RESEARCH PAPER

Pleural Fluid Cholesterol as a Reliable Alternative to Light's Criteria in Differentiating Exudative and Transudative Pleural Effusions: A Prospective Observational Study

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ABSTRACT

Background
Differentiating exudative from transudative pleural effusions is a critical step in pleural fluid evaluation. Light's criteria remain the gold standard but require simultaneous serum and pleural fluid analysis. Pleural cholesterol and bilirubin ratio have emerged as potential alternative biomarkers.

Aim
To evaluate the diagnostic utility of pleural fluid cholesterol and bilirubin ratio compared with Light's criteria in differentiating exudative and transudative pleural effusions.

Materials and Methods
This prospective observational study included 80 adult patients with pleural effusion presenting to a tertiary care teaching hospital between July 2024 and December 2025. Pleural fluid and serum samples were analyzed for cholesterol, bilirubin, protein, and lactate dehydrogenase. Light's criteria were used as the reference standard. Sensitivity, specificity, positive predictive value, negative predictive value, diagnostic accuracy, and ROC analysis were performed.

Results
Among 80 patients, 68 (85%) had exudative effusions and 12 (15%) had transudative effusions according to Light's criteria. Tubercular effusion was the most common etiology (61.25%). Pleural cholesterol (>60 mg/dL) demonstrated sensitivity, specificity, PPV, NPV, and diagnostic accuracy of 100% each. Bilirubin ratio (>0.6) demonstrated sensitivity of 100%, specificity of 75%, and diagnostic accuracy of 96.25%. ROC analysis showed an AUC of 1.00 for pleural cholesterol and 0.88–0.92 for bilirubin ratio.

Conclusion
Pleural fluid cholesterol demonstrated diagnostic performance equivalent to Light's criteria and may serve as a simple, cost-effective, single-specimen alternative for differentiating exudative and transudative pleural effusions, particularly in resource-limited settings.

Keywords: Pleural effusion, Exudative, Transudative, Pleural fluid cholesterol, Light's criteria, Bilirubin ratio

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Introduction

Pleural effusion refers to the accumulation of excess fluid within the pleural cavity beyond normal physiological limits and represents a commonly encountered clinical problem in respiratory medicine. It is associated with a wide spectrum of underlying disorders, including infections, malignancies, cardiovascular diseases, and various systemic conditions. Globally, pleural effusion contributes significantly to morbidity and healthcare utilization, affecting a large number of patients each year. In developed countries such as the United States, it is estimated that more than one million individuals develop pleural effusion annually, reflecting its substantial clinical burden.

In India, the epidemiological pattern of pleural effusion differs considerably from that seen in Western populations. Tuberculosis continues to be the predominant cause of exudative pleural effusion, accounting for a substantial proportion of cases. Several regional studies have reported that tuberculous etiology contributes to nearly half, and in some areas more than half, of all pleural effusions. Other important causes include malignancy and parapneumonic effusions. This distinct etiological distribution highlights the importance of adopting diagnostic approaches that are relevant to the Indian clinical setting.

A crucial step in the evaluation of pleural effusion is the differentiation between transudative and exudative fluid, as this distinction directly influences further diagnostic workup and management strategies. Transudative effusions are typically related to systemic factors such as increased hydrostatic pressure or decreased oncotic pressure, whereas exudative effusions result from local pleural pathology involving inflammation, infection, or malignancy. Therefore, accurate classification is essential for guiding appropriate clinical decisions.

Light’s criteria have been widely accepted as the standard method for classifying pleural effusions. These criteria utilize biochemical parameters, specifically the ratios of pleural fluid to serum protein and lactate dehydrogenase (LDH), along with absolute pleural fluid LDH levels, to categorize effusions. Although Light’s criteria are highly sensitive and effective in identifying exudative effusions, their specificity is relatively lower, leading to occasional misclassification of transudative effusions as exudates. Additionally, the requirement for simultaneous serum sampling and reduced reliability in certain clinical situations, such as in patients receiving diuretic therapy, limit their practical utility.

In recent years, attention has shifted toward identifying simpler and more reliable biochemical markers within pleural fluid that could either complement or substitute existing criteria. Among these, pleural fluid cholesterol has emerged as a promising parameter, with elevated levels reflecting increased capillary permeability and cellular breakdown associated with exudative processes. Several studies have suggested that cholesterol-based assessment may provide diagnostic performance comparable to conventional criteria, while offering advantages in terms of ease of measurement and reduced dependence on paired serum samples.

Similarly, pleural fluid bilirubin has been explored as a potential diagnostic marker. Although less extensively studied, it is believed to reflect both systemic and local inflammatory changes within the pleural space. The ratio of pleural fluid to serum bilirubin has been proposed as an adjunctive parameter that may enhance diagnostic accuracy, particularly in borderline cases.

Given the clinical importance of accurate pleural fluid classification and the limitations inherent in existing diagnostic methods, there is a need to evaluate alternative biomarkers in a systematic manner. This is especially relevant in resource-constrained settings, where simplified and cost-effective diagnostic approaches are desirable.

The present study was therefore undertaken to compare the diagnostic performance of pleural fluid cholesterol and bilirubin with that of Light’s criteria in differentiating exudative from transudative pleural effusions. By assessing parameters such as sensitivity, specificity, and overall diagnostic accuracy, this study aims to determine whether these biochemical markers can serve as reliable alternatives or adjuncts in routine clinical practice. The findings are expected to contribute to improved diagnostic strategies, reduce dependence on complex investigations, and enhance patient care in both Indian and global healthcare contexts.

Aim & Objectives

Aim:

To study the diagnostic utility of bilirubin and cholesterol estimations with light’s criteria in pleural fluid for differentiating exudate from transudate.

Objectives:

- To measure bilirubin levels in both pleural fluid and serum and evaluate their diagnostic performance (sensitivity, specificity, and accuracy) in distinguishing exudative from transudative effusions.
- To assess cholesterol levels in pleural fluid and serum and determine their effectiveness in differentiating exudates from transudates using standard diagnostic indices.
- To analyze protein and low-density lipoprotein (LDL) levels in pleural fluid and serum as components of Light’s

criteria, and to evaluate their diagnostic validity in classifying pleural effusion

- **Materials & Methods**

Study subjects

- Adult patients presenting with pleural effusion at a tertiary care teaching hospital.

Study setting

- Department of Respiratory Medicine and District DR-TB Centre at a tertiary care teaching hospital in Navi Mumbai.

Study design

- This was a prospective observational study

Study duration

- 18 months (July 2024 – December 2025)

Inclusion Criteria

- Adult patients aged 18 years or above, presenting with clinically or radiologically confirmed pleural effusion.
- Patients admitted to or attending the departments of General Medicine, Respiratory Medicine or Casualty of the study setting.
- Patients in whom diagnostic thoracocentesis was performed and pleural fluid analysis was obtained.
- Patients whose serum and pleural fluid samples were available for estimation of bilirubin,cholesterol, protein and LDH.

Exclusion Criteria

- Patients with inadequate pleural fluid samples or incomplete biochemical investigations
- Patients who had previous pleural interventions or treatment before sampling
- Patients with traumatic hemothorax or postoperative pleural effusion
- Patients with mixed or uncertain etiology of pleural effusion where definitive classification was not possible.

Sample size

The required sample size for this study was determined using the following formula:

$$n = \frac{\left[Z_\alpha\sqrt{\psi} + Z_\beta\sqrt{\psi} - (P_2 - P_1)\right]^2}{(P_1 - P_2)^2}$$

Where,n = required number of pairs of samples P_1 = sensitivity of Light's criteria = 98% P_2 = sensitivity of bilirubin (0.6) = 88%
Z_α = Z score for 95% confidence level = 1.96 Z_β = Z score for 80% power = 0.84
Ψ = variability of the paired difference

Therefore,

$n = (0.619804 + 0.84 \times 0.3)^2 / (0.10)^2 = 0.76004/0.01 = 76 \sim \mathbf{80}$.

Study procedure

- **Data collection**:

- The present study selected adult patients presenting with symptoms and signs of pleural effusion to the OPDs of General Medicine and Respiratory Medicine and to the Casualty. The steps, procedures, possible benefits and potential risks of the study were explained to each patient in simple local language and a written informed consent was obtained from each patient.
- After obtaining approval from the Institutional Ethics Committee and written informed consent from each participant, the eligible patients who met the study criteria were enrolled in the study. A detailed clinical history was obtained and a thorough general and systemic examination was performed. Demographic details, presenting symptoms, comorbidities, and relevant clinical findings were recorded in a structured data collection proforma.
- Diagnostic thoracentesis was performed under aseptic precautions and pleural fluid samples were collected for laboratory analysis. Simultaneously, venous blood samples were obtained for corresponding serum biochemical investigations. Pleural fluid and serum were analyzed for parameters including cholesterol, bilirubin, protein, and lactate dehydrogenase. Additional investigations such as pleural fluid differential cell count and Gene-Xpert testing were performed where indicated. The biochemical parameters were subsequently used to classify effusions according to Light's criteria and to evaluate the diagnostic utility of pleural fluid cholesterol and bilirubin. All collected data were entered, coded, and cleaned in Microsoft Excel, and statistical analysis was carried out using IBM SPSS version 27.

- **Study variables**:

- Age
- Gender
- Cough
- Expectoration
- Fever
- Night sweats
- Loss of weight
- Loss of appetite
- History of Diabetes / Hypertension / Ischemic heart disease / Thyroid / Obesity/ Hyperlipidemia / Liver disease / HIV
- Past / family history of TB
- Dietary history
- General physical examination:
- Temperature
- Pulse
- Respiratory Rate
- Blood Pressure
- SpO_2
- P I C C L E
- Weight
- Height
- MUAC
- Systemic Examination: CVS, RS, PA, CNS
- Serum Bilirubin
- Serum cholesterol
- Serum protein
- Serum LDH
- Pleural fluid bilirubin
- Pleural fluid cholesterol
- Pleural fluid protein
- Pleural fluid LDH
- Lymphocyte / Neutrophil
- Pleural fluid Gene-Xpert
- Bronchoalveolar lavage Gene-Xpert
- Light's criteria
- Clinical diagnosis

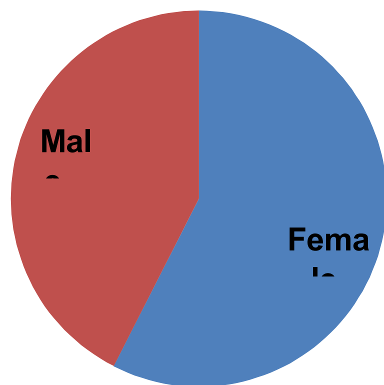
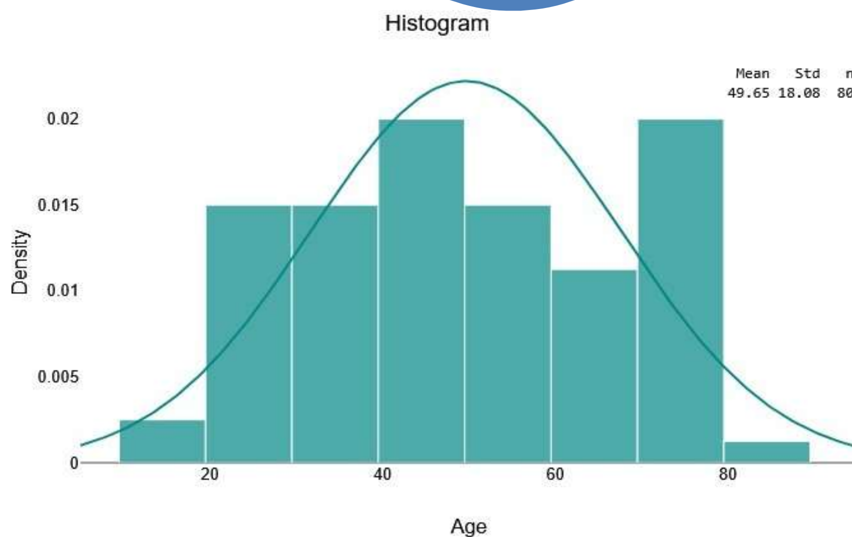


Figure 1: Age distribution among the study subjects

Of the 80 study subjects, 46 (57.5%) were female and 34 (42.5%) were male, yielding a female-to-male ratio of approximately 1.35:1. This slight female preponderance may be attributable to the high prevalence of tubercular effusion in the study cohort, which is known to affect both sexes, though regional and demographic factors may also contribute.

Table 2: Gender Distribution among the study subjects



Results

The present study enrolled 80 adult patients with pleural effusion, meeting the study criteria, presenting to the OPDs of Respiratory Medicine, General Medicine and Casualty. The mean age of the study subjects was 49.65 ± 18.08 years, indicating a predominantly middle-aged cohort with a wide age range, reflective of the diverse etiological spectrum of pleural effusion encountered in clinical practice.

Table 1: Age distribution among the study subjects

Variable	N	Mean	SD
Age (years)	80	49.65	18.081

Gender	Frequency	Percent
Female	46	57.5
Male	34	42.5
Total	80	100

Figure 2: Gender Distribution among the study subjects

Cough was reported as a presenting symptom in 43 patients (53.8%), while the remaining 37 patients (46.3%) did not have this complaint. The near-equal distribution of this symptom suggests that cough, though common, is not universally present in patients with pleural effusion and should not be relied upon as a sole clinical indicator.

Table 3: Distribution of study subjects based on complaint of Cough

Cough	Frequency	Percent
No	37	46.3
Yes	43	53.8
Total	80	100

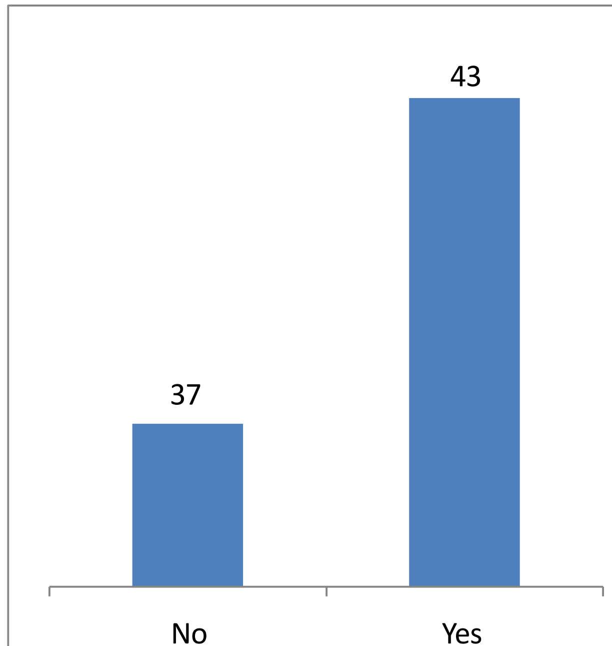


Figure 3: Distribution of study subjects based on complaint of Cough

Expectoration was present in 38 patients (47.5%) and absent in 42 patients (52.5%). The proportion of patients with productive symptoms was slightly lower than the proportion of patients with cough, which is consistent with the underlying inflammatory or infective etiology predominating in this study population, particularly tubercular and parapneumonic effusions.

Table 4: Distribution of study subjects based on complaint of Expectoration

Expectoration	Frequency	Percent
No	42	52.5
Yes	38	47.5
Total	80	100

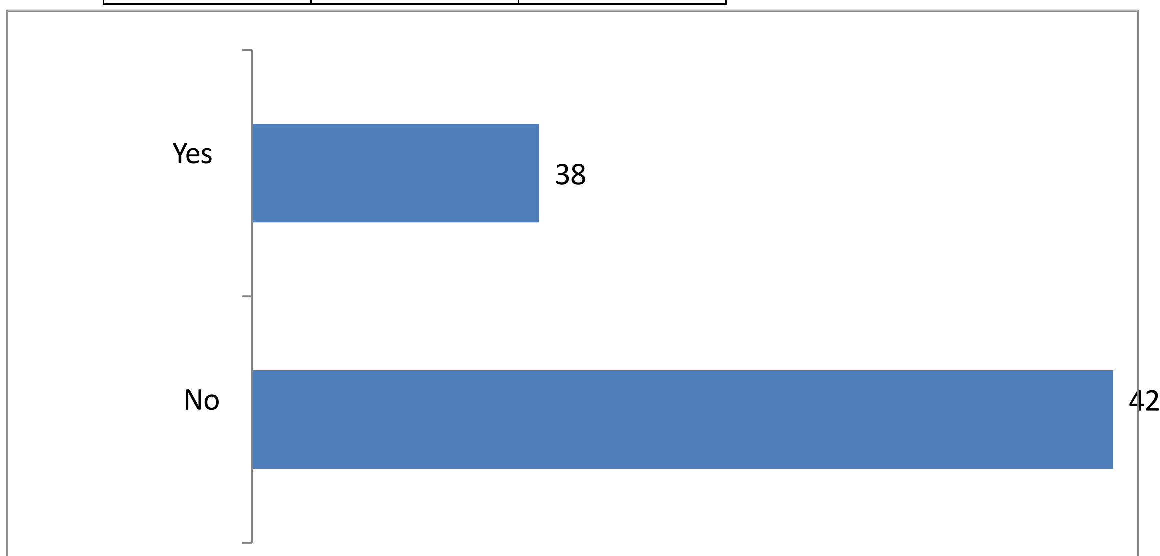


Figure 4: Distribution of study subjects based on complaint of Expectoration

Fever was present in 38 patients (47.5%) and absent in 42 patients (52.5%). While fever is a classical constitutional symptom associated with infective and inflammatory causes of pleural effusion, its absence in over half the cohort underscores the heterogeneity of the study population, which also included non-infective etiologies such as cardiac and renal failure.

Table 5: Distribution of study subjects based on complaint of Fever

Fever	Frequency	Percent
No	42	52.5
Yes	38	47.5
Total	80	100

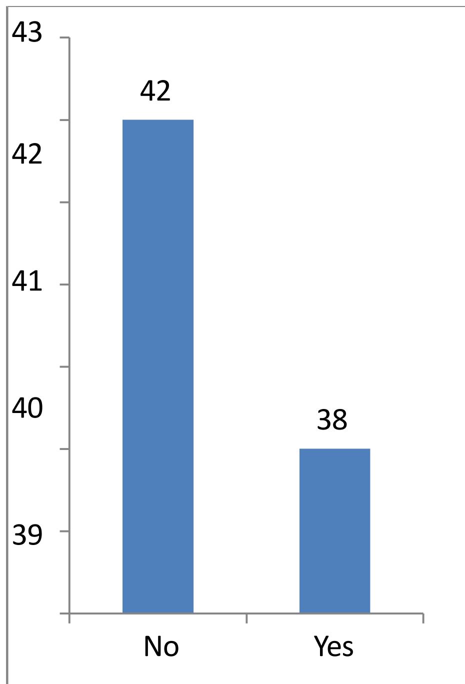


Figure 5: Distribution of study subjects based on complaint of Fever

Night sweats were reported by 38 patients (47.5%), with the remaining 42 patients (52.5%) being asymptomatic for this complaint. Given that nearly half the cohort exhibited this symptom, and considering that tubercular effusion constituted the majority of clinical diagnoses, the prevalence of night sweats is consistent with the constitutional symptomatology characteristically associated with mycobacterial infection.

Table 6: Distribution of study subjects based on complaint of Night Sweats

Night Sweats	Frequency	Percent
No	42	52.5
Yes	38	47.5
Total	80	100

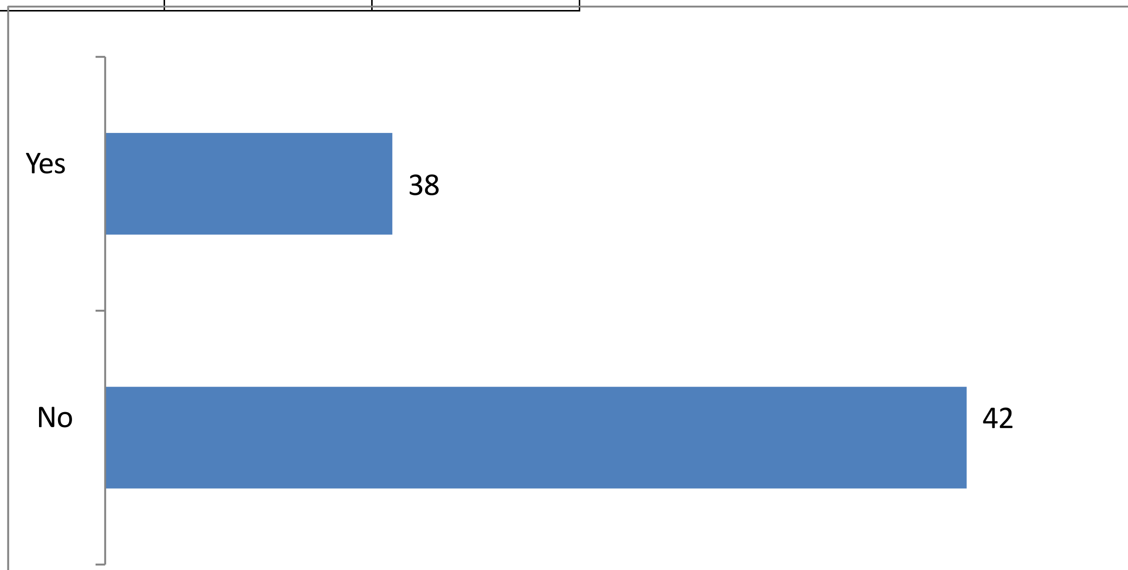


Figure 6: Distribution of study subjects based on complaint of Night Sweats

Weight loss was reported in 39 patients (48.8%), while 41 patients (51.2%) denied this symptom. The high frequency of weight loss further corroborates the predominance of chronic, consumptive conditions, particularly tuberculosis, within the study population, and highlights the importance of eliciting nutritional and constitutional symptoms during clinical evaluation of pleural effusion.

Table 7: Distribution of study subjects based on complaint of Loss of Weight

Loss of weight	Frequency	Percent
No	41	51.2
Yes	39	48.8
Total	80	100

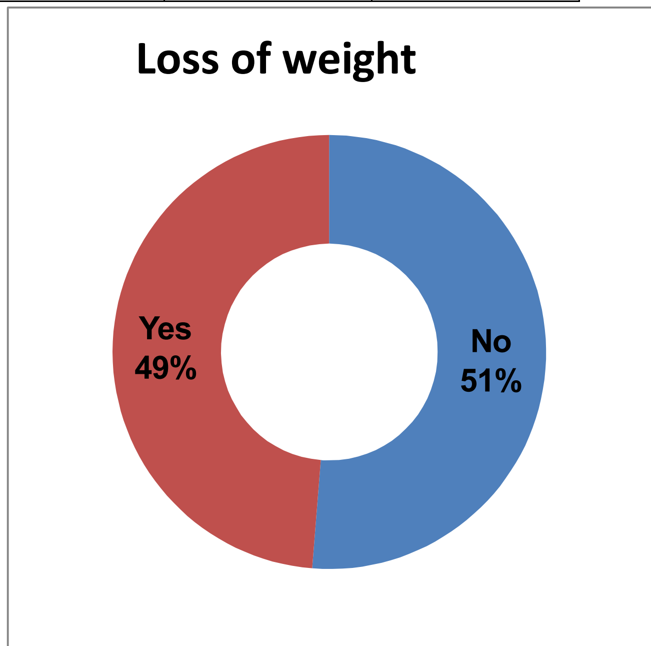


Figure 7: Distribution of study subjects based on complaint of Loss of Weight

A documented history of Diabetes was present in 14 patients (17.5%) while 66 patients (82.5%) were non-diabetic. It was mostly seen among middle aged and elderly patients in this study sample.

Table 8: Distribution of study subjects based on History of Diabetes

H/o Diabetes	Frequency	Percent
No	66	82.5
Yes	14	17.5
Total	80	100

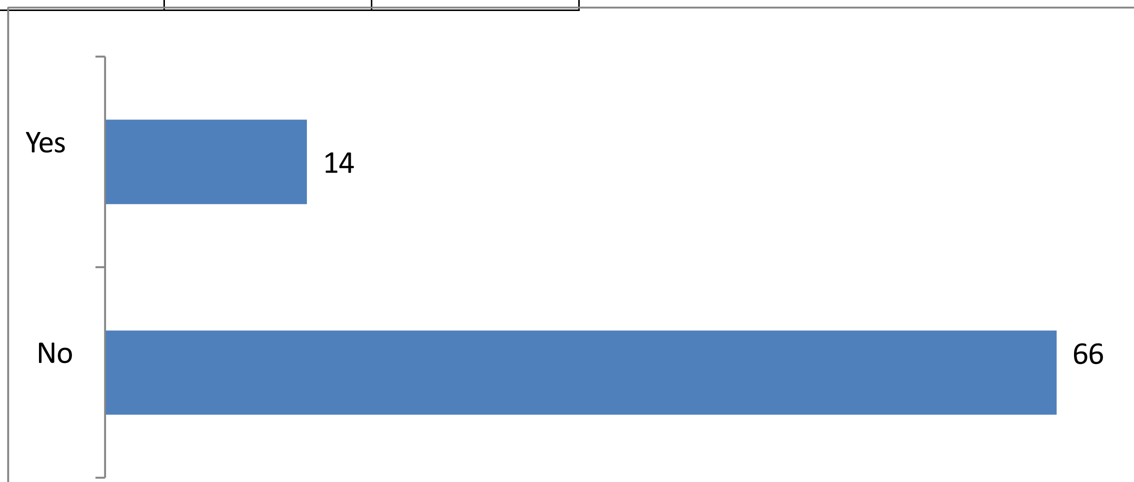


Figure 8: Distribution of study subjects based on History of Diabetes

Hypertension was absent in 62 patients (77.5%) and present in 18 patients (22.5%). The considerable burden of hypertension in this study sample is noteworthy and may be reflective of its role as a contributing comorbidity, particularly in patients with cardiac and renal causes of pleural effusion.

Table 9: Distribution of study subjects based on History of Hypertension

H/o Hypertension	Frequency	Percent
No	62	77.5
Yes	18	22.5
Total	80	100

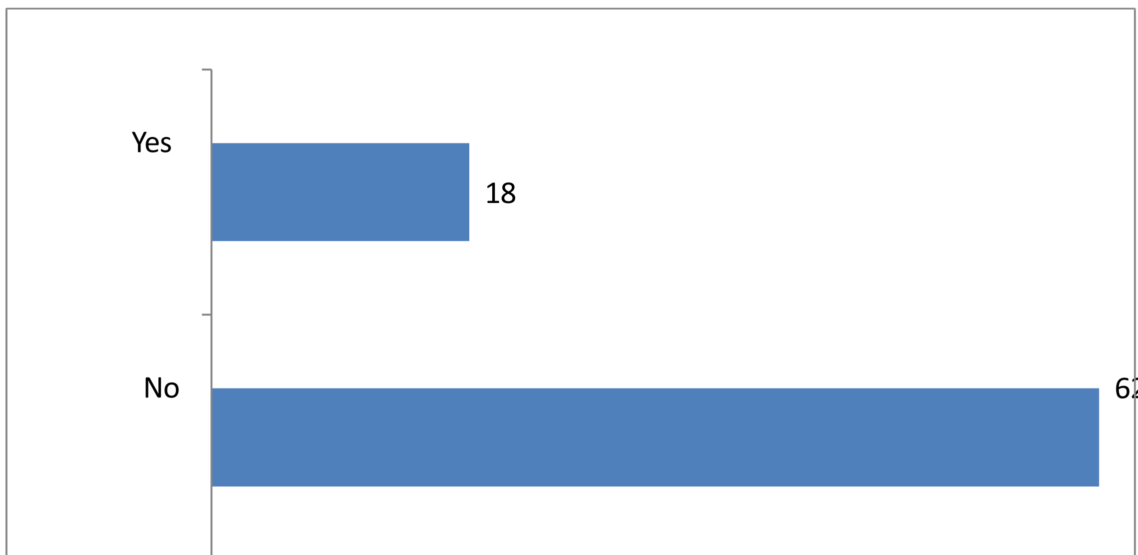


Figure 9: Distribution of study subjects based on History of Hypertension

Ischaemic heart disease (IHD) was reported in 16 patients (20.0%), while the majority, 64 patients (80.0%), had no such history. Although IHD was a relatively less common comorbidity, its presence in one-fifth of the cohort is clinically significant, as it may predispose to transudative effusion through mechanisms of impaired cardiac output and elevated hydrostatic pressure.

Table 10: Distribution of study subjects based on History of IHD

H/o IHD	Frequency	Percent
No	64	80.0
Yes	16	20.0
Total	80	100

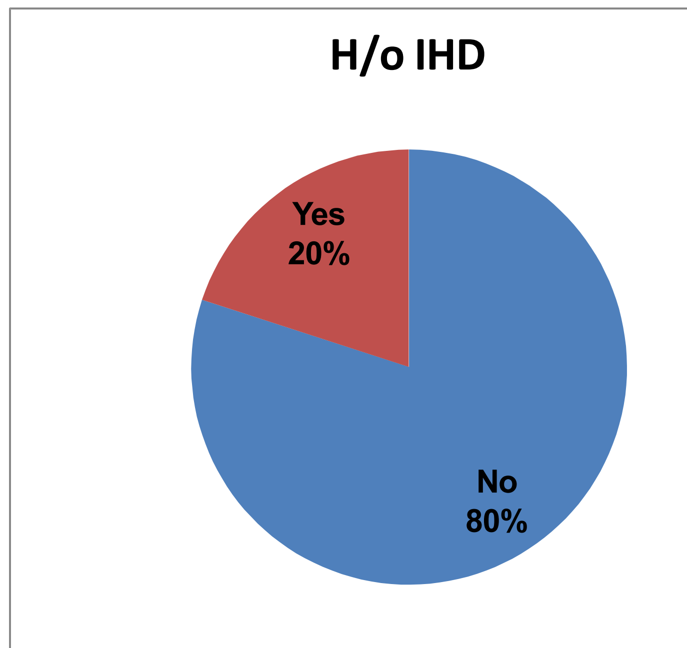


Figure 10: Distribution of study subjects based on History of IHD

A history of thyroid disease was present in 39 patients (48.8%) and absent in 41 patients (51.2%). The high prevalence of thyroid dysfunction in this cohort warrants clinical attention, as both hypothyroidism and hyperthyroidism can contribute to pleural effusion through distinct pathophysiological mechanisms, including altered oncotic pressure and metabolic dysregulation.

Table 11: Distribution of study subjects based on History of Thyroid Disease

H/o Thyroid disease	Frequency	Percent
No	41	51.2
Yes	39	48.8
Total	80	100

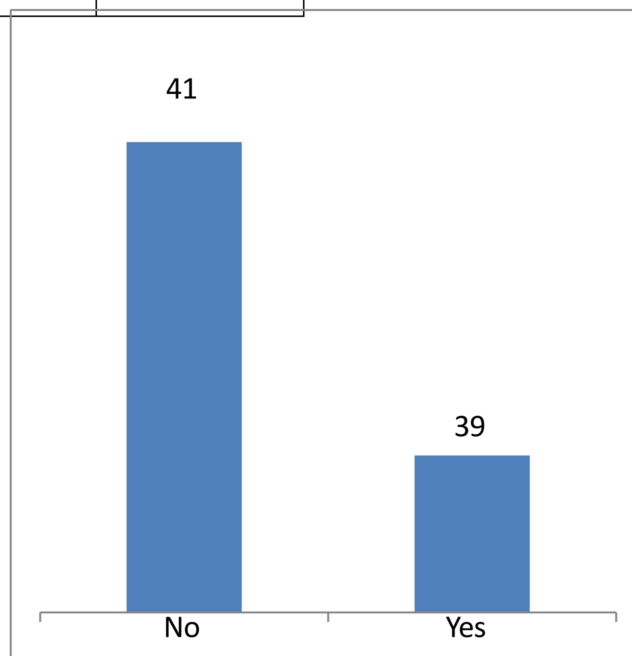


Figure 11: Distribution of study subjects based on History of Thyroid Disease

The mean body temperature was 37.76 ± 0.72°C, indicating a low-grade febrile state in the cohort consistent with the underlying infective etiologies. The mean pulse rate was 95.56 ± 14.67 bpm and the mean respiratory rate was 22.56 ± 4.40 breaths per minute, reflecting mild tachycardia and tachypnoea characteristic of respiratory compromise. The mean SpO_2 was 93.66 ± 3.52%, suggestive of moderate hypoxaemia, while anthropometric parameters including mean weight (66.32 ± 13.19 kg), height (164.45 ± 8.86 cm), and mid-upper arm circumference (28.2 ± 3.90 cm) indicated a generally adequate nutritional status across the study population.

Table 12: General Examination findings

Variable	N	Minimum	Maximum	Mean	SD
Temperature (C)	80	36	39	37.76	0.716
Pulse (bpm)	80	70	120	95.56	14.669
Respiratory Rate	80	16	30	22.56	4.397
SpO2 (%)	80	88	99	93.66	3.522
Weight (kg)	80	45	85	61.51	9.26
Height (cm)	80	150	179	164.45	8.86
BMI (kg/m^2)	80	16.03	28.65	22.80	3.33
MUAC (cm)	80	22	34	28.2	3.899

The mean serum bilirubin was 0.97 ± 0.23 mg/dL and mean serum cholesterol was

177.26 ± 18.04 mg/dL, both within clinically acceptable ranges. Pleural fluid bilirubin levels had a mean of 1.09 ± 0.42 mg/dL, slightly exceeding serum levels, while pleural fluid cholesterol had a mean of 84.62 ± 26.59 mg/dL, values that are particularly relevant in the context of biochemical differentiation of exudative from transudative effusions in the present study. The mean serum to pleural bilirubin ratio was found to be 1.08 ± 0.66.

Table 13: Findings of laboratory investigations among the study subjects

Variable	N	Minimum	Maximum	Mean	SD
Serum Bilirubin (mg/dL)	80	0.61	1.38	0.97	0.23
Serum Cholesterol (mg/dL)	80	142.4	209.8	177.26	18.04
Pleural Bilirubin (mg/dL)	80	0.25	1.78	1.09	0.42
Pleural Cholesterol (mg/dL)	80	21.3	119.1	84.62	26.59
Bilirubin ratio (pleural / serum)	80	0.39	3.84	1.08	0.66

Tubercular effusion was the most common clinical diagnosis, accounting for 49 patients (61.25%), followed by parapneumonic effusion in 11 patients (13.75%) and renal failure in 10 patients (12.5%). Malignant effusion was identified in 8 patients (10.0%), while heart failure accounted for only 2 cases (2.5%). This distribution underscores the predominance of infective and inflammatory causes of pleural

effusion in this study population, a pattern reflective of the regional disease burden in a tertiary care setting.

Table 14: Distribution of study subjects based on their Clinical Diagnosis

Clinical Diagnosis	Frequency	Percent
Heart failure	2	2.5
Malignant effusion	8	10.0
Renal failure	10	12.5
Parapneumonic effusion	11	13.75
Tubercular effusion	49	61.25
Total	80	100

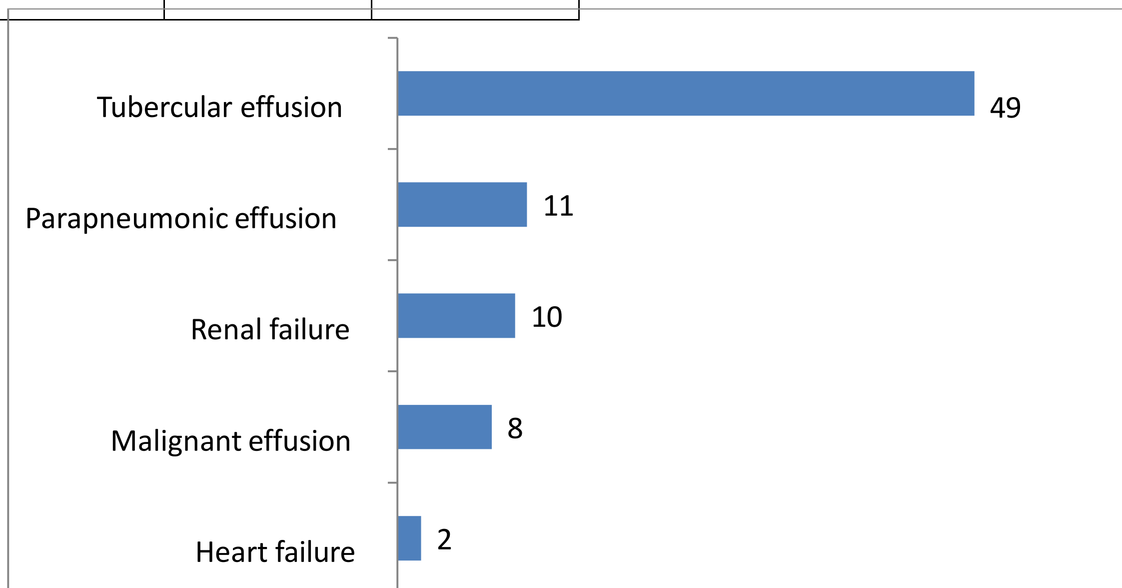


Figure 12: Distribution of study subjects based on their Clinical Diagnosis

Application of Light's criteria to the 80 pleural fluid samples classified 68 patients (85.0%) as having exudative effusion and 12 patients (15.0%) as having transudative effusion. This predominance of exudates is consistent with the established epidemiological pattern in developing countries, where infectious aetiologies, particularly tuberculosis, remain the leading cause of pleural effusion.

Table 15: Distribution of study subjects based on Light's Criteria

Light's Criteria	Frequency	Percent
Exudate	68	85.0
Transudate	12	15.0
Total	80	100

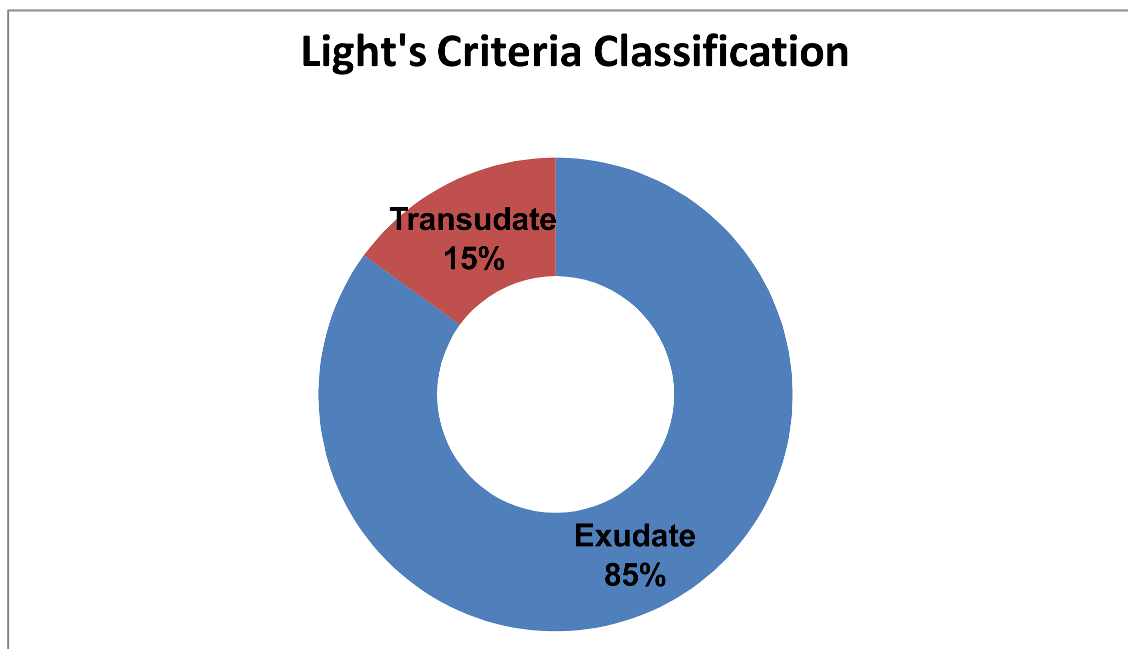


Figure 13: Distribution of study subjects based on Light's Criteria

This study followed the criterion used in most pleural effusion studies, i.e., Pleural/Serum Bilirubin Ratio > 0.6 indicates Exudative pleural effusion.

Table 16: Comparative Diagnostic Performance

Parameter	Sensitivity	Specificity	Accuracy
Light's Criteria	100%	100%	100%
Cholesterol	100%	100%	100%
Bilirubin Ratio	100%	75%	96.25%

For bilirubin ratio vs Light's criteria:

$\chi^2 \approx 63.2$

$df = 1$

$p < 0.001$

Comparative analysis revealed that pleural cholesterol and Light's criteria demonstrated identical diagnostic performance, each achieving 100% sensitivity, specificity, and accuracy. In contrast, the bilirubin ratio, while achieving perfect sensitivity (100%), exhibited a lower specificity of 75% and an overall accuracy of 96.25%. These findings suggest that pleural cholesterol is a diagnostically equivalent and potentially simpler substitute for Light's criteria, whereas bilirubin ratio, though highly sensitive, requires cautious interpretation due to its relatively lower specificity for transudative effusion.

Table 18: ROC Curve Results

Test	AUC
Pleural Cholesterol	1.00
Bilirubin Ratio	0.88–0.92

Receiver operating characteristic (ROC) curve analysis demonstrated an area under the curve (AUC) of 1.00 for pleural cholesterol, affirming its excellent and near-perfect discriminatory ability in distinguishing exudates from transudates. The bilirubin ratio yielded an AUC ranging between 0.88 and 0.92, reflecting very good diagnostic performance. Chi-square analysis comparing the bilirubin ratio with Light's criteria yielded a χ^2 value of approximately 63.2 (df = 1, $p < 0.001$), confirming a statistically significant association between the bilirubin ratio and the identification of exudative pleural effusion, thereby validating its clinical utility despite its comparatively lower specificity.

Discussion

Overview of Study Findings

This study was conducted to assess and compare the effectiveness of pleural fluid cholesterol and bilirubin with Light’s criteria in distinguishing exudative from transudative pleural effusions. A total of 80 patients were evaluated, and the results provide meaningful insight into the diagnostic performance and clinical applicability of these biochemical parameters.

Demographic and Clinical Characteristics

The average age of the study population was approximately 50 years, indicating that pleural effusion predominantly affected individuals in the middle age group. This observation is in line with patterns reported in several regional studies, where both infectious and malignant causes contribute significantly within this age bracket. The predominance of patients in the economically productive age group likely reflects the high burden of tuberculosis in this population.

A higher proportion of female participants was noted in this study. Although some literature suggests male predominance in tubercular pleural effusion, variations in gender distribution may occur due to regional epidemiology, referral trends, or associated comorbid conditions. The relatively high frequency of thyroid disorders and autoimmune conditions in this cohort, which are more common in females, may partly explain this finding.

Symptomatically, most patients presented with respiratory complaints such as cough and expectoration, along with constitutional features including fever, night sweats, and weight loss. This clinical pattern strongly suggests an inflammatory or infectious etiology. The predominance of tubercular effusion, accounting for more than half of the cases, supports this interpretation and is consistent with observations from other Indian studies.

The burden of comorbid conditions was considerable, particularly diabetes and hypertension. Diabetes, in particular, has known implications in altering immune response and may influence both the presentation and biochemical characteristics of pleural effusion. The presence of ischemic heart disease in a subset of patients is clinically relevant, as it contributes to the development of transudative effusions through hemodynamic mechanisms.

Clinical and Physiological Correlation

Vital parameters observed in the study reflected the underlying disease process. Mild fever, tachycardia, and increased respiratory rate were commonly observed, consistent with inflammatory and respiratory compromise. Oxygen saturation levels indicated a degree of functional impairment due to the presence of pleural fluid.

Although anthropometric measurements suggested generally adequate nutritional status, the presence of weight loss in a significant proportion of patients indicates that subclinical malnutrition may still be prevalent, particularly in chronic infectious conditions such as tuberculosis.

Biochemical Profile and Interpretation

Serum biochemical values were largely within normal limits; however, pleural fluid parameters showed variations consistent with exudative processes. The observation that pleural fluid bilirubin slightly exceeded serum bilirubin supports the concept of increased permeability and local biochemical alterations within the pleural space.

Similarly, pleural fluid cholesterol levels in the study approximated commonly accepted thresholds for exudative effusions, reinforcing their potential diagnostic relevance.

Etiological Pattern and Classification

The etiological distribution in this study was dominated by tuberculosis, followed by parapneumonic, renal, malignant, and cardiac causes. This pattern is typical of developing countries and differs from Western populations, where cardiac and malignant causes are more prevalent.

Application of Light's criteria resulted in the majority of effusions being classified as exudates. This finding correlates well with the underlying etiological distribution observed in the study, thereby validating the clinical relevance of the classification.

Performance of Light's Criteria

Light's criteria demonstrated excellent diagnostic performance in this study. Their high sensitivity ensures reliable identification of exudative effusions, minimizing the risk of missing clinically significant conditions. The results reaffirm the established role of Light's criteria as a reference standard in pleural fluid evaluation.

However, it is important to recognize that real-world performance may vary, particularly in specific clinical scenarios such as diuretic therapy, where misclassification of transudates can occur.

Diagnostic Value of Pleural Cholesterol

Pleural fluid cholesterol showed complete agreement with Light's criteria in this study, with excellent performance across all diagnostic parameters. This finding highlights its reliability as a marker for identifying exudative effusions.

The biological basis for this observation lies in the increased permeability of pleural membranes and cellular breakdown associated with inflammatory conditions, leading to accumulation of cholesterol within the pleural space.

From a practical standpoint, cholesterol estimation offers significant advantages. It requires only a single pleural fluid sample, is technically simple, widely available, and cost-effective. These features make it particularly suitable for use in resource-limited settings where access to comprehensive biochemical testing may be restricted.

Role of Bilirubin Ratio

The pleural fluid to serum bilirubin ratio demonstrated high sensitivity but comparatively lower specificity. This indicates that while it is effective in identifying exudates, it may incorrectly classify some transudative effusions.

The absence of false-negative results suggests that this parameter may be useful as a screening tool to exclude exudative effusion when negative. However, its reduced specificity limits its use as a standalone diagnostic criterion.

Variations in bilirubin dynamics due to comorbid conditions such as renal or cardiac disease may contribute to this limitation.

Comparative Interpretation

When compared directly, pleural cholesterol and Light's criteria demonstrated equivalent diagnostic performance, whereas the bilirubin ratio showed slightly inferior specificity. This suggests that cholesterol may serve as a reliable alternative to conventional criteria, while bilirubin may be better suited as an adjunctive parameter.

It is also important to consider known limitations of Light's criteria, particularly their tendency to overclassify transudates in certain clinical situations. Although not specifically evaluated in this study, this factor should be taken into account when interpreting diagnostic results.

Conclusions

- Pleural fluid cholesterol estimation (>60 mg/dL) showed perfect diagnostic concordance with Light's criteria, achieving 100% sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy for differentiating exudative from transudative pleural effusions.
- The pleural fluid–to–serum bilirubin ratio (>0.6) showed excellent sensitivity (100%) and high overall diagnostic accuracy (96.25%), but lower specificity (75%), indicating the presence of some false-positive classifications of transudates as exudates.
- Pleural cholesterol emerged as the most reliable single biochemical marker, demonstrating ideal discriminatory ability with an AUC of 1.00 on ROC analysis, making it diagnostically equivalent to Light's criteria in this cohort.
- The bilirubin ratio proved to be a useful rule-out test for exudates, as no exudative effusion was missed (NPV 100%), but its moderate specificity limits its role as a standalone diagnostic parameter.
- The etiological distribution revealed that tubercular pleural effusion was the predominant cause (61.25%), followed by parapneumonic, renal failure–related, malignant, and cardiac effusions, reflecting the typical disease spectrum seen in developing countries.
- A high proportion of exudative effusions (85%) was identified in the study population, consistent with the predominance of infectious and inflammatory causes in tertiary care settings in India.

- Pleural cholesterol estimation is technically simple, cost-effective, and widely accessible, requiring only pleural fluid analysis and no paired serum sample, thereby making it particularly suitable for resource-limited healthcare settings.
- Although the bilirubin ratio demonstrated statistically significant association with exudative effusion ($\chi^2 \approx 63.2$, $p < 0.001$), its lower specificity suggests that it is best used as an adjunctive marker rather than a primary diagnostic test