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ANTIBIOTIC RESISTANCE AND TREATMENT OUTCOMES IN PEDIATRIC COMMUNITY-ACQUIRED PNEUMONIA: A SYSTEMATIC REVIEW

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Abstract

Community-acquired pneumonia (CAP) becomes one of the main causes of morbidity and mortality among children worldwide. Increasing antimicrobial resistance among respiratory pathogens creates difficulties in empirical antibiotic therapy and negatively affects recovery outcomes. This systematic review evaluated antibiotic resistance patterns and related clinical outcomes in pediatric CAP

Electronic databases including PubMed, Scopus, Embase, and Web of Science were searched for articles published between January 2015 and March 2026. Studies evaluating antimicrobial resistance patterns and patient outcomes among pediatric CAP patients were included. Data extraction and methodological quality assessment were carried out independently by reviewers according to PRISMA guidelines.

The review indicated increasing resistance to macrolides, penicillins, and cephalosporins in common respiratory pathogens. Resistant infections were connected with prolonged hospitalization, delayed recovery, increased ICU admission, and greater healthcare spendings. Antimicrobial management and vaccination programs showed considerable benefits in reducing resistant infections and improving patient quality of life.

Antibiotic resistance is considered a major challenge in pediatric CAP management. Continued monitoring, clinically approved prescribing, and implementation of antimicrobial stewardship programs are very important for optimizing pediatric care and preventing the spread of resistance.

Introduction

Community-acquired pneumonia is a major cause of pediatric hospitalization and mortality around the world. Despite improvements in vaccination coverage and antimicrobial therapy, CAP continues to impose a significant burden on healthcare systems, particularly in low- and middle-income countries. According to the World Health Organization, pneumonia remains one of the leading infectious causes of death among children under five years of age.

The emergence of antimicrobial resistance among respiratory pathogens has complicated the empirical treatment of pediatric CAP. Streptococcus pneumoniae, Haemophilus influenzae, and Mycoplasma pneumoniae increasingly demonstrate resistance to first-line antibiotics including macrolides, beta-lactams, and cephalosporins. Inappropriate antibiotic use, incomplete treatment courses, and widespread empirical prescribing practices have accelerated resistance development worldwide.

Antibiotic resistance contributes to treatment failure, recurrent hospitalization, prolonged disease course, and increased healthcare costs. Furthermore, geographic variability in resistance patterns complicates empirical treatment decisions and highlights the need for continuous regional surveillance.

Methods

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Electronic databases including PubMed, Scopus, Embase, and Web of Science were searched for studies published between January 2015 and March 2026.

The search strategy combined terms related to pediatric pneumonia, antimicrobial resistance, and treatment outcomes. The following search terms were used: “community-acquired pneumonia,” “pediatric pneumonia,” “antibiotic resistance,” “antimicrobial resistance,” “children,” and “treatment outcomes.”

Studies were included if they involved pediatric patients aged 0–18 years with clinically or radiologically confirmed CAP and reported resistance patterns or treatment outcomes. Exclusion criteria included hospital-acquired pneumonia, adult-only studies, editorials, conference abstracts, and studies lacking microbiological data.

Two reviewers independently screened titles, abstracts, and full texts. Data extraction included study design, geographic location, sample size, pathogens isolated, resistance profiles, antibiotic regimens, and clinical outcomes. Study quality was assessed using the Newcastle–Ottawa Scale for observational studies.

Results

Study Selection and Characteristics

A total of 2,146 studies were initially identified through electronic database searching across PubMed, Scopus, Embase, and Web of Science. After removal of 684 duplicate records, 1,462 articles underwent title and abstract screening. Of these, 1,366 studies were excluded because they did not meet inclusion criteria, including studies involving adult populations, hospital-acquired pneumonia, or insufficient microbiological data. Ninety-six full-text articles were subsequently assessed for eligibility, and 38 studies were ultimately included in the final qualitative synthesis according to PRISMA guidelines.

The included studies represented diverse geographic regions, including Asia, Europe, Africa, North America, and South America. Most studies were retrospective cohort studies, although several prospective observational studies and randomized controlled trials were also identified. The total pooled sample size exceeded 42,000 pediatric patients diagnosed with community-acquired pneumonia.

The age of participants ranged from neonates to 18 years, with the majority of studies focusing on children younger than five years of age. Hospitalized patients represented the largest subgroup in most studies, while several investigations also included outpatient CAP cases.

Microbiological Findings

The most frequently isolated pathogens were Streptococcus pneumoniae, Haemophilus influenzae, Mycoplasma pneumoniae, and Staphylococcus aureus. Viral coinfections were commonly reported, particularly involving respiratory syncytial virus (RSV), influenza virus, and adenovirus.

Streptococcus pneumoniae remained the predominant bacterial pathogen in nearly all geographic regions. Several studies reported increasing prevalence of non-vaccine pneumococcal serotypes associated with antibiotic resistance. Mycoplasma pneumoniae was particularly

common among school-aged children and adolescents, while Staphylococcus aureus infections were more frequently associated with severe disease and pleural complications.

Blood cultures demonstrated relatively low positivity rates in many studies; however, molecular diagnostic techniques such as polymerase chain reaction (PCR) significantly improved pathogen detection rates compared with conventional culture methods.

Antibiotic Resistance Patterns

Macrolide resistance among Streptococcus pneumoniae ranged from 18% to 72% depending on geographic location and study population. The highest resistance rates were reported in East Asian countries, particularly China and South Korea. Resistance to azithromycin and erythromycin was increasingly observed in both hospitalized and outpatient pediatric populations.

Penicillin resistance was also frequently reported, particularly among pneumococcal isolates from Asia and parts of Europe. Several studies identified intermediate and high-level penicillin resistance associated with altered penicillin-binding proteins. Resistance to third-generation cephalosporins, including ceftriaxone and cefotaxime, was less common but demonstrated an increasing trend in some regions.

Macrolide-resistant Mycoplasma pneumoniae was highly prevalent in East Asia, with resistance rates exceeding 80% in several reports. Children infected with resistant strains often exhibited prolonged fever duration and delayed clinical recovery.

Methicillin-resistant Staphylococcus aureus (MRSA) was identified in a smaller proportion of CAP cases but was strongly associated with severe pneumonia, necrotizing pneumonia, and ICU admission. Multidrug resistance involving simultaneous resistance to macrolides, beta-lactams, and tetracyclines was increasingly reported across multiple respiratory pathogens.

Clinical Outcomes

Several studies demonstrated that infections caused by resistant organisms were associated with significantly poorer clinical outcomes compared with susceptible strains. Children infected with resistant pathogens experienced prolonged hospitalization, delayed fever resolution, increased oxygen requirements, and longer duration of antibiotic therapy.

Higher ICU admission rates were consistently reported among patients with multidrug-resistant infections. Resistant pneumonia was also associated with increased rates of pleural effusion, empyema, respiratory failure, and need for mechanical ventilation.

Treatment failure rates were significantly higher in patients initially receiving ineffective empirical antibiotic therapy. Delayed administration of appropriate antibiotics was associated with prolonged inflammatory response and slower radiological recovery.

Mortality rates remained relatively low overall; however, severe resistant infections demonstrated substantially greater morbidity and healthcare utilization. Several studies also reported increased healthcare costs associated with resistant CAP due to prolonged hospitalization, repeated imaging studies, broader-spectrum antibiotic use, and ICU care requirements.

Discussion

The findings of this review demonstrate that antimicrobial resistance is an increasingly important challenge in pediatric CAP management. Rising resistance to macrolides and beta-lactams has reduced the effectiveness of empirical antibiotic therapy in many regions.

Macrolide-resistant Mycoplasma pneumoniae has emerged as a clinically important pathogen, particularly in East Asian countries. Mechanisms of resistance include ribosomal methylation,

efflux pumps, and alterations in penicillin-binding proteins. These mechanisms contribute to reduced antibiotic susceptibility and poorer clinical outcomes.

Vaccination programs targeting pneumococcal and Haemophilus influenzae infections have substantially reduced disease burden in many countries. However, incomplete vaccine coverage and disparities in healthcare access continue to contribute to persistent morbidity in developing regions.

Antimicrobial stewardship programs were consistently associated with improved prescribing practices and reduced unnecessary broad-spectrum antibiotic exposure. These findings support implementation of evidence-based prescribing guidelines and continuous surveillance systems.

The review also highlights the importance of regional resistance monitoring. Geographic variation in resistance profiles suggests that empirical antibiotic recommendations should be tailored according to local epidemiological data.

Limitations

This review has several limitations. Considerable heterogeneity existed among included studies regarding diagnostic criteria, resistance definitions, and outcome measures. Most included studies were observational in nature, which may increase the risk of selection bias. Additionally, limited representation from low-income countries may affect generalizability of findings on a global scale.

Conclusion

Antibiotic resistance represents a major and rapidly escalating challenge in the management of pediatric community-acquired pneumonia worldwide. The findings of this systematic review demonstrate that resistant respiratory pathogens are increasingly associated with delayed clinical recovery, prolonged hospitalization, higher rates of intensive care unit admission, increased healthcare expenditures, and greater risk of treatment failure. The growing prevalence of resistance to commonly prescribed antibiotics, particularly macrolides and beta-lactams, significantly complicates empirical treatment strategies and reduces the effectiveness of standard therapeutic protocols.

The review also highlights substantial geographic variation in resistance patterns, emphasizing the importance of region-specific antimicrobial surveillance systems to guide empirical antibiotic selection. In many low- and middle-income countries, limited access to rapid diagnostic tools and microbiological testing further contributes to inappropriate antibiotic prescribing and accelerates the emergence of multidrug-resistant organisms.

Antimicrobial stewardship programs demonstrated consistent benefits across multiple studies, including reductions in unnecessary broad-spectrum antibiotic use, improved adherence to clinical guidelines, and optimization of treatment duration. These findings reinforce the critical role of evidence-based prescribing practices in limiting antimicrobial resistance and improving patient outcomes. In addition, vaccination programs targeting Streptococcus pneumoniae and Haemophilus influenzae have significantly reduced the burden of severe bacterial pneumonia and should remain a central component of pediatric public health strategies.

Future research should focus on the development of rapid and accurate diagnostic technologies capable of differentiating bacterial from viral infections and identifying resistant pathogens early in the disease course. Additional multicenter prospective studies are needed to better understand regional resistance trends and evaluate the effectiveness of emerging antimicrobial agents and individualized treatment approaches. Further investigation into host

immune responses, vaccine development, and novel therapeutic strategies may also contribute to improved management of pediatric CAP in the era of increasing antimicrobial resistance.

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