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Corticosteroids in severe pediatric community-acquired pneumonia: insights from a case-based narrative review

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Abstract

Pediatric community-acquired pneumonia (CAP) remains a leading cause of hospitalization worldwide. Although antimicrobial therapy is the cornerstone of treatment, severe and complicated cases are frequently characterized by an exaggerated inflammatory response that may not resolve with antibiotics alone. In this narrative review, we summarize current evidence on the use of systemic corticosteroids as adjunctive therapy in pediatric CAP and illustrate their potential role through a representative clinical case. Available data from randomized trials, observational studies, and meta-analyses suggest that corticosteroids may shorten fever duration, improve oxygenation, and reduce length of hospital stay in selected pediatric patients, particularly those with hyperinflammatory features, parapneumonic effusions, or macrolide-refractory Mycoplasma pneumoniae infections. Some studies also indicate a reduced need for surgical intervention in complicated pneumonia. However, results remain heterogeneous, and current guidelines do not support routine corticosteroid use. Adverse effects are generally mild with short treatment courses and include hyperglycemia and transient behavioral changes. In the presented clinical case, adjunctive corticosteroid therapy was associated with rapid clinical and radiological improvement in a child with severe hyperinflammatory pleuropneumonia. Corticosteroids may represent a potential adjunctive option in carefully selected children with severe or complicated CAP; however, current evidence remains limited and heterogeneous, and further prospective pediatric studies are required.

Key words: pediatric community-acquired pneumonia, corticosteroids, hyperinflammation, immunomodulation.

Introduction

Community-acquired pneumonia (CAP) remains a leading cause of morbidity and hospitalization in children worldwide [1]. A growing subset of patients present with severe or complicated disease courses, including necrotizing pneumonia, parapneumonic effusions, or empyema [2]. These cases often lead to prolonged illness, requiring medical and surgical intervention, and increasing the healthcare burden [3].

In recent years, clinicians have observed an apparent increase in the severity of pediatric CAP [4], sometimes characterized by a hyperinflammatory syndrome with features reminiscent of cytokine storm [5]. In such scenarios, adjunctive therapies targeting the immune response have garnered interest [6], particularly the use of CS as immunomodulatory agents [7]. While CS are well-established in the treatment of inflammatory conditions such as asthma and croup, their role in CAP remains controversial, especially in the pediatric population [8].

Emerging clinical observations and limited pediatric studies suggest that CS may have a potential adjunctive role in selected children with severe or hyperinflammatory CAP [6,9]. However, current evidence remains limited and heterogeneous [10], and routine CS use is not currently supported by clinical evidence [11]. Ongoing research continues to evaluate which patient subgroups may benefit most from immunomodulatory therapy [6]. Current evidence does not support routine CS use in uncomplicated CAP, and suggests their administration should be limited to selected severe or complicated phenotypes [11].

Search strategy and eligibility criteria

A literature search was performed in PubMed, Scopus, and Web of Science databases for studies published between 1966 and 2025 using the following search strategy: ("pediatric community-acquired pneumonia" OR CAP OR pleuropneumonia) AND (corticosteroids OR glucocorticoids OR methylprednisolone OR dexamethasone) AND (children OR pediatric). The search identified 100 records in PubMed, 220 in Scopus, and 163 in Web of Science.

Randomized controlled trials, observational studies, systematic reviews, meta-analyses, clinical guidelines, and relevant case reports published in English were considered for inclusion based on their relevance to severe or complicated pediatric CAP and adjunctive CS therapy. Studies were included if they evaluated adjunctive CS therapy in pediatric CAP, particularly in cases involving hyperinflammatory features, parapneumonic effusion, empyema, or refractory Mycoplasma pneumoniae infection. Studies unrelated to CS therapy or not relevant to severe or complicated CAP were excluded.

Pathophysiology of severe CAP and hyperinflammatory responses

CAP initiates a complex immunological cascade in response to microbial invasion of the alveolar space. The innate immune system plays a primary role in early recognition of pathogens through pattern recognition receptors (PRRs), such as Toll-like receptors (TLRs), expressed by alveolar macrophages and epithelial cells. This recognition triggers the release of pro-inflammatory cytokines (e.g., IL-1β, IL-6, TNF-α), chemokines, and interferons, leading to the recruitment of neutrophils and monocytes to the site of infection [12].

In most cases, this inflammatory response is self-limiting and resolves with pathogen clearance. However, in severe CAP, the immune activation may become dysregulated, leading to excessive cytokine production — a state referred to as hyperinflammation or cytokine storm. This exaggerated response contributes to alveolar-capillary membrane damage, increased vascular permeability, and progression to acute respiratory distress syndrome (ARDS) [13]. Children with severe CAP may also exhibit systemic signs of inflammation, including persistent fever, leukocytosis, and elevated CRP or procalcitonin [14].

Hyperinflammatory responses, which may occur in severe CAP, are marked by uncontrolled immune activation and elevated inflammatory markers, such as IL-6, ferritin, and D-dimer levels [15,16]. In both CAP and these syndromes, CS have been explored as immunomodulatory agents to temper the immune response and prevent progression to critical illness.

The identification of hyperinflammatory phenotypes in pediatric CAP is increasingly relevant for treatment stratification, as children with pronounced systemic inflammation may benefit from adjunctive therapies such as CS, though this remains an area of active investigation [11,17]. In clinical practice, a hyperinflammatory phenotype may be suspected in children with persistent high fever, markedly elevated inflammatory markers such as CRP >100–150 mg/L, elevated ferritin, hypoalbuminemia, progressive pulmonary infiltrates, pleural effusion, or increasing oxygen requirements despite appropriate antimicrobial therapy.

Management of severe and complicated pediatric community-acquired pneumonia

Management of severe or complicated pediatric CAP requires prompt recognition of treatment failure, repeated clinical reassessment, and early identification of pleural or parenchymal complications. Persistent fever, worsening respiratory distress, sustained elevation of inflammatory markers, or increasing oxygen requirements despite 48–72 hours of appropriate antimicrobial therapy should raise suspicion for complicated disease progression.

In children with suspected therapeutic failure, repeat laboratory evaluation and imaging studies are recommended. Chest ultrasound is particularly useful for detecting parapneumonic effusion (PPE) and empyema, while computed tomography (CT) may help identify necrotizing pneumonia, abscess formation, or extensive pleural involvement in selected cases.

Hospitalized children with severe CAP often require broad-spectrum intravenous antibiotics, oxygen supplementation, fluid management, and close respiratory monitoring. Patients with progressive respiratory failure may require non-invasive or invasive ventilatory support and admission to the intensive care unit (ICU).Supportive therapy is essential in the management of pediatric CAP and includes adequate hydration, antipyretics, and oxygen supplementation if saturation drops below 90–92% [18,19]. Nebulized bronchodilators may be beneficial for children with wheezing or underlying reactive airway disease, although their routine use in CAP without wheeze is not supported by evidence.

Moderate-to-large parapneumonic effusions frequently require pleural drainage in addition to antimicrobial therapy. Intrapleural fibrinolytic therapy may be considered in loculated effusions, while video-assisted thoracoscopic surgery (VATS) is generally reserved for patients with persistent sepsis, inadequate drainage, organized empyema, or clinical deterioration despite conservative management.

The role of adjunctive CS in complicated pediatric CAP remains controversial and is currently limited to selected severe or hyperinflammatory phenotypes rather than routine management.

Corticosteroids in pediatric pneumonia: current evidence

CS have emerged as a potential adjunctive therapy in pediatric CAP, particularly in severe or complicated cases. Their immunomodulatory and anti-inflammatory properties have led to increasing interest in their use to attenuate the excessive host inflammatory response often seen in progressive or refractory pneumonia. However, despite promising findings in certain subpopulations, the overall evidence remains heterogeneous, and current guidelines do not yet recommend routine CS use in pediatric CAP.

In severe CAP, the exaggerated inflammatory response triggered by respiratory pathogens can contribute to lung injury, alveolar damage, and systemic illness [20]. CS can dampen this hyperinflammatory cascade by modulating cytokine production and leukocyte trafficking, thereby potentially reducing lung edema, improving oxygenation, and shortening recovery time. This rationale has been particularly explored in cases involving Mycoplasma pneumoniae, parapneumonic effusions (PPE), and macrolide-refractory pneumonia [21,22].

Several randomized controlled trials (RCTs), cohort studies, and systematic reviews have evaluated the efficacy of CS in pediatric pneumonia with varying results. In children with macrolide-refractory Mycoplasma pneumoniae pneumonia, studies report that CS pulse therapy (e.g., intravenous methylprednisolone) results in faster defervescence and improved radiologic outcomes [20,21]. A meta-analysis by Kim et al. showed that CS significantly reduced hospital stay and fever duration in this subgroup [20].

In cases of complicated pneumonia, such as PPE or empyema, CS may facilitate clinical improvement and reduce the need for invasive procedures. For instance, Tagarro et al. conducted a double-blind RCT involving 60 children with PPE and found that intravenous dexamethasone led to shorter fever duration and length of stay without increasing adverse events [22].

A recent double-blind randomized controlled trial involving 132 children aged 2 months to 15 years with severe CAP further supported the potential benefit of adjunctive corticosteroid therapy. Children receiving intravenous dexamethasone for five days experienced significantly lower rates of treatment failure at 72 hours (25.8% vs 60.6%; HR 0.32, 95% CI 0.18–0.57), radiographic worsening (22.7% vs 57.6%; OR 0.22), and progression to respiratory failure (10.6% vs 31.8%; OR 0.25). However, no significant differences were observed in the need for mechanical ventilation, mortality, length of hospital stay, or readmission rates [23].

Conversely, broader studies evaluating CS in all forms of pediatric CAP have yielded mixed results. A retrospective cohort study by Weiss et al. involving 637 hospitalized children found no significant reduction in length of stay or improved outcomes in those receiving CS [8]. In a large cohort study by Ambroggio et al. [24], CS use was associated with a higher revisit rate, raising concerns about potential overtreatment or rebound effects.

Meta-analyses including both pediatric and adult populations show more consistent benefit in adults, including reductions in mortality, ICU admissions, and hospital length of stay [25,26]. However, these findings may not directly translate to pediatric populations due to differing pathophysiology, disease progression, and CS responsiveness.

Most current guidelines do not recommend routine CS use in pediatric CAP. The 2011 Infectious Diseases Society of America (IDSA) guidelines do not mention CS as a standard adjunctive therapy [27]. The 2024 update of the Surviving Sepsis Campaign provides a conditional recommendation for CS in children with septic shock or severe CAP unresponsive to fluids and vasoactive therapy [28]. This aligns with the position that CS may be considered on a case-by-case basis in children with severe, hypoxemic pneumonia or complications.

It is worth noting that international guideline recommendations remain inconsistent. The ERS/ESICM/ESCMID/ALAT guidelines conditionally recommend corticosteroids only in severe CAP accompanied by septic shock, whereas the Society of Critical Care Medicine (SCCM) guideline supports a broader use of corticosteroids in severe CAP. These differences reflect ongoing uncertainty regarding the optimal patient population most likely to benefit from adjunctive corticosteroid therapy [29,30].

Numerous studies have explored the potential benefits and risks of CS administration in this context, though the evidence remains heterogeneous with respect to study design, patient populations, and dosing regimens. To provide a clearer overview of the current body of research, the table below summarizes key clinical trials and systematic reviews that have evaluated the role of CS in pediatric CAP. It includes details on study type, patient characteristics, CS interventions, and main outcomes (Table 1).

Discussion

The use of CS as adjunct therapy in children with CAP remains an area of active investigation and clinical debate. The analyzed studies vary in design, patient populations, and clinical settings, but several trends emerge.

A number of observational and interventional studies (e.g., Weiss et al. [8]; Nagy et al., 2013 [31]; Ambroggio et al. [24]) suggest potential benefits of CS in reducing fever duration, improving oxygenation, and shortening hospital stay in children with moderate to severe CAP, particularly in those with significant inflammatory response or parapneumonic effusion. These findings are further supported by a recent 2026 systematic review and meta-analysis of 22 studies involving 75,353 children, which demonstrated significant reductions in both hospital length of stay and time to defervescence among corticosteroid-treated patients in randomized trials [9]. Some studies have suggested that adjunctive corticosteroids may potentially reduce the need for invasive procedures in selected cases of complicated pneumonia; however, available evidence remains limited and heterogeneous.

However, high-quality systematic reviews and meta-analyses (e.g., Stern et al. [10]; Principi et al. [32]) do not support routine corticosteroid use across all pediatric CAP cases. These reviews emphasize the heterogeneity of study populations and endpoints, and caution against generalizing positive results to all patients, particularly in milder cases.

Interestingly, more recent updates and guidelines recognize a potential role for corticosteroids in patients with signs of systemic inflammation or hyperinflammatory states, which aligns with

clinical observations of severe pneumococcal pneumonia accompanied by elevated inflammatory markers and rapid progression to pleural involvement or ARDS [28]. This is consistent with similar mechanisms described in COVID-19 and MIS-C, where corticosteroids have shown benefit in modulating cytokine-driven lung damage.

Nevertheless, current pediatric guidelines do not recommend routine corticosteroid administration in uncomplicated CAP, and available evidence supports their use only in selected severe or hyperinflammatory phenotypes. Careful patient selection remains essential to avoid unnecessary corticosteroid exposure and potential adverse effects.

Nevertheless, available evidence remains heterogeneous, and further prospective pediatric studies are needed to establish optimal timing, dosing, and patient selection for adjunctive corticosteroid therapy.

Clinical experience and case-based evidence

As part of our clinical experience with pediatric CAP, we present the case of a previously healthy 9-year-old child, who was admitted with severe pleuropneumonia in early 2025. The child had no prior history of serious infections or hospitalizations, had completed all age-appropriate immunizations including pneumococcal vaccines, and came from a healthy family background.

The patient developed fever exceeding 38°C and a persistent cough for over 8 days before admission, without receiving antibiotic treatment at home. On the day of hospital presentation, the child exhibited respiratory distress and poor oral intake. A chest X-ray revealed extensive right-sided pneumonia with pleural effusion, and the child was promptly admitted in serious condition to the intensive care unit (ICU).

On examination, the child was febrile, tachypnoeic (respiratory rate 46–48/min), and tachycardic (heart rate 134 bpm), with SpO_2 of 94% on room air. Pulmonary auscultation revealed bronchial breathing in the right upper lobe and diminished breath sounds at the base. Hepatosplenomegaly was also noted. Laboratory results demonstrated marked systemic inflammation: C-reactive protein (CRP) peaked at 224 mg/L, serum albumin was as low as 18–26 g/L during the acute phase, and fibrinogen and ferritin levels were elevated. Despite comprehensive microbiological testing, no specific pathogen was identified.

Initial imaging (chest radiography and CT scan) confirmed bilateral pneumonia with massive right-sided consolidation and pleural effusion (up to 26 mm separation on ultrasound). The left lower lobe was also affected, albeit less extensively. This essentially represents necrotizing

pneumonia. Given the prolonged duration of symptoms before hospitalization, together with the severity of presentation and the child's markedly abnormal laboratory profile (CRP > 200 mg/L, hypoalbuminemia, elevated ferritin, CAR > 6), our clinical assessment indicated a high risk for a complicated course potentially necessitating surgical intervention.

Treatment was initiated with broad-spectrum antibiotics (cefepime and vancomycin). However, considering the hyperinflammatory profile and risk of clinical deterioration, adjunctive systemic corticosteroid therapy was also introduced. Methylprednisolone was administered at a dose of 2 mg/kg/day during the acute phase of the illness, with gradual tapering according to clinical and laboratory improvement. During hospitalization, the patient was closely monitored for potential corticosteroid-related adverse effects, including hyperglycemia, hypertension, gastrointestinal complications, and secondary infections. No clinically significant adverse effects were observed. This decision aimed to reduce the inflammatory burden and prevent the progression to necrotizing pneumonia or empyema requiring drainage or surgery.

Despite the initial severity, the child showed steady clinical improvement. By day 5, the child was afebrile, oxygen-independent, and had significantly reduced respiratory distress. The patient was transferred out of ICU on day 6 and continued treatment in the pulmonology ward. A follow-up chest X-ray on day 12 showed near-complete resolution of infiltrates with only minor residual fibrotic changes and small cavitations (4 mm and 13 mm), likely post-inflammatory. The child was discharged on day 12 with a course of oral amoxicillin-clavulanate and supportive care at home. A control chest radiograph and spirometry performed three weeks post-discharge were normal.

This case illustrates the potential role of adjunctive corticosteroid therapy in selected children with severe hyperinflammatory CAP and pleural involvement. Clinical improvement was observed following corticosteroid initiation; however, given the multimodal treatment approach and the single-case nature of the observation, a direct causal relationship cannot be established. Further prospective pediatric studies are required to better define patient selection, timing, and safety of corticosteroid therapy in complicated CAP.

Safety, risks, and indications

While systemic corticosteroids (CS) offer promising benefits as adjunctive therapy in pediatric CAP, their use must be cautiously weighed against potential adverse effects. Potential risks of inappropriate corticosteroid use include secondary infections, hyperglycemia, behavioral changes, hypertension, delayed pathogen clearance, and masking of clinical deterioration. The

immunosuppressive nature of corticosteroids can predispose children to secondary infections, delay pathogen clearance, and obscure clinical signs of disease progression [32]. Short-term use is generally considered safe, but adverse effects such as hyperglycemia, behavioral changes, hypertension, and gastrointestinal disturbances have been reported, especially with high-dose or prolonged regimens.

In addition, there is concern about potential long-term effects, including growth suppression and hypothalamic-pituitary-adrenal (HPA) axis suppression, although these are more relevant in chronic or repeated courses. In the context of acute, severe CAP, most studies suggest that short courses (3–5 days) of corticosteroids do not result in significant long-term complications [20,26].

Timing and dosage

The optimal timing and dosage of corticosteroids in pediatric CAP remain unresolved due to heterogeneity across studies. Most successful protocols have employed early initiation (within 24–48 hours of diagnosis or clinical deterioration), using either low-to-moderate dose oral prednisolone or intravenous methylprednisolone or dexamethasone. For example, Tagarro et al. administered intravenous dexamethasone (0.15 mg/kg every 6 hours) over 48 hours in children with parapneumonic effusion, resulting in faster clinical improvement without increased adverse events [22].

In Mycoplasma pneumoniae infections, methylprednisolone pulse therapy (10–30 mg/kg/day for 1–3 days) has been associated with improved outcomes in macrolide-refractory cases [20,21]. However, the lack of consensus regarding dose standardization underscores the need for prospective trials.

Currently, there are no universally accepted protocols for corticosteroid use in pediatric CAP. Existing studies vary widely in inclusion criteria, dosing regimens, timing of initiation, and outcome measures. This variability limits the generalizability of findings and makes it challenging to formulate evidence-based guidelines. Establishing standardized clinical pathways that define clear indications (e.g., refractory M. pneumoniae pneumonia, severe PPE), dosing regimens, and monitoring strategies will be essential to guide future practice [24,28].

Future directions

Future research should prioritize large-scale, multicentre randomized controlled trials specifically in pediatric populations, as much of the current evidence is extrapolated from adult studies or derived from small, heterogeneous cohorts. Future studies should also aim to establish practical criteria for identifying hyperinflammatory phenotypes most likely to benefit from adjunctive corticosteroid therapy. Trials should stratify patients by severity, pathogen type, and comorbid conditions to identify subgroups most likely to benefit from corticosteroids [25,26].

Additionally, the integration of biomarkers such as C-reactive protein, interleukin-6, and procalcitonin could help identify children with hyperinflammatory phenotypes who may be candidates for immunomodulatory therapy [33-36]. Personalized treatment approaches, informed by host immune profiles and pathogen-specific responses, represent a promising avenue to optimize corticosteroid use [37-39].

Finally, the development of standardized protocols and consensus guidelines, ideally through international pediatric infectious disease societies, will be critical for ensuring safe and effective implementation in clinical practice [40,41]. As understanding of the immunopathogenesis of severe CAP evolves, corticosteroids may play an increasingly defined role in targeted therapy for selected patients.

Implications for practice

The available evidence suggests that systemic corticosteroids may play a supportive role in the management of selected cases of pediatric CAP, particularly those characterized by severe disease, hyperinflammatory profiles, or complicated parapneumonic effusion. While current guidelines do not recommend their routine use, clinicians should remain vigilant for clinical and laboratory indicators of excessive inflammation that may warrant adjunctive therapy. In practice, corticosteroids should be considered on a case-by-case basis, with careful attention to timing, dosage, and monitoring for adverse effects. Incorporating early recognition of high-risk patients into clinical decision-making may help optimize outcomes, reduce the need for invasive interventions, and shorten hospital stays. Future standardized protocols and multicentre trials will be essential to establish clearer recommendations and improve uniformity of care.

Conclusions

While routine use of systemic corticosteroids in pediatric CAP is not currently recommended, emerging evidence suggests that they may represent a potential adjunctive option in selected children with severe hyperinflammatory CAP, parapneumonic effusion, or macrolide-refractory Mycoplasma pneumoniae infection. However, current evidence remains limited and heterogeneous, and a direct causal relationship between corticosteroid therapy and improved outcomes cannot be established from individual cases. Further prospective pediatric studies are needed to better define patient selection, optimal timing, dosing strategies, and long-term safety.

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Table 1. Characteristics of the studies included in this review investigating adjunctive corticosteroid therapy for community-acquired pneumonia (CAP) and related conditions. The table summarizes the study population, design, clinical outcomes assessed, and the overall reported effect of corticosteroid therapy.

Study	Population type	Design/Type	Population	Main outcomes	Overall effect of CS
Darby et al. (34)	Pediatric	Narrative review	Children with complicated CAP	Review of management options	Favorable
Mahant and Long (35)	Pediatric	Editorial	Children with PPE	Comment on adjunctive management	Favorable
Principi et al. (32)	Pediatric	Narrative review	Children with CAP	Symptom resolution, complications	Uncertain
Principi et al. (36)	Pediatric	Review	Children with CAP	Treatment challenges	Uncertain
Thimmesch et al. (37)	Pediatric	Retrospective case series	Children with PPE	Surgery avoidance	Favorable
Sadikov et al. (38)	Pediatric	Observational study	Children with CAP	Symptom resolution	Favorable
Weiss et al. (8)	Pediatric	Cohort study	Children hospitalized with CAP	Length of hospital stay	No significant benefit
Nagy et al. (31)	Pediatric	Prospective trial	Children with severe CAP	Recovery time, LOS	Favorable
Tagarro et al. (22)	Pediatric	Randomized controlled trial	Children with PPE	Fever duration, LOS	Favorable
Lavi et al. (39)	Pediatric	Case report	Child with severe pneumococcal pneumonia	Clinical recovery	Favorable
Ambroggio et al. (24)	Pediatric	Retrospective cohort	Children with CAP	Revisit rate	Potentially unfavorable
Tamura et al. (21)	Pediatric	Clinical study	Children with refractory Mycoplasma pneumonia	Fever resolution, radiographic improvement	Favorable
Kim et al. (20)	Pediatric	Meta-analysis	Children with macrolide-refractory Mycoplasma pneumonia	Fever duration, LOS	Favorable
Buendía et al. (40)	Pediatric	Cost-utility analysis	Children with Mycoplasma pneumonia	Cost-effectiveness, QALY	Favorable
Geropeppa et al. (9)	Pediatric	Systemic review and meta-analysis	Children with pneumonia	Length of hospital stay, time to defervescence, treatment outcomes, adverse events	Favorable
Singh et al.(23)	Pediatric	RCT	Children with severe CAP	Mortality, LOS, or readmission	Favorable
Stern et al. (10)	Mixed	Systematic review	Patients with CAP	Mortality, LOS, adverse events	Uncertain
Chaudhuri et al. (28)	Mixed	Guideline update	Patients with CAP	Updated recommendations	Favorable
Cheema et al. (25)	Mixed	Systematic review and meta-analysis	Patients with CAP	Mortality, LOS	Favorable
Nie W (33)	Mixed	Meta-analysis	Patients with severe CAP	Mortality, recovery time	Favorable
Jiang et al. (41)	Mixed	Meta-analysis	Patients with severe CAP	Mortality, inflammation	Favorable
Chen et al. (26)	Mixed	Meta-analysis	Patients with severe CAP	Mortality, inflammation	Favorable