

Research Article

Clinicoradiological Spectrum and Predictors of Complicated Parapneumonic Effusion: A Prospective Observational Study from a Tertiary Care Center in India

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ABSTRACT

Background: Parapneumonic effusion (PPE) represents a spectrum ranging from simple exudative effusion to empyema. Early identification of severity is essential for timely intervention and improved clinical outcomes

Aim: To evaluate the clinicoradiological characteristics of parapneumonic effusion and identify independent predictors of complicated effusion

Methods: This prospective observational study was conducted over 18 months in a tertiary care center in India, including 42 adult patients with PPE. Clinical features, pleural fluid parameters, and radiological findings were analyzed. Effusions were classified as uncomplicated or complicated based on biochemical and ultrasonographic criteria. Variables with $p < 0.1$ in univariate analysis were included in multivariate logistic regression to determine independent predictors. Model calibration was assessed using the Hosmer-Lemeshow test, and multicollinearity was evaluated using variance inflation factor (VIF).

Results: The mean age was 47.8 ± 14.2 years with male predominance (78.6%). Complicated PPE was present in 57.1% of patients. These patients had significantly higher pleural fluid LDH (1980 ± 850 vs 820 ± 310 IU/L, $p < 0.001$) and lower glucose levels (36.2 ± 10.4 vs 72.4 ± 12.1 mg/dL, $p < 0.001$). Loculations were significantly more frequent (58.3% vs 11.1%, $p < 0.001$). Independent predictors included LDH > 1000 IU/L (OR 5.8, 95% CI: 2.1-15.9), glucose < 60 mg/dL (OR 6.5, 95% CI: 2.4-17.4), and presence of loculations (OR 7.4, 95% CI: 2.6-20.8). ROC analysis showed good discriminative ability (LDH AUC = 0.82; glucose AUC = 0.85). The model demonstrated good calibration (Hosmer-Lemeshow $p > 0.05$) with no multicollinearity (VIF < 2).

Conclusion: Combined biochemical and ultrasonographic parameters reliably predict complicated parapneumonic effusion and can guide early aggressive management.

Keywords: Parapneumonic Effusion, Pleural Infection, Ultrasonography, Lactate Dehydrogenase, Empyema.

INTRODUCTION

Parapneumonic effusion (PPE) is a common complication of pneumonia, occurring in approximately 20–40% of hospitalized patients and contributing significantly to morbidity. PPE progresses through three stages: exudative, fibrinopurulent, and organizing, with potential progression to empyema if inadequately treated.

The pathophysiology involves bacterial invasion of the pleural space leading to an inflammatory cascade characterized by cytokine release, increased vascular permeability, and fibrin deposition. Impaired fibrinolysis, mediated by plasminogen activator inhibitor-1 (PAI-1), promotes septation and loculation, complicating drainage.

Pleural fluid biochemical markers are essential in assessing severity. Elevated lactate dehydrogenase (LDH) reflects pleural inflammation and cellular destruction, while reduced glucose indicates increased metabolic activity of leukocytes and bacteria.

Radiological evaluation plays a critical role. Chest radiography provides initial assessment, whereas thoracic ultrasonography offers superior sensitivity in detecting septations and loculations and facilitates image-guided intervention.

In India, delayed presentation and high infectious burden often result in a higher proportion of complicated PPE. Therefore, identifying clinicoradiological predictors is crucial for early intervention and improved outcomes.

MATERIALS AND METHODS

Study Design

Prospective observational study

Study Setting:

Department of Respiratory Medicine, tertiary care teaching hospital, Rajasthan, India

Duration:

18 months

Sample Size:

42 patients

Inclusion Criteria

- Age ≥ 18 years
- Clinical and radiological evidence of pneumonia
- Presence of pleural effusion

Exclusion Criteria

- Tubercular pleural effusion
- Malignancy-related effusion
- Transudative effusions

Data Collection

Clinical Parameters

- Fever

- Cough
- Dyspnea
- Chest pain

Pleural Fluid Analysis

- Total and differential cell count
- Protein
- LDH
- Glucose
- ADA

Radiological Assessment

- Chest X-ray
- Thoracic ultrasonography (septations, loculations)

Definitions

Complicated PPE (any one):

- LDH >1000 IU/L
- Glucose <60 mg/dL
- Presence of septations/loculations on ultrasonography

Statistical Analysis

- Continuous variables expressed as mean $\pm$ SD
- Categorical variables expressed as frequency and percentage
- Independent t-test for continuous variables
- Chi-square/Fisher's exact test for categorical variables
- Variables with $p < 0.1$ included in multivariate logistic regression
- Odds ratio (OR) with 95% confidence interval (CI) calculated
- ROC curves used to assess diagnostic performance (cut-offs via Youden index)
- Model calibration assessed using Hosmer–Lemeshow test
- Multicollinearity assessed using VIF
- $p < 0.05$ considered statistically significant

RESULTS

Table 1: Baseline Demographic and Clinical Profile (N=42)

Parameter	Value
Mean Age (years)	47.8 $\pm$ 14.2
Male	33 (78.6%)
Female	9 (21.4%)

Clinical Features

Symptom	Frequency (%)
Fever	38 (90.5%)
Cough	35 (83.3%)
Dyspnea	32 (76.2%)
Chest Pain	28 (66.7%)

Table 2: Pleural Fluid Characteristics

Parameter	Mean ± SD
Protein (g/dL)	5.2 ± 0.6
LDH (IU/L)	1520 ± 910
Glucose (mg/dL)	48.6 ± 15.2

Cellular Distribution

Type	Frequency (%)
Neutrophilic	31 (73.8%)
Lymphocytic	9 (21.4%)
Mixed	2 (4.8%)

Table 3: Radiological Findings

Parameter	Frequency (%)
Moderate Effusion	26 (61.9%)
Loculations	16 (38.1%)
Septations	18 (42.9%)

Table 4: Comparison between Uncomplicated and Complicated PPE

Parameter	Complicated (n=24)	Uncomplicated (n=18)	p-value
LDH (IU/L)	1980 ± 850	820 ± 310	<0.001
Glucose (mg/dL)	36.2 ± 10.4	72.4 ± 12.1	<0.001
Neutrophils (%)	Higher	Lower	0.01
Loculations	14 (58.3%)	2 (11.1%)	<0.001

Table 5: Predictors of Complicated PPE

Variable	Odds Ratio (OR)	95% CI	p-value
LDH >1000 IU/L	5.8	2.1–15.9	<0.001
Glucose <60 mg/dL	6.5	2.4–17.4	<0.001
Neutrophils >75%	3.2	1.2–8.5	0.02
Loculations	7.4	2.6–20.8	<0.001

ROC Analysis

- LDH: AUC = 0.82 (95% CI: 0.70–0.93)
 - Glucose: AUC = 0.85 (95% CI: 0.74–0.95)
- Both parameters demonstrated good diagnostic accuracy.

The regression model showed good calibration (Hosmer–Lemeshow $p > 0.05$) and no multicollinearity (VIF <2).

DISCUSSION

Parapneumonic effusion remains one of the most frequent pleural complications of pneumonia and continues to contribute significantly to morbidity and healthcare burden, particularly in developing countries where delayed diagnosis and treatment are common. In our prospective observational study evaluated the clinikoradiological spectrum and predictors of complicated parapneumonic effusion in patients admitted to a tertiary care teaching hospital in India. Our study finding demonstrate that a combination of pleural fluid biochemical abnormalities and ultrasonographic findings can reliably identify

patients at increased risk of complicated disease.^{1–3}

In our study, the mean age of patients was 47.8 ± 14.2 years, with a marked male predominance (78.6%). Similar demographic patterns have been reported in previous studies on pleural infection. Chen et al. also observed predominance of middle-aged male patients with pleural infection and empyema requiring intervention.⁹ Davies et al. similarly reported higher incidence among males, likely related to smoking exposure, alcohol use, occupational risk factors, and delayed healthcare access.¹⁰ These findings are comparable to the demographic profile observed in our study. Fever, cough, and dyspnea were the most common presenting symptoms in our study. Similar clinical presentations have been described previously in studies evaluating parapneumonic effusion and pleural infection.^{1,7} Chest pain observed in our study likely reflects pleural irritation associated with active inflammatory involvement of the pleura.

Pleural fluid analysis in our study demonstrated neutrophilic predominance in the majority of patients, particularly among those with complicated parapneumonic effusion. Comparable findings were reported by Idell et al., where acute pleural infection was characterized by intense neutrophilic inflammatory response leading to cytokine release, fibrin deposition, and progression toward fibrinopurulent disease.² Similar neutrophilic predominance in complicated pleural infection has also been documented in previous observational studies evaluating parapneumonic effusions.^{13, 14}

In our study was the significantly elevated pleural fluid LDH levels among patients with complicated parapneumonic effusion. Patients with complicated disease demonstrated markedly higher LDH values compared to uncomplicated cases (1980 ± 850 vs 820 ± 310 IU/L, $p < 0.001$). Similar observations were reported by Heffner et al., where elevated LDH levels correlated strongly with severe pleural inflammation, loculation and poor clinical outcomes.⁸ Light RW also emphasized that elevated pleural fluid LDH reflects increased pleural membrane permeability, cellular injury, and ongoing inflammatory activity.¹ In our study, LDH >1000 IU/L emerged as an independent predictor of complicated parapneumonic effusion with an odds ratio of 5.8, reinforcing its established diagnostic significance.

Pleural fluid glucose levels were significantly lower in patients with complicated parapneumonic effusion (36.2 ± 10.4 vs 72.4 ± 12.1 mg/dL, $p < 0.001$). These findings are consistent with previous observations where low glucose concentration was identified as an important marker of advanced pleural inflammation and active bacterial metabolism.^{7, 13} Similar findings were also incorporated in the British Thoracic Society guideline, which recommends low pleural fluid glucose as an indicator of complicated pleural infection requiring aggressive management.^{6, 10} In our study, glucose <60 mg/dL showed strong predictive association with complicated disease with an odds ratio of 6.5.

Thoracic ultrasonography played a particularly important role in identifying radiological complexity in our patients. Septations and loculations were significantly more frequent among complicated parapneumonic effusions. Similar findings were reported previously where impaired fibrinolytic activity and increased

plasminogen activator inhibitor-1 (PAI-1) activity promoted fibrin deposition and septation formation within the pleural cavity.² Koegelenberg et al. also emphasized the importance of thoracic ultrasonography in detecting loculations and guiding pleural intervention.⁵ In our study, loculations demonstrated the strongest predictive association with complicated disease, with an odds ratio of 7.4.

The findings of our multivariate logistic regression analysis are broadly consistent with currently available literature. Pleural fluid LDH >1000 IU/L, glucose <60 mg/dL, neutrophilic predominance and ultrasonographic loculations emerged as significant independent predictors of complicated parapneumonic effusion. Similar predictors have been described in previous studies evaluating pleural infection severity and drainage outcomes.^{3, 9, 13} The strong association observed in our study further reinforces the combined utility of pleural fluid analysis and thoracic ultrasonography in risk stratification of parapneumonic effusion.

ROC curve analysis performed in our study demonstrated good diagnostic accuracy for both pleural fluid LDH and glucose levels. The observed AUC values for LDH (0.82) and glucose (0.85) indicate satisfactory discriminative ability for identifying complicated parapneumonic effusion. Comparable diagnostic performance of pleural fluid biochemical markers has been reported in previous studies assessing pleural infection severity.^{8, 14} Additionally, the regression model demonstrated acceptable calibration on Hosmer–Lemeshow testing with no evidence of significant multicollinearity, supporting the statistical robustness of our predictive model.

The findings of our study have an important clinical implications. Early integration of pleural fluid biochemical parameters with thoracic ultrasonographic assessment may facilitate prompt identification of patients at higher risk of complicated disease. Timely recognition of complicated parapneumonic effusion allows early institution of appropriate therapy, including chest tube drainage, intrapleural fibrinolytic therapy or surgical referral where indicated. Similar management approaches have been recommended in British Thoracic Society pleural disease guidelines and supported by the MIST-2 trial conducted by Rahman et al.^{3, 6, 10}

CONCLUSION

Parapneumonic effusion severity is strongly predicted by a combination of pleural fluid biochemical markers and ultrasonographic findings.

Key predictors of complicated PPE include:

- LDH >1000 IU/L
- Glucose <60 mg/dL
- Presence of loculations

Early integration of these parameters enables timely diagnosis and guides appropriate intervention and reducing morbidity.

Limitations

1. Single-center study
2. Moderate sample size (n=42)
3. Lack of long-term follow-up

Declarations

- Written informed consent obtained
- No conflict of interest
- No funding

Figure Legends

1. Distribution of clinical symptoms
2. Pleural fluid cellular profile
3. Comparison of uncomplicated vs complicated PPE
4. ROC curve for LDH and glucose
5. Diagnostic algorithm for PPE

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