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Clinical Course and Outcomes of Complicated Community-Acquired Pneumonia in Children During a 5-Year Period Including the COVID-19 Pandemic

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What is already known on this topic?

- *Complicated community-acquired pneumonia (cCAP) remains an important cause of morbidity in children, most commonly presenting with parapneumonic effusion or empyema.*
- *Although pneumococcal conjugate vaccines have substantially reduced the overall burden of pneumococcal disease, complicated pneumonia continues to occur in vaccinated children, including vaccine breakthrough infections.*
- *The etiology and clinical course of pediatric cCAP are heterogeneous, and optimal strategies for invasive management, including pleural drainage and surgical intervention, remain incompletely standardized.*

ABSTRACT

Objective: Community-acquired pneumonia (CAP) remains a significant cause of morbidity in children. Despite widespread vaccination, the incidence and clinical course of complicated CAP (cCAP) continue to pose diagnostic and therapeutic challenges. This study aimed to evaluate the clinical course, management, and outcomes of children with cCAP in pediatric clinical practice.

Methods: This retrospective–prospective observational study was conducted at a tertiary university hospital between December 2019 and December 2024. Children under 18 years of age diagnosed with cCAP were included.

Results: A total of 52 children were included, with a median age of 70.5 months; 48.1% were female. Parapneumonic effusion (PPE) was the most common complication (86.5%), followed by empyema (21.2%) and necrotizing pneumonia (7.6%). Bacterial pathogens were identified in a minority of cases. Among the limited number of culture-positive cases, group A *Streptococcus* and *Streptococcus pneumoniae* were the most frequently identified organisms (11.5%, n = 6). Chest tube thoracostomy was required in 60% of patients, and surgical intervention in 9.6%. Patients requiring chest tube placement had significantly higher C-reactive protein (CRP) levels and longer durations of intravenous (IV) antibiotic therapy. No mortality was observed.

Conclusions: Despite extensive vaccination in healthy children, cases of cCAP still occur, and the causative agent is isolated only in a very few cases. The findings are consistent with the fact that vaccine breakthrough infections, including those caused by pneumococcal serotypes 3 and 14, may still contribute to severe cCAP, whereas group A *Streptococcus* was identified in a minority of culture-positive cases. Elevated CRP levels at admission may serve as a useful predictor for invasive interventions.

Keywords: Children, community-acquired pneumonia, complicated pneumonia, parapneumonic effusion

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INTRODUCTION

Community-acquired pneumonia (CAP) remains a major cause of morbidity and mortality among children worldwide, despite substantial advances in vaccination strategies.[1] Community-acquired pneumonia complicated by parapneumonic effusion (PPE), empyema, abscess, and/or necrotizing pneumonia is defined as complicated CAP (cCAP).[2] Approximately 50%–60% of bacterial pneumonia cases in children are complicated by PPE.[3,4]

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What this study adds to this topic?

- *Higher CRP levels at admission were associated with the need for chest tube drainage, suggesting a potential role for CRP in identifying children who may require invasive intervention.*
- *Group A Streptococcus was the most frequently identified bacterial pathogen among culture-positive cases, particularly in the post-pandemic period.*

The most frequently identified etiologic agent of CAP and its complications in children is *S. pneumoniae*.[2] However, the distribution of causative pathogens is not uniform and varies according to geographic region and vaccination coverage. Other commonly implicated pathogens include group A *Streptococcus, Staphylococcus aureus*, and various other streptococcal species.[2,5]

Following the introduction of pneumococcal conjugate vaccines (PCVs), a substantial reduction in the burden of pneumococcal disease and pneumonia-related mortality was observed. Nevertheless, several studies reported an increase in the incidence of CAP complicated by effusion or empyema during the same period.[3,4,6-8] Currently, no standardized diagnostic or management approach exists for cCAP. Moreover, even when caused by the same pathogen, the clinical course of cCAP may vary among children.[9] In some cases, this variability necessitates prolonged hospitalization and invasive interventions, including intercostal tube drainage, video-assisted thoracoscopic surgery (VATS), or thoracotomy. Overall, pediatric cCAP is a heterogeneous condition with variable etiologies and no clearly defined optimal treatment strategies.[10]

This study aimed to evaluate the clinical course and outcomes of children diagnosed with cCAP, a condition frequently encountered by pediatricians, infectious disease specialists, and pediatric surgeons.

MATERIALS AND METHODS

This retrospective–prospective observational study was conducted at a tertiary center between December 2019 and December 2024. The study was approved by the Dokuz Eylül University (Approval no: 2021/09-25; Date: March 15, 2021). Written informed consent was obtained from patients and their parents. Cases diagnosed before ethics approval (between December 2019 and March 2021) were retrospectively recruited from medical records, whereas cases diagnosed thereafter were prospectively enrolled until December 2024. The same inclusion and exclusion criteria were applied throughout the entire study period. For both phases, the same predefined core variables were evaluated, including demographic characteristics, clinical presentation, laboratory findings, imaging results, microbiological data, treatment modalities, invasive procedures, and follow-up outcomes. During the prospective phase, these variables were recorded using a standardized data collection form prepared in advance. Children younger than 18 years of age who were diagnosed with cCAP and followed up at the Pediatric Infectious Diseases Clinic were included. Community-acquired pneumonia was defined as the presence of clinical signs and symptoms of pneumonia acquired outside a healthcare setting in previously healthy children.[11-13] Community-acquired pneumonia accompanied by complications such as PPE, pleural empyema, necrotizing pneumonia, or lung abscess was classified as cCAP.[2,11] The presence, extent, and distribution of complications were assessed using radiologic imaging modalities, including chest radiography, computed tomography (CT), and thoracic ultrasonography.

Patients admitted with a diagnosis of cCAP were eligible for inclusion. Those diagnosed with uncomplicated pneumonia, hospital-acquired pneumonia, and those with underlying comorbidities, including tracheostomy, cystic fibrosis, chronic lung disease, congenital heart disease, malignancy, conditions requiring immunosuppressive therapy, primary or severe acquired immunodeficiency, chronic renal or hepatic dysfunction, congenital metabolic disorders, and neurological or neuromuscular diseases were not included in the study.

For both phases (retrospective–prospective), the same predefined core variables were evaluated, including demographic characteristics, clinical features (fever, cough, chest pain, respiratory distress, and other symptoms), laboratory parameters at admission (complete blood count, C-reactive protein [CRP], procalcitonin, albumin, and liver and renal function tests), imaging findings (chest radiography, thoracic ultrasonography, and thoracic CT), vaccination status, administered treatments, surgical interventions, and treatment duration, and follow-up outcomes. Information on vaccination status was obtained from the national immunization records presented by the parents.

All patients were hospitalized, and blood cultures as well as respiratory viral panel testing were performed at admission. Sputum cultures were obtained only in selected patients who were able to produce an adequate respiratory sample, and were not performed routinely in

all cases. Thoracic ultrasonography was performed in patients with pleural fluid detected on chest radiography. Thoracic CT scans, follow-up laboratory investigations, and control chest radiographs were obtained only when clinically indicated. In selected patients, tuberculosis was included in the differential diagnosis, particularly in the presence of persistent symptoms, pleural effusion, and/or radiological findings requiring further etiological evaluation. In these patients, tuberculin skin testing (PPD), interferon-gamma release assay (IGRA), and pleural fluid tuberculosis polymerase chain reaction (PCR)/culture were performed as clinically indicated.

The operational definition of empyema and the decision to perform chest tube thoracostomy were based on clinical and radiological assessment, in accordance with the 2011 Infectious Diseases Society of America/Pediatric Infectious Diseases Society (IDSA/PIDS) recommendations, particularly in cases with moderate pleural effusions causing respiratory compromise, large effusions, or purulent/complicated pleural collections.[9] In patients requiring chest tube drainage, pleural fluid analyses, including glucose, pH, lactate dehydrogenase, cell differential counts, and pleural fluid cultures, were performed. Respiratory viruses (rhinovirus, respiratory syncytial virus, influenza virus, parainfluenza virus, human metapneumovirus, seasonal coronavirus, enterovirus, parechovirus, adenovirus, and bocavirus) were detected using real-time reverse transcription PCR (RT-PCR) assays on nasopharyngeal swab samples. During the pandemic and post-pandemic period, all patients presenting with pneumonia were systematically tested for SARS-CoV-2.

Bacterial pathogens were identified using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) according to the manufacturer's protocol. Identification was considered reliable when score values met the recommended threshold for species-level identification. Antimicrobial susceptibility testing was performed using disk diffusion or broth microdilution methods in accordance with the European Committee on Antimicrobial Susceptibility Testing (EUCAST) guidelines. Results were interpreted according to EUCAST breakpoints.[14] Pneumococcal serotyping was performed by PCR on culture-positive *S. pneumoniae* isolates. Molecular bacterial diagnostic methods beyond conventional culture were not routinely used during the study period. Microbiological evaluation was primarily based on culture results, although PCR-based serotyping was performed for culture-confirmed *Streptococcus pneumoniae* isolates.

According to the national childhood immunization program, the 7-valent PCV (PCV7) was introduced in November 2008 and subsequently replaced by the 13-valent PCV (PCV13) in November 2010. The 13-valent PCV was initially administered as a 4-dose schedule and has been updated to a three-dose schedule since January 2022.[15]

Post-discharge follow-up visits were planned, with the first visit scheduled 2 weeks after discharge and subsequent visits every 1-3 months for 1 year. However, following the declaration of the COVID-19 pandemic by the World Health Organization (WHO), some outpatient visits were disrupted or conducted via telephone.

Statistical Analyses

Statistical analyses were performed using SPSS version 28 (IBM SPSS Corp.; Armonk, NY, USA). The distribution of continuous variables was assessed using the Kolmogorov–Smirnov test. Descriptive statistics are presented as medians (25th-75th percentiles) due to the non-normal distribution of the variables. Categorical variables are presented as n (%). Comparisons of continuous variables between 2 independent groups were performed using the Mann–Whitney *U*-test. A *P*-value < .05 was considered statistically significant.

RESULTS

A total of 52 children were admitted with cCAP during the study period. The median age was 70.5 months (8-209 months), and 48.1% (n = 25) were female. In the 2 weeks preceding admission, 90.4% of patients (n = 47) reported symptoms of an upper respiratory tract infection, while 3.8% (n = 2) had a history of acute otitis media. A history of antibiotic use before admission was observed in 71.1% (n = 37) of the patients.

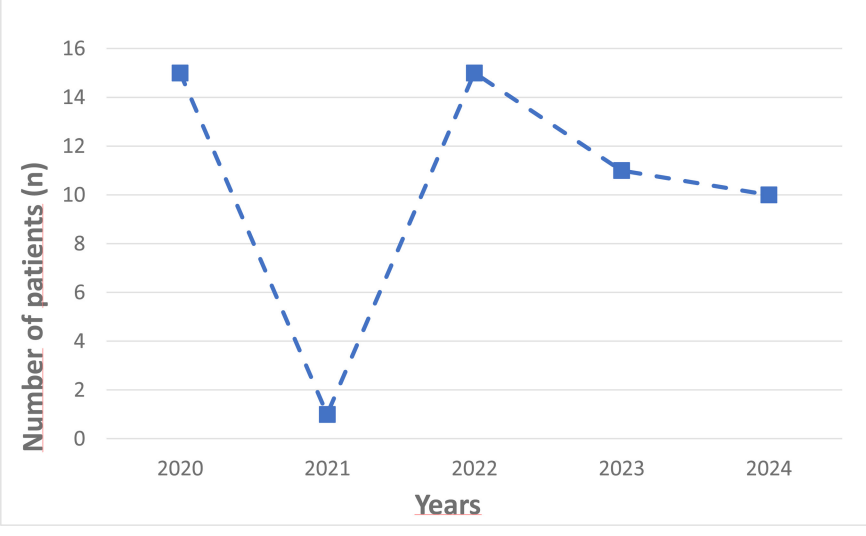


Figure 1. Distribution of the number of patients diagnosed with complicated community-acquired pneumonia by year.

Only 2 patients (3.9%) received 2 doses of PCV13; all remaining patients completed the recommended pneumococcal vaccination schedule. Eleven patients (21.1%) received 4 doses of PCV7, while the remaining patients received PCV13. The annual distribution of cases was 15 in 2020, 1 in 2021, 15 in 2022, 11 in 2023, and 10 in 2024 (Figure 1). The highest frequencies were observed in November, December, and January.

The most common presenting symptoms were fever (82.3%, n = 43) and dyspnea (36.5%, n = 19) (Table 1). Blood cultures were positive in 2% of cases (n = 1), yielding *S. pneumoniae*. Pleural fluid cultures were positive in 9.6% of patients (n = 5), identifying group A *Streptococcus* (5.8%, n = 3), *S. pneumoniae* (1.9%, n = 1), and *S. aureus* (1.9%, n = 1). The annual distribution of group A *Streptococcus* and *S. pneumoniae* cases from 2020 to 2024 is presented in a bar chart (Figure 2). The 2 *S. pneumoniae* isolates recovered from blood and pleural fluid cultures were serotyped as 3 and 14 by PCR, and both patients had received 3 complete doses of PCV13. Sputum cultures were obtained in a limited number of patients, and no bacterial growth was detected in any sample.

Table 1. Demographic, Clinical, and Laboratory Characteristics of Patients with Complicated Community-Acquired Pneumonia and the Distribution of Bacterial and Viral Pathogens

Baseline characteristics	**n (%)**
Median age (months)	70.5 (8-209)
Male/female	27/25
Presenting symptoms	
Fever	82.3% (n = 43)
Shortness of breath	36.5% (n = 19)
Cough	34.6% (n = 18)
Chest pain	17.3% (n = 9)
Laboratory results	
TLC (/mm^3)	14.900 (8.450-17.875)
ANC (/mm^3)	10.350 (6.450-14.200)
CRP (mg/L)	180.5 (85.2-292.6)
Procalcitonin (n = 26) (ng/mL)	1.0 (0.4-7.9)
Sedimentation (mm/h)	57 (45-85)
AST (IU/L)	26 (21-32.7)
ALT (IU/L)	13 (10-18)
BUN (mg/dL)	9.2 (7.1-12.6)
Creatinine (mg/dL)	0.3 (0.28-0.45)
Serum albumin (g/dL)	3.3 (3.0-3.8)
Pleural fluid pH	7.50 (7.22-7.69)
Pleural fluid LDH (IU/L)	1765.5 (567.3-4509.3)
Pleural fluid glucose (mmol/L)	60 (11-83.8)
Pleural fluid leukocyte count (/mm^3)	8000 (1100-17300)
Pleural fluid neutrophil rate (%)	82 (56.5-90.8)
Pleural fluid albumin (g/dL)	2.58 (2.31-2.84)
Complications	
Pleural effusion	86.5% (n = 45)
Empyema	21.2% (n = 11)
Necrotizing pneumonia	7.6% (n = 4)
Pneumothorax	5.7% (n = 3)
Bronchopleural fistula	2% (n = 1)
Bacterial pathogens (n = 6, 11.5%)	
Group A *Streptococcus*	5.8% (n = 3)
S. pneumoniae	3.8% (n = 2)
S. aureus	1.9% (n = 1)
Viral pathogens (n = 11, 21.2%)	
Rhinovirus	7.7% (n = 4)
Human metapneumovirus	3.8% (n = 2)
Human coronavirus	3.8% (n = 2)
Influenza	3.8% (n = 2)
Parainfluenza	1.9% (n = 1)

ALT, alanine aminotransferase; ANC, absolute neutrophil count; BUN, blood urea nitrogen; AST, aspartate aminotransferase; CRP, C-reactive protein; TLC, total leukocyte count.

Respiratory viral pathogens were detected in 21.2% of patients (n = 11) tested with the viral respiratory panel. The most frequently identified viruses were rhinovirus (7.7%, n = 4), human coronavirus (3.8%, n = 2), and human metapneumovirus (3.8%, n = 2) (Table 1). In 1 patient, a respiratory virus panel revealed simultaneous positivity for both metapneumovirus and influenza virus. SARS-CoV-2 was not detected in any patient. Bacterial–viral coinfection was identified in 1 patient only (group A *Streptococcus* and human coronavirus). Laboratory findings are also presented in Table 1.

Parapneumonic effusion was the most common complication (86.5%, n = 45), followed by empyema (21.2%, n = 11) and necrotizing pneumonia (7.6%, n = 4) (Table 1). Thoracic ultrasonography revealed septations in 35.5% (n = 16) of patients with PPE. Thoracic CT was performed in 27 of 52 patients. The most frequent CT findings included PPE (71.4%, n = 20), pneumonic consolidation (55.6%, n = 15), atelectasis (40.7%, n = 11), pneumonic infiltration (18.5%, n = 5), necrosis (14.8%, n = 4), cavity formation (14.8%, n = 4), pneumothorax (11.1%, n = 3), nodular densities (11.1%, n = 3), mediastinal lymphadenopathy (11.1%, n = 3), empyema (7.4%, n = 2), and bronchopleural fistula (3.7%, n = 1), respectively.

Histopathological examination of pleural fluid revealed fibrinous pleuritis in 5.8% of patients (n = 3), suppurative pleuritis in 2% of patients (n = 1), and abundant neutrophilic infiltration in 2% of patients (n = 1). For differential diagnosis, PPD was performed in 23 patients, of whom 10 patients also underwent QuantiFERON testing. Pleural fluid tuberculosis PCR and culture were performed in these 23 patients, and all results were negative. QuantiFERON testing was not performed in all patients because the assay was unavailable at the hospital during certain periods of the study.

The median duration of intravenous (IV) antibiotic therapy was 11 days (8-14 days). All patients initially received empirical treatment with ceftriaxone plus clindamycin. Clarithromycin was added in 69.2% of patients (n = 36), and levofloxacin in 2% of patients (n = 1). In 9.6% of patients (n = 5), clindamycin was replaced with vancomycin, and in another 9.6% of patients (n = 5), empirical therapy was switched to meropenem plus vancomycin. In all cases, clindamycin was switched to vancomycin based on inadequate clinical response to the initial empirical therapy. Intravenous immunoglobulin was administered in 3.8% of patients (n = 2) for invasive group A streptococcal infection. A chest thoracostomy tube was inserted in 31 patients (60%), with a median of 2 days (range, 1-4) after admission. Intrapleural fibrinolytic therapy was applied in 45% of patients (n = 14) with pleural effusion. Surgical intervention

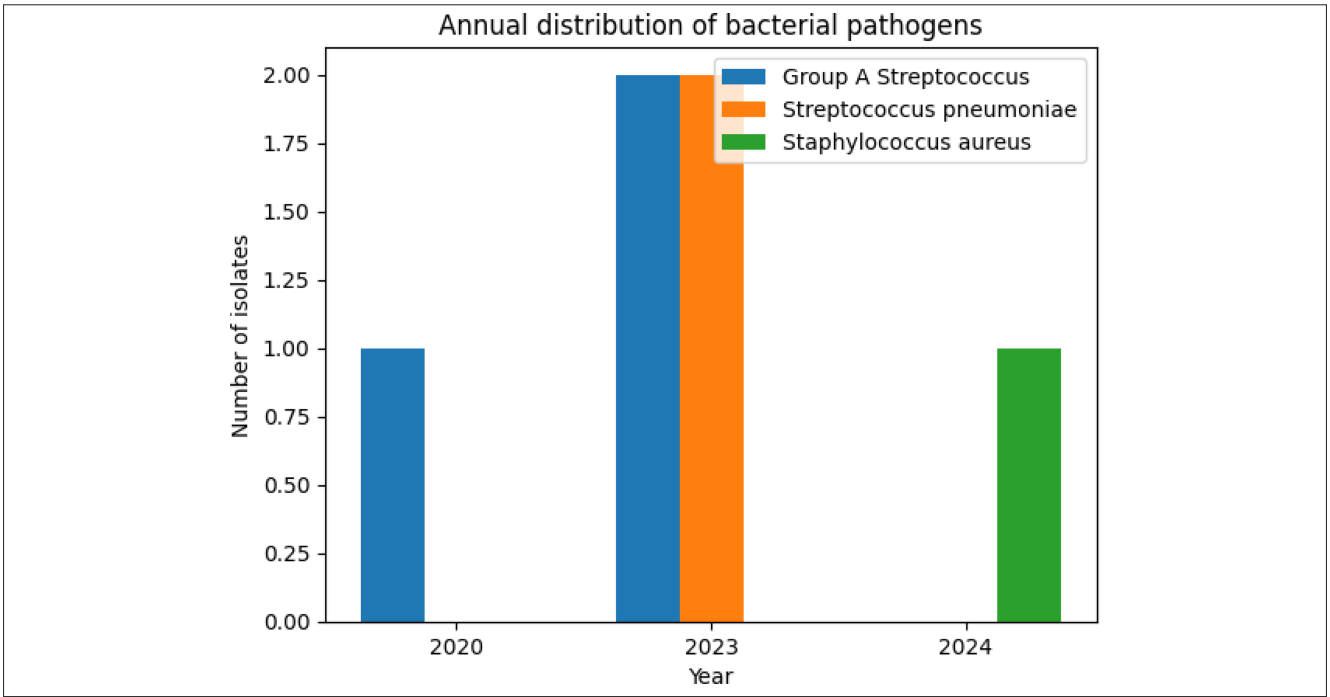


Figure 2. Annual distribution of culture-confirmed group A *Streptococcus* and *Streptococcus pneumoniae* cases in children with complicated community-acquired pneumonia, 2020-2024.

via VATS or thoracotomy was performed in 9.6% of patients (n = 5). Intensive care unit admission was required in 1 patient (2%) due to streptococcal toxic shock syndrome. There were no deaths among the patients. Post-discharge oral antibiotic therapy was administered to 90% of patients (n = 47), with a median duration of 14 days (7-14 days). Outpatient follow-up was continued in 71% of patients (n = 37). At the first outpatient visit, respiratory auscultation was completely normal in 75.6% of these patients (n = 28), while partial improvement in auscultatory findings was observed in the remaining patients.

Table 2. Comparison of Demographic Characteristics, Laboratory Findings, and Treatment Duration Between Patients Who Underwent Chest Tube Thoracostomy and Those Who Did Not

	Chest Tube Thoracostomy		
	Yes (n = 31)	**No (n = 21)**	***P***
Age (months)	48 (25.5-77)	87 (63-117.5)	.201
TLC (/mm^3)	17.150 (9.675-19.775)	16.750 (10.375-18.825)	.318
ANC (/mm^3)	11.750 (7.525-15.225)	12.400 (6.800-14.425)	.327
CRP (mg/L)	252.3 (139.9-351)	191.9 (96.5-254.7)	**.011**
Procalcitonin (n = 26) (ng/mL)	1.20 (0.6-13.1)	0.38 (0.3-6.6)	.356
Sedimentation (mm/h)	69.5 (56-88)	64 (42.5-101.5)	.547
Duration of IV antibiotic therapy	14 (9-18)	9.5 (5-13)	**.001**
Duration of PO antibiotic therapy	14 (10-14)	12 (7-14)	.081

ANC, absolute neutrophil count; CRP, C-reactive protein; IV, intravenous; PO, per oral; TLC, total leukocyte count..
P values of < .05 were written in bold.

Compared with patients without chest tube placement, those who required a chest tube thoracostomy had significantly higher CRP values and longer treatment durations of IV therapy (*P* = .011 and *P* = .001, respectively) (Table 2).

DISCUSSION

This study provides a comprehensive evaluation of pediatric cCAP over a 5-year period encompassing the pre-pandemic, pandemic, and post-pandemic eras. The findings highlighted important changes in epidemiological characteristics, inflammatory burden, and management strategies, while also reinforcing the persistent challenges in the diagnosis and treatment of cCAP, despite high pneumococcal vaccination coverage.

Streptococcus pneumoniae remains the most frequently reported etiologic agent of pediatric CAP, followed by group A *Streptococcus* and *Staphylococcus aureus*. However, a marked increase in the incidence and severity of invasive group A *Streptococcus* infections was reported across multiple countries in recent years, particularly since 2022.[16-19] In this cohort, group A *Streptococcus* was the most commonly isolated pathogen, followed by *S. pneumoniae*. This may be partly explained by the post-pandemic epidemiological changes and increased circulation of invasive group A *Streptococcus* reported during that period. In this cohort, the low culture positivity rate precludes any firm conclusion regarding a definite etiological shift. The relative contribution of these pathogens varies by region and is influenced by local epidemiology, as well as pneumococcal and *Haemophilus influenzae* type b vaccination coverage.[20] The widespread implementation of PCVs led to a substantial decline in the overall incidence of pneumonia and invasive pneumococcal disease in children.[21-25] Nevertheless, several studies paradoxically reported an increased proportion of cCAP cases following vaccine introduction.[2] Importantly, this reduction in disease burden

was not uniform across all pneumococcal serotypes included in PCV13. Accumulating evidence indicated that pneumococcal vaccine breakthrough infections were predominantly associated with serotype 3 and were frequently complicated by PPE or empyema. The unique capsular polysaccharide synthesis of serotype 3, characterized by excessive capsule production and limited anchoring to the bacterial cell wall, was thought to facilitate immune evasion and reduce vaccine effectiveness. In addition to serotype 3, serotypes 14 and 19A were also implicated in vaccine breakthrough infections despite complete PCV13 immunization.[26] Consistent with these observations, the pneumococcal isolates identified in this study belonged to serotypes 3 and 14, both of which were included in the PCV13 formulation. Notably, both affected patients received 3 complete doses of PCV13, which may suggest possible vaccine breakthrough infections.

Microbiological confirmation in pediatric cCAP remains challenging. Previous studies reported blood culture positivity rates ranging from 13% to 26% and pleural fluid culture yields between 19% and 49%.[2,3,27] Prior antibiotic exposure before hospital admission was shown to reduce culture positivity by up to 11-fold.[27] Molecular tests such as multiplex real-time PCR provide more sensitive and rapid detection of multiple pathogens than conventional cultures, with detection rates up to 87%, even in patients receiving prior antibiotics, thereby enabling earlier targeted therapy.[28,29] In contrast, this study demonstrated substantially lower culture yields, with bacterial growth detected in only 2% of blood cultures and 9.6% of pleural fluid samples. This low detection rate was likely related to the high prevalence of antibiotic use before presentation. These findings underscored the ongoing difficulty in identifying causative pathogens in cCAP and highlighted the need for improved diagnostic strategies. The relatively low microbiological confirmation rate in this study may be attributed to the high rate of prior antibiotic use before admission, which reduces culture yield. Therefore, molecular diagnostic methods, such as PCR-based assays, may enhance pathogen detection, particularly in these patients.

Recent studies demonstrated a notable increase in pediatric cCAP incidence over the past 5 years, a trend partially attributed to the impact of the COVID-19 pandemic.[30,31] During the pandemic, nonpharmaceutical interventions such as quarantine measures, school closures, and mask use significantly altered the epidemiology of respiratory infections worldwide.[32] These measures were associated with a temporary reduction in pediatric pneumonia hospitalizations. However, following the relaxation of restrictions, a rebound increase in respiratory infections was reported, including invasive group A *Streptococcus* disease and meningococcal meningitis.[17,19,33] Similarly, Pavel Heinige et al.[31] reported an increase in cCAP cases during the post-pandemic period. In this cohort, cCAP admissions decreased during the first year of the pandemic, likely reflecting the impact of strict infection control measures, and subsequently returned to pre-pandemic levels. Although the authors did not observe a numerical increase beyond baseline, some variation in etiologic distribution was observed, with group A *Streptococcus* identified more frequently among the culture-positive cases; however, the small number of microbiologically confirmed cases may preclude definitive conclusions. This finding may be associated with the pandemic, which might have influenced the clinical and microbiological characteristics of cCAP rather than its overall incidence. Seasonal variation was also observed in cCAP admissions, with most hospitalizations occurring during the influenza season. Previous studies showed that approximately half of pediatric cCAP cases coincide with peak influenza activity, emphasizing the role of viral infections in predisposing children to severe bacterial pneumonia.[34] Consistent with these reports, cCAP admissions in this study were most frequent in November, December, and January. Notably, the COVID-19 pandemic did not appear to alter the seasonal distribution of cCAP in this cohort.

Higher serum CRP levels were associated with an increased risk of cCAP and a greater need for invasive intervention, likely reflecting a higher bacterial burden.[3,4,35,36] In line with previous studies, patients in this cohort who required chest tube thoracostomy had significantly higher CRP levels at admission compared with those managed conservatively.

Management of pediatric cCAP is primarily based on antimicrobial therapy, with drainage and/or surgical intervention considered according to the size, stage, and characteristics of PPE or empyema.[5] However, optimal treatment strategies remain poorly standardized, and there is no universal consensus regarding the indications or timing for chest tube placement, fibrinolytic therapy, or surgical approaches such as VATS or thoracotomy.[2,37] Moreover, clear radiologic or volumetric thresholds for invasive intervention were not consistently defined.[38,39] In this cohort, surgical intervention was limited to the years 2020-2023, with no patients requiring surgery in 2024. This observation may be a result of evolving clinical practice, improved patient selection, or increased experience with less invasive management approaches.

The duration of antibiotic therapy was individualized based on clinical response and adequacy of drainage. In most pediatric patients, a total treatment duration of 2-4 weeks was generally considered sufficient.[9] A recent meta-analysis reported that longer hospital stays among children managed conservatively compared with those undergoing surgical intervention.[37] In contrast, the median duration of IV antibiotic therapy in this cohort was 11 days, which is shorter than that reported in many previous studies. As expected, patients requiring chest tube thoracostomy had longer durations of IV therapy, although total antibiotic exposure was not prolonged, as oral therapy duration was similar between groups. Importantly, the COVID-19 pandemic did not appear to prolong IV treatment duration. Reported mortality rates in pediatric cCAP ranged from 3.3% to 16%, although most contemporary studies reported no mortality.[40-42] Increased mortality was associated with severe disease caused by highly virulent pathogens, including *Staphylococcus aureus* and pneumococcal serotype 3.[31,37,43] Despite the presence of these high-risk pathogens in this cohort, no deaths were observed. These favorable outcomes may be attributed to early recognition of disease severity, prompt initiation of appropriate antimicrobial therapy, and timely implementation of invasive interventions when clinically indicated.

This study has several limitations. First, this was a single-center study conducted at a tertiary-care referral hospital, which might have resulted in overrepresentation of more severe

cCAP cases, including those requiring drainage or surgical intervention. Therefore, the generalizability of the findings to the broader pediatric CAP population is limited. Second, the relatively small sample size represents a limitation, as it may reduce the statistical power and limit the generalizability of results. Third, microbiological confirmation rates were low, largely due to frequent antibiotic exposure prior to hospital admission, which constrained pathogen-specific analyses and precluded more detailed evaluation of antimicrobial resistance patterns. In addition, imaging studies were not performed uniformly in all patients but were obtained based on clinical judgment. This might have introduced selection bias in the assessment of radiologic findings. Despite these limitations, the study provides valuable real-world data on the evolving epidemiology, clinical course, and management of pediatric cCAP in the context of high vaccination coverage and the COVID-19 pandemic.

In conclusion, pediatric cCAP remained a heterogeneous condition with evolving etiologic patterns despite high pneumococcal vaccination coverage. The identification of *Streptococcus pneumoniae* serotypes 3 and 14 in 2 fully vaccinated children, along with the relatively frequent detection of group A *Streptococcus* among culture-confirmed cases, may indicate a possible role for these pathogens in disease severity. However, these findings should be interpreted cautiously, given the limited number of confirmed cases. The COVID-19 pandemic appeared to influence the etiologic characteristics of cCAP rather than its overall incidence or seasonal distribution. Higher CRP levels at admission appeared to be more common in patients who required invasive intervention. Timely antimicrobial therapy combined with selective invasive management may enable favorable outcomes and shorter IV treatment durations, highlighting the importance of individualized management strategies in pediatric cCAP.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: The study was approved by the Ethics Committee of Dokuz Eylül University (approval number: 2021/09-25; Date: March 15, 2021).

Informed Consent: Written informed consent was obtained from patients and their parents.

Peer-review: Externally peer-reviewed.

Author Contributions: Conceptualization – İ.C.E., N.B.; Data curation – İ.C.E., B.U.K., Ş.Ö.A.; Formal analysis – İ.C.E., A.Ç.G., H.K.A.; Investigation – İ.C.E., B.U.K., N.C.A.; Methodology – İ.C.E., Ş.Ö.A., N.C.A.; Project administration – N.B., E.K.Ö., O.U.; Resources – İ.C.E., B.U.K., N.C.A.; Software – H.K.A., C.Ö., A.Ç.G.; Supervision – N.B., O.U., E.K.Ö.; Validation – N.B., H.K.A., N.C.A.; Visualization – İ.C.E., B.U.K., C.Ö.; Writing – original draft – İ.C.E.; Writing – review & editing – N.B., Ş.Ö.A., A.Ç.G., E.K.Ö., O.U.

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