

Research Article**Effect of Early Corticosteroid Therapy on Oxygenation and ICU Stay in Severe Community-Acquired Pneumonia Treated in the critical care unit**
Aun Muhammad¹, Faheed ul Haque², Abdul Waheed³, Saleem Adil⁴, Usman Zeeshan⁵, Muhammad Azhar Khan⁶**Affiliations:**¹ Registrar Anaesthesiology, Blackrock Health, Dublin.² Assistant Professor Perioperative Medicine, Anesthesia and Critical Care, Sialkot Medical College, Sialkot.³ Assistant Professor Anesthesia, Akhtar Saeed Medical College.⁴ Associate Professor Community Medicine, Pak Red Crescent Medical and Medical College, Dina Naath, Lahore.⁵ Assistant Professor Anesthesia, Abu Umara Medical College.⁶ Assistant Professor Community Medicine, CMH Kharian Medical College, Kharian.**Corresponding author: Aun Muhammad**

Abstract: Severe community-acquired pneumonia (CAP) remains a major cause of acute respiratory failure and prolonged intensive care unit (ICU) admission despite advances in antimicrobial and ventilatory management. Corticosteroids, through their potent anti-inflammatory action, have been proposed to modulate dysregulated host immune responses, reduce alveolar exudation, and improve oxygenation. However, their optimal timing in severe CAP remains debated. This prospective comparative study evaluated the effect of early corticosteroid administration on oxygenation indices and ICU outcomes among critically ill CAP patients in a tertiary care hospital in Pakistan.

A total of 120 patients fulfilling criteria for severe CAP were randomly allocated to two groups: early corticosteroid therapy (intravenous methylprednisolone 1 mg/kg/day initiated within 24 h of ICU admission, n = 60) and control (standard therapy without steroids, n = 60). Arterial blood gases, PaO₂/FiO₂ ratio, duration of mechanical ventilation, and ICU stay were recorded. At 72 h, mean PaO₂/FiO₂ ratio improved significantly in the corticosteroid group (283 ± 52) compared to control (224 ± 49; p < 0.001). Median ICU stay was shorter (6.3 ± 2.1 vs 9.1 ± 3.4 days; p < 0.001), and mortality trend favored steroid use (13.3% vs 23.3%; p = 0.18).

Early corticosteroid therapy significantly enhanced oxygenation and shortened ICU stay without increasing complications, supporting its adjunctive role in severe CAP management when initiated promptly.

Keywords: corticosteroids, severe community-acquired pneumonia, oxygenation, ICU stay

Introduction: Severe community-acquired pneumonia (CAP) is a major global health burden and among the leading causes of intensive care unit admissions for respiratory failure. Despite appropriate antibiotic therapy and advanced supportive measures, mortality in severe CAP remains high, ranging between 20% and 50% depending on comorbidities and the need for mechanical ventilation. The pathophysiology extends beyond infection alone: an exaggerated host inflammatory response contributes to alveolar damage, endothelial dysfunction, and impaired oxygen diffusion. Consequently, the therapeutic approach has expanded to include immunomodulatory agents capable of restoring inflammatory balance.¹⁻⁴

Corticosteroids have long been recognized for their broad anti-inflammatory and anti-exudative properties. They inhibit nuclear factor kappa-B (NF- κ B) signaling, reduce cytokine production (IL-6, TNF- α), and stabilize capillary membranes, thereby limiting alveolar flooding and hypoxemia. However, clinical adoption has been cautious due to concerns regarding secondary infection, delayed bacterial clearance, and hyperglycemia. Recent high-quality trials (2022–2024) and meta-analyses have renewed interest in their role, particularly emphasizing early initiation before the inflammatory cascade becomes irreversible.⁵⁻⁹

The degree of hypoxemia, typically assessed through the PaO₂/FiO₂ ratio, serves as a key prognostic marker in severe CAP. Studies suggest that early attenuation of inflammatory injury may directly improve this oxygenation index, reduce ventilator dependence, and shorten ICU stay. Delayed corticosteroid use, by contrast, may fail to influence established alveolar damage. Therefore, the timing of intervention appears crucial in translating biochemical modulation into clinical recovery.¹⁰⁻¹²

Despite promising international evidence, regional data from South Asia remain scarce. Factors such as delayed presentation, higher pathogen diversity, and resource limitations may influence therapeutic outcomes differently. Moreover, the optimal steroid dose and duration in these settings

remain uncertain. Understanding the impact of early corticosteroid use on oxygenation and ICU length of stay in local patient populations can inform context-specific protocols.

This study was designed to evaluate the effect of early corticosteroid therapy on oxygenation, ventilator dependency, and ICU outcomes among patients with severe community-acquired pneumonia treated in the critical care unit. The hypothesis was that early administration within the first 24 hours of ICU admission improves oxygenation indices and shortens ICU stay without substantially increasing adverse events.

Methodology: This prospective randomized controlled study was conducted at Sialkot medical college, from March 2023 to May 2024. Ethical approval was obtained from the institutional review board, and verbal informed consent was secured from patients or their next of kin.

Using **Epi Info 7.2**, a minimum sample of 110 patients was calculated based on an expected 20% improvement in $\text{PaO}_2/\text{FiO}_2$ ratio with corticosteroid therapy, power 80%, and confidence interval 95%. A total of 120 patients meeting inclusion criteria were enrolled.

Inclusion criteria included adults aged 18–75 years fulfilling the 2019 IDSA/ATS criteria for severe CAP (≥ 1 major or ≥ 3 minor criteria) and requiring ICU admission. **Exclusion criteria** were immunosuppression, prior corticosteroid use, viral or fungal pneumonia, uncontrolled diabetes, gastrointestinal bleeding, or pregnancy.

Patients were randomized into two equal groups ($n = 60$ each):

- **Group A (Early Corticosteroid Group):** Received intravenous methylprednisolone 1 mg/kg/day within 24 hours of ICU admission for five days.
- **Group B (Control Group):** Received standard antibiotic and supportive care without corticosteroids.

Both groups received protocol-based antibiotic therapy, mechanical ventilation as indicated, and supportive management per ICU guidelines. Arterial blood gases were recorded at baseline and after 72 hours. Primary outcome was improvement in $\text{PaO}_2/\text{FiO}_2$ ratio; secondary outcomes included duration of mechanical ventilation, ICU length of stay, and 28-day mortality.

Statistical analysis was conducted using SPSS v26. Quantitative data were presented as mean $\pm$ SD; categorical variables as percentages. Independent t-test and χ^2 test were applied; $p < 0.05$ was considered significant.

Results

Table 1. Baseline Demographic and Clinical Data (n = 120)

Variable	Early Corticosteroid (n = 60)	Control (n = 60)	p-Value
Age (years)	55.8 $\pm$ 12.6	56.2 $\pm$ 13.1	0.84
Male/Female	38/22	36/24	0.69
BMI (kg/m ²)	27.3 $\pm$ 4.5	27.1 $\pm$ 4.1	0.77
PaO ₂ /FiO ₂ at admission	189 $\pm$ 44	191 $\pm$ 47	0.81
CURB-65 score $\geq$ 3	35 (58.3%)	33 (55%)	0.71

Both groups were comparable at baseline, ensuring balanced allocation and minimizing selection bias.

Table 2. Oxygenation and Ventilation Outcomes

Parameter	Early Corticosteroid	Control	p-Value
PaO ₂ /FiO ₂ after 72 h	283 $\pm$ 52	224 $\pm$ 49	<0.001
Improvement (%)	49.7 $\pm$ 21.5	17.3 $\pm$ 18.6	<0.001
Duration of mechanical ventilation (days)	4.9 $\pm$ 2.1	7.2 $\pm$ 3.3	<0.001

Early corticosteroid administration resulted in a statistically significant improvement in oxygenation and reduced ventilatory duration.

Table 3. ICU Stay and Outcome Indicators

Variable	Early Corticosteroid	Control	p-Value
ICU stay (days)	6.3 ± 2.1	9.1 ± 3.4	<0.001
28-day mortality (%)	13.3	23.3	0.18
Secondary infection (%)	6.6	5.0	0.73

Patients receiving early corticosteroids had significantly shorter ICU stay, with no increase in secondary infection or mortality.

Discussion: This study demonstrated that early initiation of corticosteroid therapy within 24 hours of ICU admission significantly improved oxygenation and reduced ICU stay in severe community-acquired pneumonia. These findings support the hypothesis that prompt immunomodulation mitigates the inflammatory cascade responsible for alveolar dysfunction and impaired gas exchange.¹³⁻¹⁵

The PaO₂/FiO₂ ratio, a well-established marker of pulmonary oxygenation efficiency, improved by nearly 50% in the corticosteroid group compared to only 17% in controls. This statistically robust difference (p < 0.001) aligns with recent clinical trials conducted between 2022 and 2024, which consistently demonstrated improved oxygenation when steroids were administered early rather than delayed. The mechanism likely involves suppression of cytokine-mediated alveolar permeability and stabilization of endothelial tight junctions.¹⁶⁻¹⁸

The reduction in mechanical ventilation duration observed in the corticosteroid group further corroborates the physiologic benefit. Shorter ventilator dependence reduces risks of ventilator-associated pneumonia and sedation-related complications.¹⁹⁻²⁰ Although overall mortality reduction was not statistically significant, a downward trend was evident, suggesting that early steroid use may confer survival benefit with adequate sample size and longer follow-up.

Importantly, no significant increase in secondary infections or hyperglycemia-related complications was observed, addressing a major historical concern regarding steroid use. This finding mirrors newer studies indicating that short-course, moderate-dose regimens maintain immunologic balance without excessive suppression.

ICU stay was reduced by nearly three days on average, a clinically meaningful difference that translates into improved bed turnover and cost efficiency—critical factors in resource-limited critical care settings such as Pakistan. Early steroid use thus offers both clinical and economic advantages when incorporated judiciously into CAP management algorithms.

The results affirm the evolving understanding that the hyperinflammatory phenotype of CAP, rather than pathogen load alone, drives disease severity. Corticosteroids serve as targeted anti-inflammatory therapy when used early, synergizing with antibiotics to restore physiological homeostasis.

While this study's single-center design limits generalizability, its prospective randomized structure and standardized protocols strengthen its reliability. Future multicentric research incorporating biomarker-guided therapy (e.g., CRP, IL-6 thresholds) may refine patient selection to maximize benefit and minimize unnecessary exposure.

Conclusion: Early administration of corticosteroids in severe community-acquired pneumonia significantly improves oxygenation and shortens ICU stay without increasing complications. Initiating therapy within 24 hours of ICU admission offers clear clinical benefit and should be considered as adjunctive treatment in severe CAP protocols, especially in high-burden critical care settings.

References

1. Torres A, et al. Corticosteroids in severe community-acquired pneumonia: updated evidence and practice. *J Clin Med*. 2023;12(15):5142.
2. Cheng H, et al. Early methylprednisolone therapy improves oxygenation in severe CAP: a randomized trial. 2024; DOI: 10.1186/s12890-024-02817-3.
3. Singh N, et al. Timing of corticosteroids in pneumonia-related ARDS. 2023; DOI: 10.1016/j.chest.2023.02.012.
4. Lopez M, et al. Cytokine modulation and outcome in CAP with early steroids. 2022; DOI: 10.1093/cid/ciac598.
5. Qureshi S, et al. Critical care outcomes in severe CAP: Pakistani experience. 2024; DOI: 10.1186/s13054-024-04815-6.

6. Wang J, et al. Corticosteroids and inflammation resolution in bacterial pneumonia. 2023; DOI: 10.1007/s00134-023-07123-1.
7. Zhao Y, et al. Oxygenation response and mechanical ventilation duration with corticosteroids. 2023; DOI: 10.1097/CCM.0000000000005945.
8. Ahmed H, et al. Impact of early anti-inflammatory therapy in ICU pneumonia. 2024; DOI: 10.3390/jcm13020594.
9. Li X, et al. Corticosteroids in critical pneumonia: timing matters. 2022; DOI: 10.1016/j.jcrc.2022.103121.
10. Rehman A, et al. Clinical predictors of ICU stay in severe CAP. 2023; DOI: 10.1186/s12931-023-02317-4.
11. Pletz M, et al. Immunomodulatory adjuncts in severe pneumonia. 2024; DOI: 10.1007/s00134-024-07256-2.
12. Javed S, et al. Pakistani data on steroid use in CAP: a prospective analysis. 2023; DOI: 10.1007/s15010-023-01957-9.
13. Ranzani O, et al. Systemic corticosteroids in CAP: clinical outcomes and biomarkers. 2022; DOI: 10.1016/j.chest.2022.04.013.
14. Mehta M, et al. Corticosteroid benefit in early inflammatory control of pneumonia. 2024; DOI: 10.1007/s12016-024-09212-1.
15. Kumar D, et al. Ventilation outcomes in severe CAP with steroids. 2023; DOI: 10.1186/s13054-023-04712-7.
16. Wu C, et al. Glucocorticoid-mediated lung protection: molecular mechanisms. 2023; DOI: 10.3390/ijms242317111.
17. Bukhari S, et al. ICU cost reduction with early corticosteroids. 2024; DOI: 10.1186/s12931-024-02455-8.
18. Tanaka T, et al. Steroid timing and clinical trajectory in severe pneumonia. 2023; DOI: 10.1016/j.rmed.2023.107341.
19. Yousaf H, et al. Local practice audit of corticosteroid use in critical pneumonia. 2022; DOI: 10.1186/s13054-022-03861-2.
20. Kablak-Ziembicka A, Przewlocki T. Clinical significance of systemic inflammatory modulation and critical outcomes. J Clin Med. 2021;10(20):4628. DOI: <https://doi.org/10.3390/jcm10204628>.