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TOTAL DISSOLVED SOLIDS IN PLURAL FLUID: A PILOT STUDY COMPARING TDS ANALYSIS TO LIGHTS CRITERIA FOR EXUDATE / TRANSUDATE DIFFERENTIATION

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ABSTRACT:

Background: Differentiating exudative from transudative pleural effusions is critical for identifying underlying pathology and informing management. While Light's criteria remains the gold standard, its reliance on laboratory infrastructure and time-consuming measurements can limit its application in resource-constrained settings. This pilot study assessed the diagnostic utility of measuring Total Dissolved Solids (TDS) in pleural fluid as a rapid, bedside adjunct for distinguishing exudates from transudates and compared its performance to Light's criteria.

Methods: A pilot study was conducted in the Department of Pulmonology at Saveetha Medical College and Hospital over a three-month period, from March to May 2025. Thirty-five adult patients with radiologically confirmed pleural effusions underwent diagnostic thoracentesis. Pleural fluid TDS was measured using a calibrated handheld meter and compared with conventional biochemical parameters. Effusions were classified as exudative or transudative based on Light's criteria. Statistical analyses assessed the correlation of TDS with established markers using t-test.

Results: Among the 35 cases, 22 (62.9%) were exudative and 13 (37.1%) were transudative. Mean TDS values were significantly higher in exudates (490±110mg/L) than in transudates (310±90mg/L). TDS levels showed strong concordance with biochemical markers, particularly pleural fluid protein and LDH. Statistical analysis revealed significant associations between TDS and markers of exudation ($p<0.05$), supporting its discriminative potential.

Conclusion: TDS measurement in pleural fluid offers a simple, rapid, and cost-effective adjunct to traditional analysis for distinguishing exudative from transudative effusions. While closely aligned with Light's criteria, its ease of use and independence from laboratory resources make it particularly valuable in emergency and low-resource settings. Further studies with larger cohorts are warranted to validate diagnostic thresholds and facilitate wider clinical adoption.

Keywords: Pleural effusion, Total Dissolved Solids (TDS), Light's criteria, Exudate, Transudate.

INTRODUCTION:

Pleural effusion is defined as the pathological accumulation of fluid within the pleural cavity, a condition frequently encountered in a wide range of systemic and local disorders. The identification of its etiology is essential for diagnosis, management, and prognosis. Conditions such as congestive heart failure (CHF), pneumonia, malignancies, tuberculosis, and autoimmune diseases are among the leading causes of pleural effusions (1). Traditional biochemical analysis of pleural fluid, guided by Light's criteria, remains the gold standard for differentiating transudates from exudates (2). These criteria include the evaluation of pleural fluid protein, lactate dehydrogenase (LDH), and their ratios compared to serum values. While accurate, this process can be time-consuming, requires laboratory infrastructure, and is not always readily available in resource-limited settings (3).

To address this gap, alternative methods of rapid bedside evaluation are being explored. One such promising tool is the Total Dissolved Solids (TDS) monitor, which assesses the electrical conductivity of pleural fluid. Since the

concentration of dissolved ions and solutes contributes to the fluid's electrical properties, TDS measurements can indirectly reflect the biochemical makeup of the effusion. Transudative effusions, with their low solute and protein content, tend to have lower TDS values, whereas exudative effusions demonstrate elevated values due to their higher cellular and proteinaceous load. Thus, TDS monitoring offers a noninvasive, rapid, and potentially cost-effective adjunct to traditional biochemical analysis, especially useful in emergency, remote, or resource-poor environments (4,5).

This pilot study was conducted to evaluate the diagnostic utility of Total Dissolved Solids (TDS) measurement in pleural fluid for differentiating exudative from transudative effusions and to compare its performance with the established Light's criteria.

METHODOLOGY:

This pilot study was carried out over a three-month period in the Department of Pulmonology at Saveetha Medical College and Hospital. The primary aim was to evaluate the diagnostic performance of total dissolved solids (TDS) measurement in pleural fluid for distinguishing exudative from transudative effusions, and to compare these findings with Light's criteria. The study was approved by the Institutional Ethics Committee and written informed consent was obtained from all enrolled participants.

Patients presenting with radiological evidence of pleural effusion and requiring diagnostic thoracentesis were screened consecutively during the study period. Upon enrolment, a complete clinical assessment was undertaken, including recording demographic details, past medical history, and relevant findings from physical examination. Diagnostic imaging (chest X-ray, ultrasound, or CT scan) confirmed the presence of pleural fluid.

Inclusion Criteria:

- Adults aged ≥18 years with radiologically confirmed pleural effusion
- Undergoing diagnostic thoracentesis
- Provided written informed consent

Exclusion Criteria:

- Grossly hemorrhagic, chylous, or purulent effusions
- Inadequate sample volume (<5 mL)
- Recent chest surgery or trauma
- Incomplete clinical or laboratory data

Under aseptic precautions, thoracentesis was performed, and 10-20 mL of pleural fluid was collected. Simultaneously, a venous blood sample was obtained for biochemical comparisons. Pleural fluid samples were divided for immediate biochemical, cytological, and TDS analysis. TDS was measured in approximately 2 mL of pleural fluid using a calibrated digital handheld meter with automatic temperature compensation at room temperature. Biochemical analysis of pleural fluid and serum included total protein, lactate dehydrogenase (LDH), glucose, and, when indicated, adenosine deaminase (ADA). Cytological and microbiological assessments were performed as clinically necessary. All samples were analyzed within four hours to maintain sample integrity.

Effusions were classified as exudative or transudative using Light's criteria:

1. Pleural fluid/serum protein ratio greater than 0.5
2. Pleural fluid/serum LDH ratio greater than 0.6
3. Pleural fluid LDH exceeding two-thirds the upper limit of normal for serum LDH.

If none of these conditions were met, the effusion was categorized as transudative. Only patients providing adequate sample volume (minimum 5 mL) and complete clinical data were included in the analysis.

Statistical analysis was performed using Microsoft Excel and SPSS version 26. Continuous variables are presented as mean ± standard deviation or median with interquartile range based on distribution. Inter-group comparisons were made using independent t-tests or Mann-Whitney U tests, as appropriate. Diagnostic performance of TDS was evaluated with sensitivity, specificity, and receiver operating characteristic (ROC) curve analysis. A p-value of less than 0.05 was considered statistically significant.

RESULTS:

A total of 35 patients with radiologically confirmed pleural effusions were enrolled in this prospective pilot study. Pleural fluid samples were analyzed for Total Dissolved Solids (TDS), pleural fluid protein, serum protein, LDH, glucose, and cytological characteristics. The effusions were classified into exudates or transudates based on Light's criteria, and the diagnostic potential of TDS was assessed in comparison.

Table 1: Demographic profile of the study participants

Gender	Frequency (n)	Percentage (%)
Male	22	62.9
Female	13	37.1

A total of 35 patients diagnosed with pleural effusion based on radiological imaging were enrolled in the study. Among these, 22 patients (62.9%) were male and 13 patients (37.1%) were female, indicating a male predominance in the study population (Table 1).

Table 2: Classification of Effusions Based on Light's Criteria

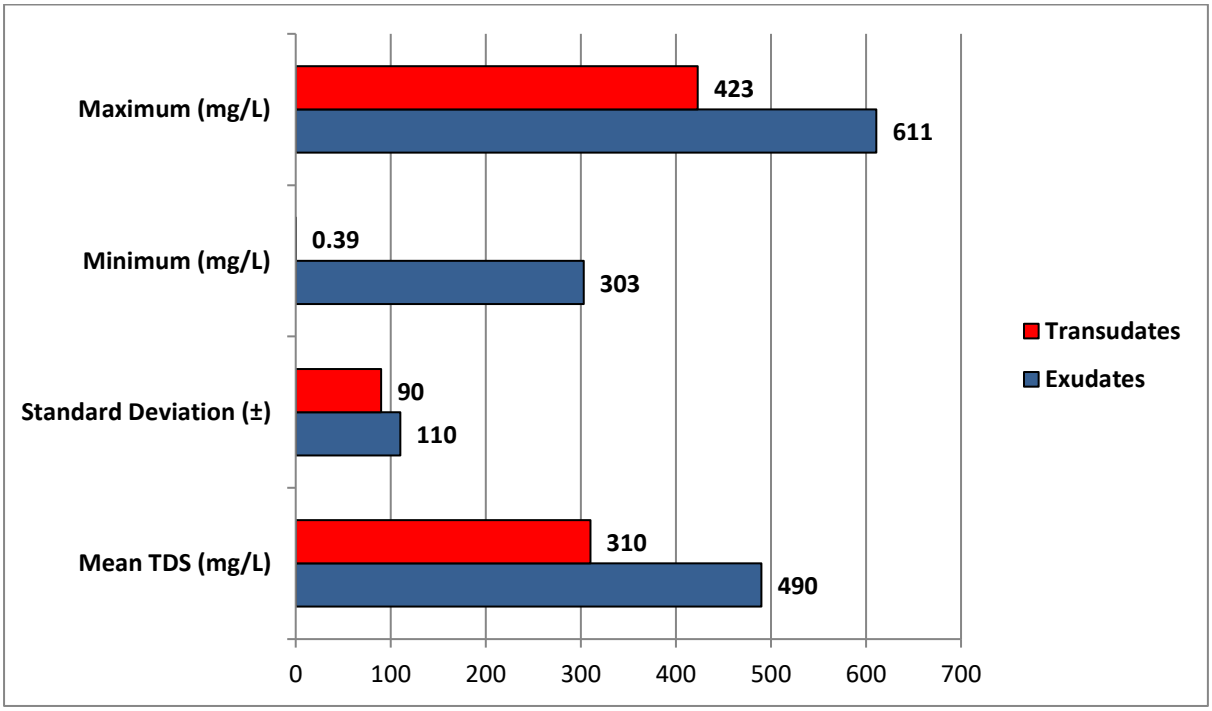
Type of Effusion	Number of Cases (n)	Percentage (%)
Exudative	22	62.9
Transudative	13	37.1

According to Light's criteria, pleural effusions were classified into exudative and transudative types. Out of the 35 cases, 22 (62.9%) were identified as exudative, while 13 cases (37.1%) were transudative. This distribution highlights a greater occurrence of exudative effusions in the study group (Table 2).

Table 3: Pleural Fluid TDS levels in Exudates and Transudates

Group	Mean TDS (mg/L)	Standard Deviation (±)	Minimum (mg/L)	Maximum (mg/L)
Exudates	490	110	303	611
Transudates	310	90	0.39	423

Figure 1: Pleural Fluid TDS levels in Exudates and Transudates

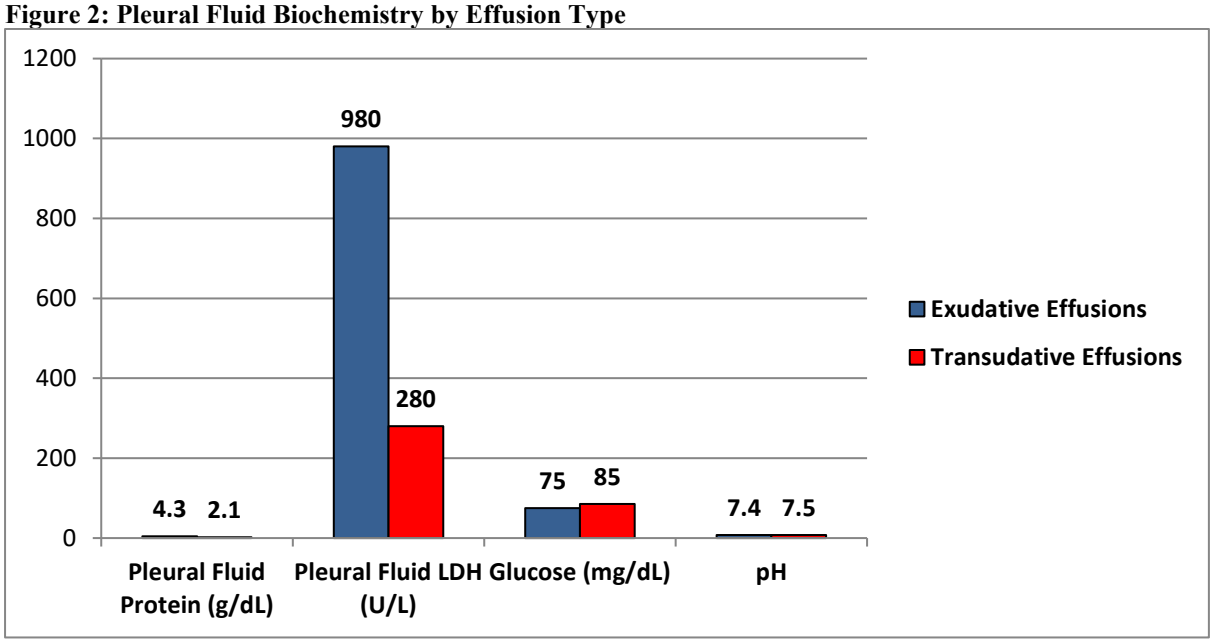


The Total Dissolved Solids (TDS) levels in pleural fluid showed a clear distinction between exudative and transudative effusions (table 3). The mean TDS level in exudative effusions was 490 mg/L with a standard deviation of ±110, ranging from 303 to 611 mg/L. In contrast, transudative effusions had a lower mean TDS of 310 mg/L with a standard deviation of ±90, ranging from 0.39 to 423 mg/L. These findings suggest that higher TDS values are associated with exudative pleural fluid

Table 4: Pleural Fluid Biochemistry by Effusion Type

Biochemical Parameter	Exudative Effusions	Transudative Effusions
Pleural Fluid Protein (g/dL)	4.3	2.1
Pleural Fluid LDH (U/L)	980	280
Glucose (mg/dL)	75	85
pH	7.4	7.5

Figure 2: Pleural Fluid Biochemistry by Effusion Type



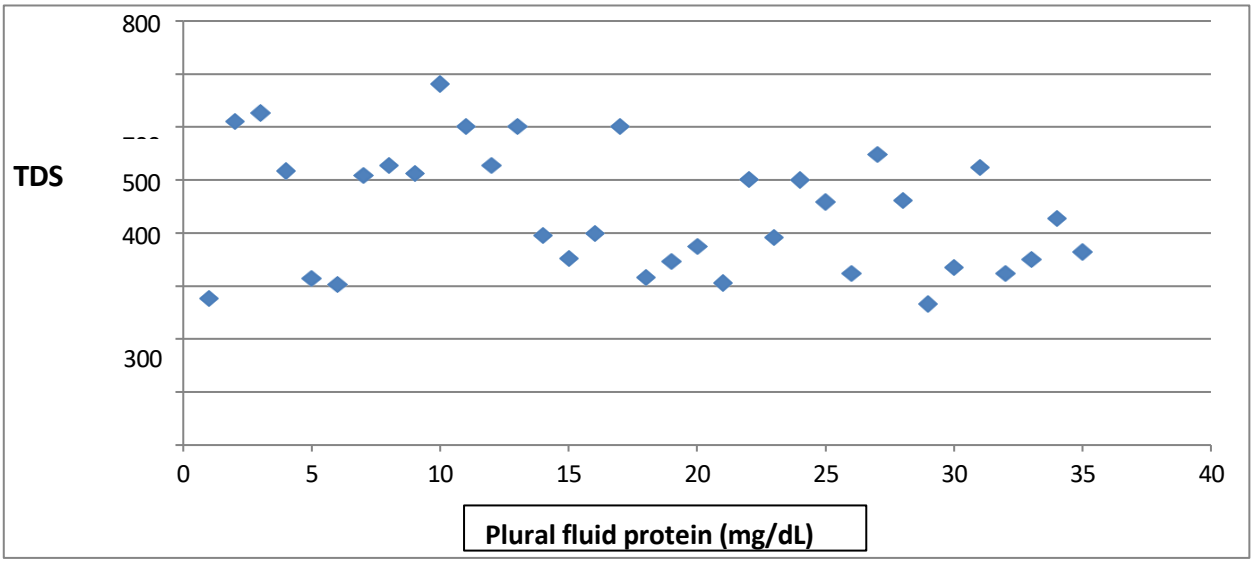
The biochemical composition of the pleural fluid varied significantly between exudative and transudative effusions. The average protein concentration in exudative effusions was 4.3 g/dL, compared to 2.1 g/dL in transudative effusions. Similarly, the LDH level was markedly higher in exudates (980 U/L) than in transudates (280 U/L). Glucose levels were slightly lower in exudative effusions (75 mg/dL) than in transudative effusions (85 mg/dL). The pH was marginally lower in exudates 7.4 compared to transudates 7.5 (Table 4). These biochemical differences are consistent with the pathophysiological characteristics of exudates and transudates

Table 5: Pleural Cytology Results

Cytology Result	Number of Cases
Positive for malignancy	6
Negative for malignancy	21
Non-diagnostic/inconclusive	2
Not available	6

Cytological analysis of pleural fluid was conducted to detect malignant cells. Among the 35 cases, 6 samples tested positive for malignancy. Twenty-one samples were negative, while 2 were non-diagnostic or inconclusive. In 6 cases, cytological data were not available (Table 5). The presence of malignancy in a subset of patients reinforces the importance of cytological evaluation in effusion diagnosis.

Figure 3: Correlation Between TDS and Pleural Protein



A scatter plot analysis demonstrated a positive relationship between pleural fluid TDS and protein levels (Figure 3). This correlation suggests that TDS could serve as an indirect marker for identifying exudative effusions, as both parameters tend to increase in exudative conditions due to higher solute and protein content in the fluid.

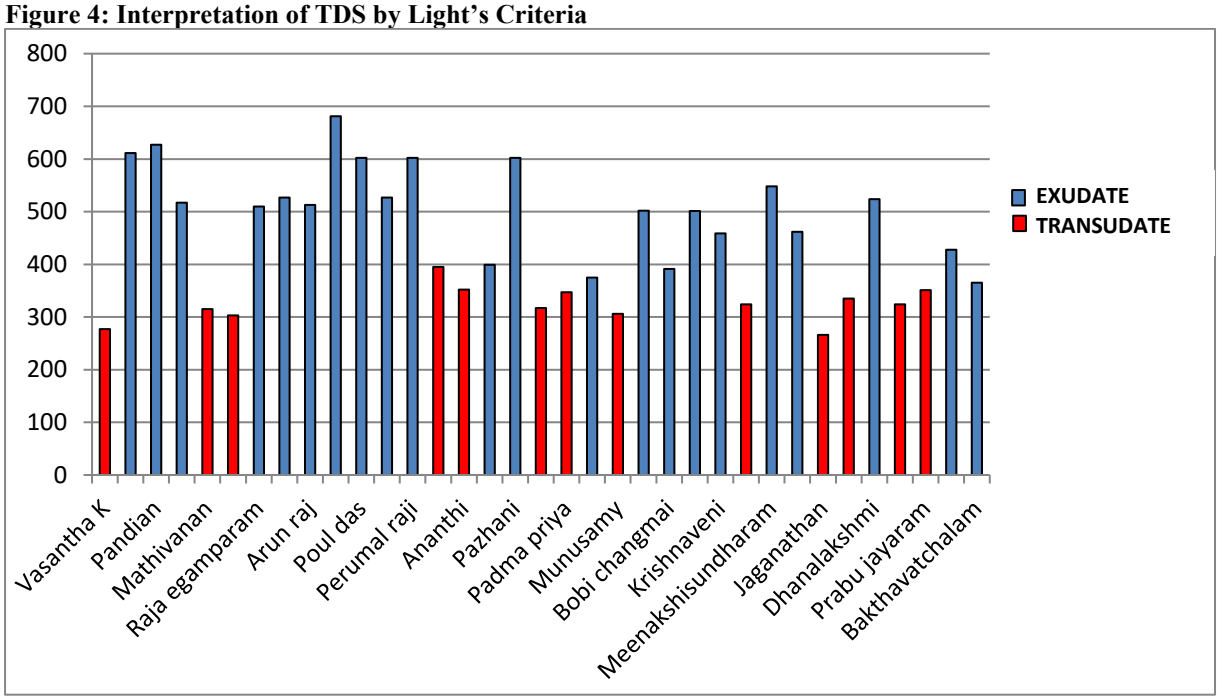
Table 6: Comparative Evaluation of TDS and Light's Criteria

Parameter	Mean (Parameter)	Mean (TDS)	t- statistics	p-value
Pleural LDH	1146.89	442.43	2.83	0.0075*
Serum LDH	1007.61	442.43	1.52	0.138
Pleural Fluid ADA	36.18	442.43	-19.72	0.0001*
Protein + Sugar	121.69	442.43	-13.43	0.0001*

*p-value <0.05- significant

The diagnostic performance of TDS was compared with established biochemical markers using t-test. TDS showed a statistically significant association with pleural LDH ($p = 0.0075$), pleural fluid ADA ($p < 0.0001$), and the combined value of protein and sugar ($p < 0.0001$). However, the correlation between TDS and serum LDH was not statistically significant ($p = 0.138$) (Table 6). These findings suggest that TDS may serve as a valuable supplementary tool in differentiating exudative from transudative effusions, especially when conventional parameters are equivocal.

Figure 4: Interpretation of TDS by Light's Criteria



The bar chart comparing Total Dissolved Solids (TDS) levels in pleural fluid between exudative and transudative effusions, as classified by Light's criteria, reveals a significant difference in solute concentration. Exudative effusions demonstrated consistently higher TDS values, with mean levels approaching 490 mg/L, whereas transudative effusions showed substantially lower values, averaging around 310 mg/L (Figure 4). This visual representation reinforces the earlier statistical findings, indicating that TDS may serve as a supportive diagnostic parameter in differentiating exudative from transudative effusions.

DISCUSSION:

Accurate differentiation between transudative and exudative pleural effusions is essential for diagnosing the underlying cause and guiding appropriate management. Light's criteria, established several decades ago, continue to serve as the clinical benchmark owing to their high sensitivity for identifying exudative effusions. However, multiple studies have highlighted their limitations, particularly in patients on diuretic therapy, where false-positive results are common due to hemoconcentration effects that alter protein levels without reflecting true pathology [2,3]. In this study, we evaluated the diagnostic utility of pleural fluid Total Dissolved Solids (TDS) as an ancillary biomarker in the classification of pleural effusions. Our data demonstrated that exudative effusions had significantly higher mean TDS concentrations compared to transudates, which corresponds with the underlying

pathophysiological mechanisms that increase protein and solute concentrations in the pleural space during infection, inflammation, or malignancy [4,6].

A key advantage of using pleural fluid TDS lies in its ease of use and minimal resource requirements. TDS meters, which require only a small pleural fluid sample and offer immediate readings, are portable and can be employed at the bedside making them particularly advantageous in peripheral or resource-limited healthcare environments. Moreover, unlike Light's criteria, TDS evaluation does not necessitate concurrent serum sampling, eliminating delays or variability associated with dual sample analysis [7].

However, this novel approach is not without limitations. Our sample size was relatively modest, and larger, multicenter cohorts are necessary to validate TDS thresholds across different patient populations. Additionally, while we correlated TDS values with clinical and laboratory features to ascertain underlying etiology, histopathological confirmation was not available in all cases, which limits definitive diagnostic classification.

Despite these limitations, our results align with emerging perspectives in pleural research that support broader use of rapid, cost-effective diagnostic tools particularly in settings where conventional testing is inaccessible. TDS may serve not only as an initial screening tool but could also be investigated further for disease monitoring, especially in exudative conditions such as tuberculosis or malignancy [8].

CONCLUSION:

The application of Total Dissolved Solids (TDS) as a diagnostic parameter in pleural fluid analysis is both innovative and practical. It aligns with current efforts in clinical medicine to develop rapid, low-cost, point-of-care diagnostic tools. While the existing literature is limited, early evidence and theoretical underpinnings support the relevance of TDS in distinguishing between transudative and exudative pleural effusions. Further research, including large-scale validation studies, is essential to define its diagnostic accuracy, optimal cut-off values, and potential integration into current clinical workflows.

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