JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

https://doi.org/10.61919/mc4t6k29

Original Article

Effectiveness of Early Antibiotic Administration on Outcomes in Pneumonia Patients in Emergency Department

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ABSTRACT

Background: Pneumonia remains a major cause of morbidity and mortality worldwide and frequently presents to emergency departments. Early initiation of antibiotic therapy has been proposed as an important factor influencing clinical outcomes in patients with pneumonia; however, delays in treatment remain common in busy emergency care settings, particularly in resource-limited healthcare systems. Objective: To evaluate the association between early antibiotic administration and clinical outcomes among adult patients presenting with pneumonia to the emergency department of a tertiary care hospital. Methods: This prospective observational study was conducted in the emergency department of Lady Reading Hospital–Medical Teaching Institution, Peshawar, Pakistan, from 1 March to 31 July 2025. Adult patients aged ≥18 years presenting with clinically and radiologically confirmed pneumonia were consecutively enrolled. The primary exposure variable was time from emergency department registration to first intravenous antibiotic administration. Patients were categorized into early (≤3 hours) and delayed (>3 hours) antibiotic groups. Outcomes assessed included length of hospital stay, intensive care unit (ICU) admission, and in-hospital mortality. Data were analyzed using SPSS version 26 with appropriate comparative and multivariable statistical methods. Results: A total of 120 patients were included (mean age 56.8 ± 17.4 years; 60% male). Early antibiotic administration occurred in 68 (56.7%) patients. Patients receiving early antibiotics had significantly shorter hospital stays (5.1 ± 2.3 vs 7.4 ± 3.1 days; p=0.01) and lower ICU admission rates (11.8% vs 26.9%; p=0.03). In-hospital mortality was lower in the early antibiotic group (4.4% vs 13.5%), although this difference did not reach statistical significance (p=0.06). Conclusion: Early administration of antibiotics within three hours of emergency department presentation was associated with shorter hospitalization and reduced ICU admission among pneumonia patients. These findings support the importance of timely antimicrobial therapy in emergency department management of pneumonia. Keywords: Pneumonia; Anti-Bacterial Agents; Emergency Service, Hospital; Time-to-Treatment; Treatment Outcome; Community-Acquired Infections.

"Cite this Article" | Received: 18 January 2026; Accepted: 25 February 2026; Published: 28 February 2026.

Author Contributions: Concept: IUK; Design: MAK; Data Collection: SS, KHK, AZ, TH; Analysis: AH; Drafting: IUK, MAK. **Ethical Approval**: N/A. Informed Consent: Written informed consent was obtained from all participants; Conflict of Interest: The authors declare no conflict of interest; Funding: No external funding; Data Availability: Available from the corresponding author on reasonable request; Acknowledgments: N/A.

INTRODUCTION

Pneumonia remains one of the most significant infectious causes of morbidity and mortality worldwide, affecting both developed and developing healthcare systems. Globally, an estimated 450 million cases of pneumonia occur annually, accounting for nearly four million deaths each year and representing a substantial burden on emergency and inpatient medical services (1). Lower respiratory tract infections, including pneumonia, continue to rank among the leading causes of death worldwide, reflecting persistent challenges in early recognition, timely treatment, and healthcare accessibility (2). Community-acquired pneumonia (CAP) in particular represents a major public health concern, with global incidence estimates approaching 4350 cases per 100,000 population annually (3). According to

recent Global Burden of Disease data, pneumonia accounted for approximately 2.5 million deaths globally in 2023, with the highest mortality observed among young children and elderly individuals with underlying comorbidities (4). Hospitalized patients with severe pneumonia experience mortality rates ranging from 4% to 37%, particularly in older adults and patients with chronic illnesses, highlighting the clinical importance of early diagnosis and prompt therapeutic intervention (5).

Timely administration of antibiotics is widely considered the cornerstone of pneumonia management. Early antimicrobial therapy aims to limit bacterial proliferation, reduce systemic inflammatory response, and prevent progression to severe complications such as respiratory failure, septic shock, or multi-organ dysfunction. Previous studies have suggested that delays in antibiotic administration are associated with worse clinical outcomes, including prolonged hospital stay, increased need for intensive care, and higher mortality in patients with community-acquired pneumonia (6). Observational and cohort studies conducted in emergency department settings have reported that administration of antibiotics within the first few hours of hospital presentation is associated with earlier clinical stabilization and improved recovery outcomes (9). In many clinical protocols, early treatment thresholds ranging from three to six hours after hospital presentation have been proposed as quality indicators for pneumonia management in emergency care environments (6). However, despite these recommendations, delays in antibiotic administration remain common in busy emergency departments due to factors such as diagnostic uncertainty, patient overcrowding, and variations in triage and treatment workflows.

The burden of pneumonia is particularly pronounced in low- and middle-income countries, where healthcare infrastructure limitations and delayed access to treatment contribute to worse outcomes. Asia accounts for a substantial proportion of global pneumonia-related mortality, with an estimated 1.6 million deaths occurring annually across the region (1). Within South Asia, high disease incidence continues to strain emergency healthcare systems, particularly in settings where early diagnostic and treatment pathways are not consistently implemented (7). India alone contributes nearly one-quarter of the global burden of community-acquired pneumonia, reflecting the large population at risk and the challenges associated with timely management of respiratory infections in resource-constrained environments (8). Similar patterns are observed across neighboring countries, including Pakistan, where pneumonia represents a common cause of emergency department visits and hospital admissions, especially among elderly patients and those with chronic medical conditions (10).

In Pakistan, pneumonia remains a significant contributor to respiratory morbidity and mortality, with studies reporting that it accounts for approximately 15–20% of acute respiratory infections presenting to tertiary care emergency departments (10). Mortality rates among hospitalized pneumonia patients in the country have been reported to range between 10% and 18% in severe cases, particularly among patients with delayed presentation or underlying comorbidities (10). Although international evidence suggests that earlier antibiotic administration may improve patient outcomes, the impact of treatment timing can vary across healthcare systems due to differences in patient characteristics, disease severity, and hospital workflow efficiency. Moreover, while several studies from high-income settings have examined the relationship between antibiotic timing and outcomes, evidence from emergency departments in low- and middle-income countries remains relatively limited. Local studies have highlighted the high burden of pneumonia in Pakistan, yet few investigations have prospectively evaluated the association between timing of antibiotic administration and clinical outcomes among emergency department patients.

Given the high burden of pneumonia and the operational challenges faced by emergency departments in resource-constrained healthcare systems, evaluating the relationship between treatment timing and patient outcomes is essential for improving clinical management strategies. Understanding whether earlier initiation of antibiotic therapy is associated with improved outcomes such as reduced hospital stay, lower intensive care unit admission, and decreased mortality may provide important evidence to

guide emergency care protocols and optimize patient triage and treatment pathways. Therefore, this prospective observational study aimed to assess the association between early antibiotic administration and clinical outcomes among adult patients presenting with pneumonia to the emergency department of a tertiary care hospital in Pakistan. Specifically, the study sought to determine whether administration of antibiotics within three hours of emergency department presentation is associated with shorter hospital stay, reduced need for intensive care admission, and lower in-hospital mortality compared with delayed antibiotic administration.

MATERIALS AND METHODS

This prospective observational study was conducted in the Emergency Department of Lady Reading Hospital–Medical Teaching Institution (LRH-MTI), Peshawar, a large tertiary care referral hospital serving patients from Khyber Pakhtunkhwa and neighboring regions of Pakistan. The emergency department receives a high volume of medical and respiratory emergency cases and functions as a primary entry point for patients requiring urgent hospital care. The study was carried out over a five-month period from 1 March 2025 to 31 July 2025. The prospective design was selected to allow real-time recording of exposure and outcome variables and to minimize recall bias associated with retrospective data extraction. The study specifically evaluated the association between timing of antibiotic administration and clinical outcomes among adult patients presenting with pneumonia to the emergency department.

Adult patients presenting to the emergency department with a clinical diagnosis of pneumonia during the study period were assessed for eligibility. Pneumonia was defined based on the presence of compatible clinical features including fever, cough, sputum production, dyspnea, or pleuritic chest pain together with radiological evidence of pulmonary infiltrates on chest radiography consistent with pneumonia, in accordance with internationally accepted diagnostic criteria for community-acquired pneumonia (11).

Eligible participants included patients aged 18 years or older who required initiation of intravenous antibiotic therapy after presentation to the emergency department. Patients were excluded if they had received systemic antibiotics prior to arrival at the emergency department, had hospital-acquired or ventilator-associated pneumonia, were immunocompromised due to conditions such as human immunodeficiency virus infection or ongoing chemotherapy, or declined participation in the study. Consecutive sampling was used, whereby all eligible patients presenting during the study period were screened and enrolled to reduce selection bias and enhance representativeness of the emergency department population.

Upon presentation to the emergency department, eligible patients were identified by the treating clinical team and subsequently enrolled after obtaining informed written consent. For patients who were unable to provide consent due to acute illness, consent was obtained from a legally authorized representative in accordance with institutional ethical standards. Data were collected prospectively using a structured standardized data collection proforma developed for the study.

Information recorded included demographic characteristics such as age and gender, presenting symptoms, vital signs at presentation, relevant comorbid conditions including hypertension, diabetes mellitus, and chronic obstructive pulmonary disease, and laboratory and radiological findings relevant to pneumonia diagnosis and management. The timing of antibiotic administration was recorded using the electronic medication administration record and nursing documentation to ensure accuracy. Time zero for exposure assessment was defined as the time of emergency department registration, which reflects the standardized point at which patient care documentation begins in the hospital system.

The primary exposure variable was the time from emergency department registration to administration of the first intravenous antibiotic dose. Based on established emergency care performance metrics and

prior literature evaluating time-to-treatment in pneumonia, patients were categorized into two groups: early antibiotic administration, defined as antibiotic delivery within three hours of emergency department presentation, and delayed antibiotic administration, defined as administration occurring more than three hours after presentation (6,9).

The primary outcome measures included length of hospital stay, need for admission to the intensive care unit, and in-hospital mortality. Length of hospital stay was defined as the total duration from hospital admission to discharge or death and was measured in days. Intensive care unit admission was defined as transfer to the ICU at any time during hospitalization for advanced respiratory or hemodynamic support. In-hospital mortality was defined as death from any cause occurring during the same hospital admission. Additional clinical variables were recorded to characterize disease severity and potential confounding factors, including respiratory rate, oxygen saturation at presentation, systolic blood pressure, and presence of comorbid medical conditions.

Several methodological steps were implemented to minimize bias and address potential confounding. Prospective data collection reduced recall bias and ensured standardized measurement of exposure and outcomes. Consecutive enrollment minimized selection bias and improved the representativeness of the study sample. Uniform diagnostic criteria for pneumonia were applied to all patients to reduce misclassification bias.

Baseline clinical variables and comorbidities were systematically documented to allow adjustment for potential confounders during statistical analysis. Data entry was independently verified by two investigators to ensure data integrity, and periodic cross-checking with medical records was performed to confirm accuracy of key variables including antibiotic timing and outcome measures.

The sample size was determined based on feasibility considerations and the expected number of pneumonia cases presenting to the emergency department during the study period. Based on hospital records indicating an average monthly volume of pneumonia presentations, a target sample of approximately 120 patients was considered adequate to detect clinically meaningful differences in outcomes between early and delayed antibiotic groups while maintaining sufficient statistical power for comparative analysis. Continuous monitoring of patient enrollment ensured that the target sample size was achieved within the predefined study period.

All collected data were entered into a secure database and analyzed using the Statistical Package for Social Sciences (SPSS) software version 26 (IBM Corp., Armonk, NY, USA). Continuous variables such as age and length of hospital stay were summarized as mean with standard deviation or median with interquartile range depending on distribution. Normality of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of histograms.

Comparisons between the early and delayed antibiotic administration groups were performed using the independent samples t-test for normally distributed continuous variables or the Mann–Whitney U test for non-normally distributed variables. Categorical variables including gender, ICU admission, and mortality were compared using the chi-square test or Fisher's exact test where appropriate. Effect estimates were calculated and presented as mean differences or odds ratios with corresponding 95% confidence intervals.

Multivariable logistic regression analysis was conducted to evaluate the independent association between early antibiotic administration and binary outcomes including ICU admission and in-hospital mortality while adjusting for potential confounders such as age, gender, and major comorbidities. Missing data were assessed during data cleaning and were minimal; analyses were performed using complete case analysis. A two-tailed p-value of ≤ 0.05 was considered statistically significant.

Ethical approval for the study was obtained from the Institutional Ethical Review Board of Lady Reading Hospital–Medical Teaching Institution, Peshawar, prior to initiation of the study (approval number:

101/LRH/MTI). The study was conducted in accordance with the principles outlined in the Declaration of Helsinki for research involving human participants (12). Participation in the study was voluntary, and confidentiality of patient information was strictly maintained by anonymizing all collected data and restricting access to authorized research personnel only. Data were stored securely in password-protected files, and all analyses were performed using de-identified datasets to ensure patient privacy and data protection.

RESULTS

A total of 120 adult patients presenting with pneumonia to the emergency department during the study period were included in the analysis. The mean age of participants was 56.8 ± 17.4 years, with ages ranging from 18 to 88 years. Among the enrolled patients, 72 (60.0%) were male and 48 (40.0%) were female. Based on the timing of antibiotic administration, 68 patients (56.7%) received antibiotics within three hours of emergency department presentation (early antibiotic group), while 52 patients (43.3%) received antibiotics after three hours (delayed antibiotic group).

Baseline demographic and clinical characteristics of the study population are presented in Table 1. The distribution of age, gender, presenting symptoms, and comorbid conditions was generally comparable between the early and delayed antibiotic groups, with no statistically significant differences observed in baseline characteristics.

Table 1. Baseline demographic and clinical characteristics of patients according to timing of antibiotic administration

Variable	Early Antibiotics ≤3h (n=68)	Delayed Antibiotics >3h (n=52)	Total (n=120)	p-value
Age (years), mean ± SD	55.9 ± 16.8	58.0 ± 18.1	56.8 ± 17.4	0.48
Male gender, n (%)	40 (58.8)	32 (61.5)	72 (60.0)	0.76
Fever, n (%)	47 (69.1)	37 (71.2)	84 (70.0)	0.81
Cough, n (%)	51 (75.0)	41 (78.8)	92 (76.7)	0.64
Shortness of breath, n (%)	43 (63.2)	35 (67.3)	78 (65.0)	0.65
Hypertension, n (%)	21 (30.9)	15 (28.8)	36 (30.0)	0.80
Diabetes mellitus, n (%)	17 (25.0)	15 (28.8)	32 (26.7)	0.64
COPD, n (%)	10 (14.7)	10 (19.2)	20 (16.7)	0.50

Clinical outcomes according to the timing of antibiotic administration are summarized in Table 2. Patients who received antibiotics within three hours of presentation experienced a significantly shorter mean length of hospital stay compared with those receiving delayed antibiotics (5.1 ± 2.3 vs 7.4 ± 3.1 days; mean difference −2.3 days, 95% CI −3.3 to −1.2; p = 0.01).

A total of 22 patients (18.3%) required admission to the intensive care unit during hospitalization. ICU admission occurred in 8 patients (11.8%) in the early antibiotic group and 14 patients (26.9%) in the delayed antibiotic group. Early antibiotic administration was associated with a significantly lower likelihood of ICU admission (odds ratio 0.36; 95% CI 0.14–0.92; p = 0.03).

Overall hospital mortality occurred in 10 patients (8.3%). Mortality was lower in the early antibiotic group compared with the delayed antibiotic group (3 patients [4.4%] vs 7 patients [13.5%]). Although the

direction of effect favored early treatment, this difference did not reach conventional statistical significance (odds ratio 0.29; 95% CI 0.07–1.17; p = 0.06).

Table 2. Clinical outcomes according to timing of antibiotic administration

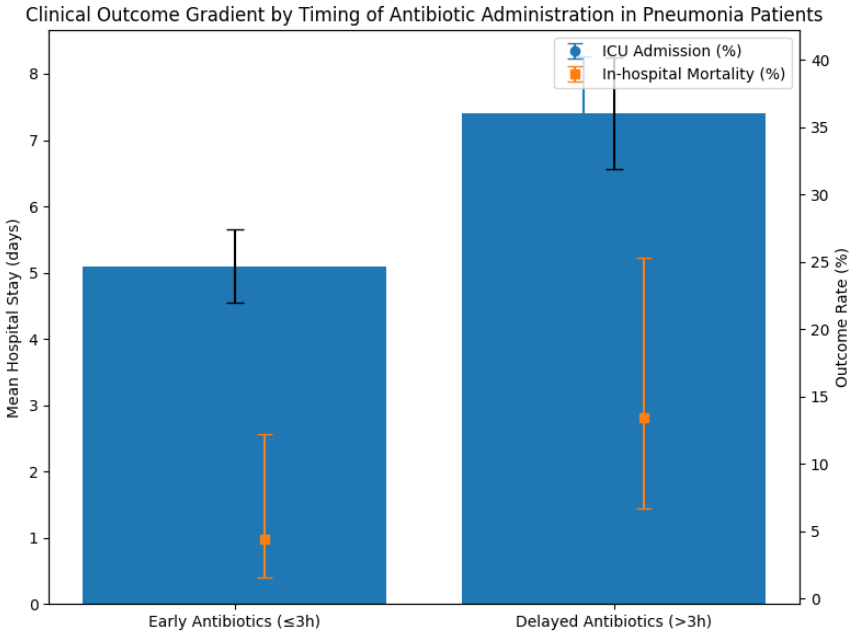
Outcome	Early Antibiotics ≤3h (n=68)	Delayed Antibiotics >3h (n=52)	Effect Estimate	95% CI	p-value
Length of hospital stay (days), mean ± SD	5.1 ± 2.3	7.4 ± 3.1	Mean difference −2.3	−3.3 to −1.2	0.01
ICU admission, n (%)	8 (11.8)	14 (26.9)	OR 0.36	0.14–0.92	0.03
In-hospital mortality, n (%)	3 (4.4)	7 (13.5)	OR 0.29	0.07–1.17	0.06

Multivariable logistic regression analysis was performed to evaluate whether early antibiotic administration was independently associated with ICU admission after adjusting for age, gender, hypertension, diabetes mellitus, and chronic obstructive pulmonary disease. As shown in Table 3, early antibiotic administration remained significantly associated with reduced odds of ICU admission after adjustment for these potential confounders (adjusted odds ratio 0.39; 95% CI 0.15–0.98; p = 0.04).

Table 3. Multivariable logistic regression analysis for predictors of ICU admission

Variable	Adjusted Odds Ratio (a OR)	95% CI	p-value
Early antibiotic administration (≤3 hours)	0.39	0.15–0.98	0.04
Age (per year increase)	1.02	0.99–1.05	0.17
Male gender	1.11	0.46–2.68	0.82
Hypertension	1.27	0.51–3.14	0.61
Diabetes mellitus	1.41	0.56–3.52	0.46
COPD	1.89	0.69–5.18	0.21

Overall, early antibiotic administration within three hours of emergency department presentation was associated with shorter hospital stay and a significantly lower likelihood of ICU admission. Although mortality was numerically lower among patients receiving early antibiotics, the difference did not reach statistical significance in this cohort.



The figure illustrates the outcome gradient associated with the timing of antibiotic administration among pneumonia patients presenting to the emergency department. Patients receiving antibiotics within three hours demonstrated a substantially shorter mean hospital stay of 5.1 days (95% CI ≈ 4.6–5.6) compared with 7.4 days (95% CI ≈ 6.6–8.2) in the delayed treatment group, representing an absolute reduction of approximately 2.3 hospitalization days. A parallel pattern is observed in severe clinical outcomes. ICU admission occurred in 11.8% (8/68) of patients receiving early antibiotics compared with 26.9% (14/52) in those with delayed treatment, reflecting more than a twofold relative increase in critical care utilization among delayed cases. Similarly, in-hospital mortality increased from 4.4% (3/68) in the early treatment group to 13.5% (7/52) in the delayed group. The integrated visualization highlights a clinically meaningful gradient in which delayed antibiotic administration aligns with both longer hospitalization and higher severity outcomes, suggesting that earlier treatment may contribute to improved clinical stabilization and reduced care in pneumonia management.

DISCUSSION

The present prospective observational study evaluated the association between the timing of antibiotic administration and clinical outcomes among adult patients presenting with pneumonia to the emergency department of a tertiary care hospital in Pakistan. The findings indicate that patients who received antibiotics within three hours of emergency department presentation experienced significantly shorter hospital stays and lower rates of intensive care unit admission compared with those receiving delayed antibiotic therapy. Although in-hospital mortality was numerically lower in the early antibiotic group, the difference did not reach conventional statistical significance. These results suggest that early initiation of antimicrobial therapy may contribute to improved clinical recovery and reduced disease severity among pneumonia patients presenting to emergency departments.

Timely administration of antibiotics is considered a critical component in the management of community-acquired pneumonia because bacterial replication and the host inflammatory response can progress rapidly during the early stages of infection. Early antimicrobial therapy may limit the progression of infection, reduce systemic inflammatory response, and prevent complications such as respiratory failure or sepsis (13). Previous studies have demonstrated that delays in antibiotic administration may be associated with worse outcomes, including longer hospitalization and increased need for advanced supportive care (14). The findings of the present study are consistent with this concept, as patients receiving early antibiotic therapy had significantly shorter hospital stays than those receiving

delayed treatment. Early treatment may facilitate faster clinical stabilization, thereby reducing the duration of hospitalization and the burden on healthcare resources.

The observed reduction in ICU admissions among patients receiving early antibiotics further supports the clinical importance of prompt treatment. In this study, ICU admission occurred more frequently among patients who received delayed antibiotics, suggesting that delays in treatment may allow disease progression to more severe forms requiring critical care support. Similar observations have been reported in other studies evaluating emergency department management of pneumonia. A multicenter cohort study reported that early antibiotic administration was associated with reduced disease severity and lower rates of ICU admission among patients with community-acquired pneumonia (15). Another study examining emergency department patients found that timely antibiotic therapy contributed to earlier clinical stabilization and improved recovery outcomes (16). These findings collectively highlight the potential benefits of early antibiotic initiation as part of standard emergency department management protocols for pneumonia.

Although the present study observed lower mortality among patients receiving early antibiotics, the difference did not reach statistical significance. This finding is consistent with several previous studies that have reported mixed results regarding the direct impact of antibiotic timing on mortality outcomes. Some large observational studies have suggested that early antibiotic administration improves survival among patients with severe pneumonia, while others have reported that early treatment is primarily associated with earlier clinical recovery rather than significant reductions in mortality (17). Differences in patient populations, disease severity, healthcare system characteristics, and study design may partly explain these variations. In the current study, the relatively small number of mortality events and the limited sample size may have reduced the statistical power to detect significant differences in mortality outcomes.

Another important consideration is the potential influence of baseline patient characteristics and disease severity on clinical outcomes. Although the baseline demographic and comorbidity profiles were generally comparable between the early and delayed antibiotic groups in this study, variations in disease severity at presentation could still influence outcomes such as ICU admission and mortality. Severity scoring systems such as CURB-65 and the Pneumonia Severity Index have been widely used to stratify risk in pneumonia patients and guide treatment decisions (13). The absence of standardized severity scoring in the current study represents a limitation that may affect interpretation of the observed associations. Future studies incorporating standardized severity assessment tools may provide more precise evaluation of the independent effect of antibiotic timing on pneumonia outcomes.

The results of this study also have important implications for emergency department workflow and quality improvement initiatives. Emergency departments in low- and middle-income countries often face challenges such as high patient volume, limited diagnostic resources, and delays in treatment initiation. These operational constraints may contribute to delays in antibiotic administration and adversely affect patient outcomes. Implementing structured clinical pathways, early triage systems, and standardized pneumonia management protocols may help ensure that patients receive timely antibiotic therapy. Studies evaluating emergency department process improvements have shown that protocol-driven management and rapid treatment pathways can significantly reduce treatment delays and improve patient outcomes in infectious diseases (18).

The strengths of the present study include its prospective design and real-time data collection in a busy tertiary care emergency department. Prospective data collection minimized recall bias and allowed accurate documentation of antibiotic administration timing and clinical outcomes. Additionally, the study provides valuable local evidence from Pakistan, where limited prospective research has examined the relationship between treatment timing and outcomes in pneumonia patients presenting to emergency departments. Such context-specific evidence is important for informing clinical practice and health system improvements in resource-constrained settings.

Despite these strengths, several limitations should be acknowledged. First, the study was conducted in a single tertiary care hospital, which may limit the generalizability of the findings to other healthcare settings. Second, the sample size was relatively modest, which may have reduced the statistical power to detect significant differences in mortality outcomes. Third, although adjustments were made for some baseline characteristics, residual confounding cannot be entirely excluded due to the observational design of the study. Finally, standardized pneumonia severity scores were not consistently recorded, which may affect risk stratification and outcome interpretation. Future multicenter studies with larger sample sizes and standardized severity assessments are needed to further evaluate the relationship between antibiotic timing and clinical outcomes in pneumonia patients.

Overall, the findings of this study support the growing body of evidence suggesting that early initiation of antibiotic therapy in pneumonia patients presenting to emergency departments is associated with improved clinical outcomes. Ensuring timely antibiotic administration may represent a practical and achievable intervention to enhance patient recovery and reduce complications in pneumonia management, particularly in high-volume emergency care settings.

CONCLUSION

Early administration of antibiotics within three hours of emergency department presentation was associated with shorter hospital stay and lower rates of intensive care unit admission among adult patients with pneumonia. Although in-hospital mortality was numerically lower in patients receiving early antibiotics, the difference did not reach statistical significance in this study. These findings highlight the potential clinical benefits of timely antimicrobial therapy and support the implementation of emergency department protocols aimed at minimizing delays in antibiotic initiation for patients presenting with pneumonia..

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