuation values in CT for identifying pleural effusion, we observe that the exudate group has a higher number of patients.[10,11,15,17] We believe that this dominance of exudates is due to clinicians performing fewer diagnostic thoracenteses in cases where they consider transudates for patient management. Transudate cases respond better to noninvasive treatments due to their formation mechanism, while exudate cases require cause-specific treatments, leading to a need for further investigation, which directs clinicians to determine the type of pleural fluid. In light of our study data, the high positive predictive value of high HU values for exudates may significantly contribute to these investigative processes. This could facilitate the acceleration of diagnostic procedures and ensure that patients are appropriately triaged.

Although the use of the HU scale in CT for the classification of pleural fluids has been addressed by various studies, there is still no generally accepted approach in this regard. While studies in the literature suggest that HU values may serve as a potential diagnostic tool for differentiating between exudates and transudates, varying cutoff points and performance results have been reported.

In the study conducted by Zhang et al, significant differences were found in the mean HU values between the exudate and transudate groups, with a cutoff value of 10.81 HU resulting in a 95.76% NPV and an 88.89% sensitivity. However, the PPV of 43.96% indicates that the HU scale does not fully distinguish between the 2 types of effusions.[15] Similarly, in the study by Gümüş et al, the mean HU value for exudative effusions was reported to be 15.1, while for transudative effusions, it was 5 HU. Using a cutoff point of 10 HU, a sensitivity of 89.7%, a specificity of 94%, and a positive predictive value of 97% were achieved.[10] These results indicate that HU values obtained from CT can accurately detect exudative pleural effusions, especially at higher HU values. In the study by Şafak et al, the mean HU value for exudative effusions was found to be 8.82, while for transudative effusions, it was 2.91. Using a cutoff point of 5 HU, a sensitivity of 72%, a specificity of 70%, a positive predictive value of 87%, and an NPV of 46% were obtained.[9] These findings suggest that HU values can be particularly useful in differentiating exudative effusions, although they may overlap with transudates in some cases. In the study by Kiran et al, the mean HU value for exudative pleural effusions was found to be 17.1, while for transudative effusions, it was 12.1. Although a statistically significant difference was observed between the 2 groups, it was noted that HU values largely overlapped. The authors emphasized that using HU values alone as a definitive diagnostic tool is not appropriate and do not recommend clinical use.[18]

**Table 3**

**Efficacy of HU value in differentiating between exudate and transudate.**

| HU cut point | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Youden index | AUC (95% CI), *P* value |
|---|---|---|---|---|---|---|
| 2.3 | 99.38 | 2.27 | 78.82 | 50.00 | 0.016 | 0.710 (0.626–0.794), <.001 |
| 2.5 | 98.76 | 2.27 | 78.71 | 33.33 | 0.010 | |
| 13.6 | 65.22 | 70.45 | 88.98 | 35.63 | 0.357 | |
| **14.2** | **62.73** | **75** | **90.18** | **35.48** | **0.377** | |
| 14.8 | 57.76 | 75 | 89.42 | 32.67 | 0.328 | |
| 48 | 1.24 | 100 | 100 | 21.67 | 0.012 | |
| 60 | 0.62 | 100 | 100 | 21.57 | 0.006 | |

Bold values indicate statistically significant.
The value at which Youden index is highest is 0.377.
AUC = area under the curve, CI = confidence interval, HU = Hounsfield unit, NPV = negative predictive value, PPV = positive predictive value.

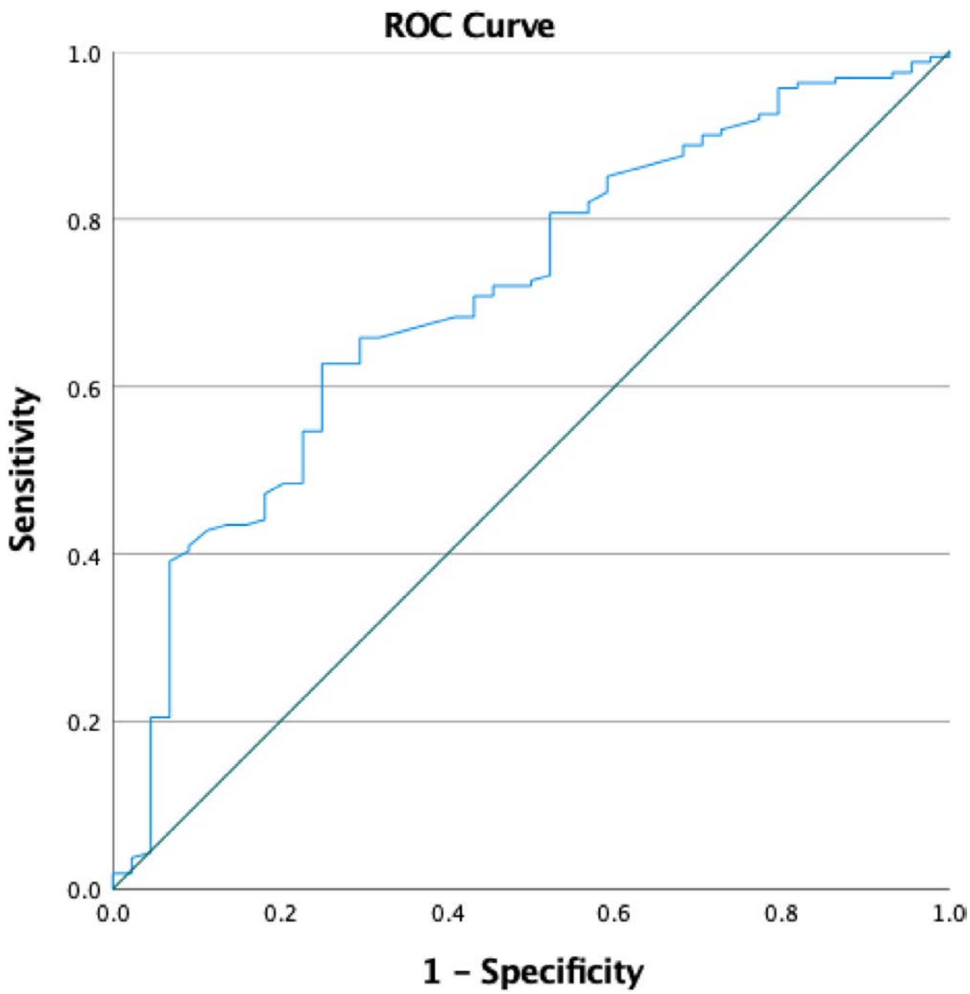


**Figure 3.** Receiver operating characteristic (ROC) curve showing the relationship between Hounsfield unit values and differentiation between transudate and exudate.

In the study conducted by Çullu et al, a significant difference in HU values was identified between exudative and transudative pleural effusions. However, it was observed that HU values overlapped to some extent. Nevertheless, the authors suggested that values above 15 HU could be interpreted as exudates, and this assessment could yield more reliable results when used in conjunction with other clinical parameters.[11]

A similar situation applies to our study group. Although there is a certain level of overlap in the values, our AUC value of 0.710 indicates that the technique has a significant discriminative power. When the cutoff value is taken as 14.2, the positive predictive value of 90.18% shows that it largely identifies exudates, similar to the literature.

Our study's primary distinction from existing literature is that it was conducted in an emergency department setting. While the use of tomographic attenuation is limited by overlapping HU values, its ability to differentiate exudates is evident. Considering that patients requiring further investigation and treatment are typically those with exudative effusions, accurately identifying and appropriately managing these cases is critical. The variations in HU cutoff values and diagnostic performance reported in different studies suggest that while HU values support the distinction between exudative and transudative pleural effusions, they may not be sufficient on their own. In the emergency department, correctly identifying and managing patients with suspected exudative effusions is crucial for effective care. Using noninvasive tomographic attenuation can reduce the risk of complications from invasive procedures. Despite its limitations, the ability of high HU values to identify exudates and potentially avoid unnecessary interventions supports the use of the HU scale in emergency departments.

Accurate triage of patients diagnosed with pleural effusion in the emergency department, particularly those believed to have exudates, is critical for effective patient management. Especially in evaluations using tomographic attenuation, a noninvasive method, it is possible to protect against potential complications from invasive procedures. Given the limitations of using tomographic attenuation for definitive diagnoses, the ability of high HU values to identify exudates, and the opportunity to avoid invasive procedures, we recommend the use of the HU scale in emergency departments.

Our study is based on a retrospective design and single-center data, focusing on emergency department management processes. We acknowledge the lack of analysis of subgroups and the absence of long-term data. Additionally, while our findings contribute to emergency department decision-making processes, it is important to note that definitive conclusions regarding the transudate group cannot be drawn due to population distribution. We recognize the need for future prospective and multicenter studies to validate these findings.

In conclusion, our study demonstrates that tomographic attenuation can be used as a noninvasive method for the management of pleural effusions in the emergency department, enabling the high-accuracy detection of exudative effusions. However, the necessity of evaluating HU values alongside clinical parameters and the varying cutoff values reported in different studies indicate that this method may not be sufficient on its own. Particularly in the limited resources of the emergency department, the use of the HU scale can enhance patient management by avoiding complications from invasive procedures such as diagnostic thoracentesis.

## Author contributions

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