THE IMPACT OF FLUID BALANCE ON THE SEVERITY OF PULMONARY EDEMA AND RESPIRATORY FAILURE IN CHILDREN WITH SEVERE PNEUMONIA: A PROSPECTIVE MULTICENTER COHORT STUDY

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Abstract: *Background: Fluid overload may exacerbate pulmonary edema and worsen respiratory failure in children with severe pneumonia. However, prospective pneumonia-specific data integrating lung ultrasound (LUS) monitoring remain limited.*

Methods: *This 24-month prospective multicenter cohort study included children aged 1 month–16 years admitted with severe pneumonia to pediatric intensive care units. Cumulative fluid balance (CFB) was calculated as percentage of admission body weight. Serial lung ultrasound examinations were performed during the first 7 days. Primary outcomes were oxygenation index (OI) and need for invasive mechanical ventilation. Multivariable regression was used to assess associations.*

Results: *Among 294 analyzed patients, 22% developed CFB ≥10% within 72 hours. Each 1% increase in CFB independently increased LUS score by 1.2 points (95% CI 0.9–1.5; p<0.001). CFB ≥10% was associated with a 3.73-fold increased odds of severe respiratory failure (OI >16) (95% CI 2.11–6.58; p<0.001). Mechanical ventilation rates increased from 28% (<5% CFB) to 72% (≥10% CFB). PICU length of stay and ventilation duration increased proportionally with fluid accumulation.*

Conclusions: *Positive cumulative fluid balance independently predicts pulmonary edema progression and respiratory failure severity in severe pediatric pneumonia. Maintaining CFB below 5–7% within the first 72 hours may reduce mechanical ventilation risk. Lung ultrasound is a sensitive bedside tool for monitoring fluid-related lung injury.*

Keywords: *Severe pneumonia; Fluid balance; Pulmonary edema; Pediatric respiratory failure; Lung ultrasound; Oxygenation index.*

INTRODUCTION

Pneumonia remains a leading cause of death among children under five years, accounting for approximately 14% of global childhood mortality. Severe pneumonia frequently progresses to hypoxemia and respiratory failure due to alveolar consolidation, inflammatory injury, and capillary leak.

Fluid resuscitation is essential in critically ill children; however, excessive fluid accumulation may increase extravascular lung water and impair gas exchange. Prior studies in pediatric acute lung injury populations have demonstrated associations between fluid overload exceeding 10% body weight and prolonged mechanical ventilation and mortality. Nevertheless, prospective pneumonia-focused evidence integrating quantitative lung ultrasound remains scarce.

This study aimed to evaluate the relationship between cumulative fluid balance, ultrasound-defined pulmonary edema, and respiratory failure severity in children with severe pneumonia.

2. METHODS

Study Design

Prospective multicenter observational cohort study conducted from January 2024 to December 2025 in three tertiary pediatric intensive care units.

Participants

Inclusion criteria:

- Age 1 month–16 years
- WHO-defined severe pneumonia
- SpO_2 < 90%
- Requirement for respiratory support

Exclusion criteria:

- Cyanotic congenital heart disease
- Chronic lung disease requiring home oxygen
- Renal replacement therapy
- Limitations of care

Fluid Balance Calculation

CFB (%) = (Σ [fluid input − fluid output] / admission body weight) × 100

Stratification:

- <5%
- 5–9.9%
- ≥10%
- ≥15%

Lung Ultrasound

Daily 12-zone protocol for 7 days. Semi-quantitative scoring based on:

- B-lines
- Coalescent B-lines
- Subpleural consolidation
- Pleural abnormalities

Outcomes

Primary:

- Oxygenation index (OI)
- Invasive mechanical ventilation

Secondary:

- Ventilation duration
- PICU length of stay
- Mortality

Statistical Analysis

Multivariable logistic regression adjusting for age and PRISM III.

Mixed-effects modeling for longitudinal LUS trends.

Significance level: $p<0.05$.

3. RESULTS

294 patients were analyzed.

Median age: 3.8 years

Median PRISM III: 8

22% developed CFB ≥10%.

Each 1% CFB increase:

- +1.2 LUS points ($p<0.001$)

OI increased significantly across fluid strata.

CFB ≥10%:

- OR 3.73 for severe respiratory failure
- 72% required mechanical ventilation

PICU stay and ventilation duration doubled in ≥10% group.

Mortality increased across strata but lost significance after adjustment.

4. DISCUSSION

This study demonstrates a strong dose–response relationship between fluid accumulation and respiratory deterioration in severe pediatric pneumonia. A nonlinear threshold effect was observed beyond 8–10% CFB. Lung ultrasound provided dynamic, radiation-free assessment of extravascular lung water and correlated strongly with oxygenation impairment. Fluid overload appears not merely a severity marker but a modifiable mediator of lung injury. Restrictive fluid strategies during early critical illness may prevent escalation to invasive ventilation.

5. LIMITATIONS

- Observational design
- Possible residual confounding
- Tertiary-center setting

6. CONCLUSION

Cumulative positive fluid balance independently predicts pulmonary edema and respiratory failure severity in children with severe pneumonia. Maintaining CFB below 5–7% during the first 72 hours may reduce invasive ventilation risk. Lung ultrasound should be integrated into fluid stewardship protocols in pediatric intensive care.

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