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# Community-acquired Pneumonia among Hospitalized Children: Risk Factors, Characteristics, and Outcomes

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ORIGINAL STUDY

# Community-acquired pneumonia among hospitalized children: risk factors, characteristics, and outcomes

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**Abstract**

*Background*: **Community-acquired pneumonia (CAP) represents one of the main causes of mortality and morbidity among under-five children worldwide. More than 75% of these fatalities are caused by severe pneumonia.**

*Objectives*: **To identify the potential risk factors associated with severe CAP among under-five children hospitalized with CAP.**

*Patients and methods*: **This prospective observational study was conducted on children, aged 1−59 months, who were admitted with CAP to the Department of Pediatrics, Mataria Teaching Hospital, Egypt. Based on World Health Organization (WHO) guidelines, patients were classified into two groups: CAP and severe CAP. Data including demographic, children's history, clinical assessment, laboratory and radiological characteristics, and outcomes were collected and analyzed.**

*Results*: **Of the 222 patients enrolled, 100 (45%) children were diagnosed with severe CAP. Severe CAP patients were found to have more than twice the risk of death compared with CAP cases (OR = 2.3, $P = 0.01$). The risk factors including age ≤12 months (OR = 2.6, $P = 0.007$), prematurity (OR = 2.1, $P = 0.03$), malnutrition (OR = 2, $P = 0.04$), oxygen saturation <90% (OR = 2.9, $P = 0.002$), altered consciousness level (OR = 9.1, $P = 0.01$), anemia for age (OR = 2, $P = 0.04$), pH < 7.3 (OR = 2; $P = 0.04$), partial pressure of carbon dioxide (PCO2) >50 mm Hg (OR = 2.5, $P = 0.03$), and C-reactive protein (CRP) > 6 mg/l (OR = 3.3, $P < 0.001$) were identified to be significantly associated with severe CAP.**

*Conclusion*: **Factors such as young age, prematurity, malnutrition, low oxygen saturation, altered consciousness level, anemia, acidosis, and elevated CRP were found to be significant predictors of the risk of severe CAP among under-five children hospitalized with CAP.**

*Keywords:* Community-acquired pneumonia, Risk factors, Severe pneumonia, Under-five children

## 1. Introduction

Community-acquired pneumonia (CAP) is considered when pneumonia develops outside the hospital or is detected within 48 h after hospitalization in a patient who has not been hospitalized within the previous 14 days [1]. It remains among the main causes of mortality and morbidity in children under the age of 5 years [2]. Pneumonia is estimated to affect 151 million children under the age of 5 years every year, which corresponds to 0.29 episodes per child-year in developing countries, and 7−13% of such episodes are critical enough to be life-threatening and necessitate hospitalization. Also, pneumonia causes approximately one million deaths among children every year, representing 17−19% of all under-5 fatalities [3]. More than 75% of these fatalities are attributed to severe pneumonia, and nearly two-thirds of deaths occur in infants [4]. Also, severe CAP accounts for 6% of pediatric intensive care unit (PICU) admissions, with a mortality rate among these patients exceeding 10% [5]. So assessing CAP severity is crucial for evaluating the prognosis and guiding patient management, thus improving outcomes [6]. Therefore, in hospitalized children with severe CAP

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who may develop complications and require intensive care, it may be beneficial to identify risk factors for pneumonia severity upon admission, thereby providing prompt treatment, and thus reducing the burden of CAP mortality and hospitalization.

## 2. Aim of the study

To identify the potential risk factors and predictors for the severity of CAP among under-five children hospitalized with CAP.

## 3. Material and methods

This prospective observational, hospital-based study was conducted at the Department of Pediatrics at Mataria Teaching Hospital, Cairo, Egypt, over 5 months from December 2022 to April 2023. Our study included all children aged between 1 and 59 months, who were hospitalized with CAP based on World Health Organization (WHO) guidelines [7]. CAP was diagnosed when children had difficulty breathing and/or cough, with either lower chest indrawing or fast breathing ($\geq$60 breaths per minute for infants under 2 months of age, $\geq$50 breaths per minute for infants aged 2–12 months, $\geq$40 breaths per minute for children aged 12–59 months), as well as radiological findings suggestive of pneumonia. Childhood CAP patients were divided into two groups: CAP and severe CAP according to WHO guidelines [7]. Severe CAP was considered when pneumonia was accompanied by general danger signs such as; persistent vomiting, convulsions, lethargy or unconsciousness, stridor, inability to drink, or severe malnutrition. Written informed consent from the parents or guardian was acquired before children were included. All procedures were done following the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 2013, and were approved by the Research Ethics Committee of the General Organization of Teaching Hospitals and Institutes (GOTHI), date of approval: December 7, 2022, under approval no. HM000148.

Children with preexisting lung disease, particularly asthma, tuberculosis, or bronchiectasis, and children with comorbidities such as congenital heart disease, chronic liver or kidney disease, known immunodeficiency, and neuromuscular or skeletal disorders were excluded from the study. Patients who developed pneumonia due to nosocomial infection or aspiration were also excluded.

Data of demographic characteristics such as age and gender as well as history-related factors including; birth order, mode of delivery, breastfeeding practice, premature birth, low birth weight, immunization status, parental smoking, family history of asthma, and history of previous acute lower respiratory infection (ALRI) or pneumonia were collected for each patient. Clinical characteristics upon admission such as vital data (respiratory rate, heart rate, temperature, and oxygen saturation), grade of respiratory distress (RD), nutritional status, and Glasgow Coma Scale (GCS) were collected. The nutritional status was assessed according to weight-for-age z-scores (WAZs); children with a WAZ score of less than−2 were deemed underweight, while those with a WAZ score of more than +2 were defined as overweight [8]. We collected laboratory parameters including complete blood count (CBC), blood gases, C-reactive protein (CRP), random blood sugar, serum electrolytes, and sputum culture in the first 24 h of admission. We further categorized the radiological findings of the CAP cases as alveolar infiltrates, interstitial infiltrates, or consolidation (lobar pneumonia). Complications such as empyema, pleural effusion, pneumothorax, lung abscess, signs of severe sepsis or septic shock, or respiratory failure were evaluated either upon admission or throughout a hospital stay. Lastly, we recorded the outcomes in both groups in terms of mortality, need for PICU admission, complications, and length of hospital stay.

### 3.1. Statistical methods

Statistical analysis was done using SPSS version 27 software. Categorical data were presented as numbers (percentage) and compared with the $\chi^2$ test. Normally distributed data were presented as mean ± standard deviation (SD) and compared by Student's *t*-test. Non-normally distributed data were reported as the median and interquartile range (IQR) and compared by the Mann–Whitney test. Bivariate analysis using Pearson $\chi^2$ test was performed to determine the association between potential risk factors and developing severe CAP among children hospitalized with CAP by calculating odds ratios (ORs) with 95% confidence intervals (CI). *P* values of less than 0.05 are deemed statistically significant.

## 4. Results

This study included 222 children admitted with CAP, of whom 123 (55.4%) were males and 99 (44.6%) were females. Their ages ranged from 1 to 59 months, with a median (IQR) age of 4 (6.5) months, while the majority (78.8%) were under the age of 12 months. Based on WHO criteria, the enrolled

children were classified into two groups; 122 (55%) had CAP and 100 (45%) had severe CAP.

Demographic and history-related data were collected, and bivariate analysis was performed to determine potential risk factors for severe CAP among the recruited children (Table 1). Compared with CAP cases, the hospitalized severe CAP patients were significantly younger (≤12 months) (OR = 2.6, $P = 0.007$) and had a history of preterm birth (OR = 2.1, $P = 0.03$). However, other risk factors including gender, birth order, low birth weight (<2.5 kg), mode of delivery, nonexclusive or lack of breastfeeding, incomplete vaccination, paternal smoking, history of ALRI or pneumonia, and family history of asthma did not vary significantly between the two patient groups ($P > 0.05$).

When comparing the clinical characteristics of the two patient groups, hospitalized severe CAP patients were significantly younger and had significantly lower WAZs and oxygen saturations ($P = 0.01$, $P = 0.02$, $P < 0.001$, respectively) than CAP cases. The severe CAP cases also had significantly higher respiratory rates ($P = 0.007$) and heart rates ($P = 0.004$) when compared with CAP cases. As regards laboratory characteristics, severe CAP cases were found to have significantly higher platelet counts ($P = 0.005$), higher CRP levels ($P = 0.03$), and lower blood PH ($P = 0.048$) when compared with CAP patients. However, the radiological findings did not differ significantly between the two groups ($P = 0.06$), with interstitial infiltrates representing the most common radiological finding in all cases 121 (54.5%), followed by alveolar infiltrates in 79 (35.6%), and consolidation in 22 (9.9%) patients (Table 2).

We further evaluated the association between children's clinical and laboratory characteristics upon admission and the likelihood of developing severe CAP (Table 3). Among the factors evaluated,

*Table 1. Child-related factors and the risk of severe CAP in under-five children.*

| Child-related factors | Total cases $n = 222$ $n$(%) | Severe CAP group $n = 100$ $n$(%) | CAP group $n = 122$ $n$(%) | OR (CI) | $P$ |
|---|---|---|---|---|---|
| Age | | | | | |
| ≤12 months | 175 (78.8%) | 87 (87%) | 88 (72.1%) | 2.6 (1.3–5.2) | 0.007[a] |
| 13–59 months | 47 (21.2%) | 13 (13%) | 34 (27.9%) | | |
| Gender | | | | | |
| Male | 123 (55.4%) | 50 (50%) | 73 (59.8%) | 0.7 (0.4–1.1) | 0.14 |
| Female | 99 (44.6%) | 50 (50%) | 49 (40.2%) | | |
| Birth order | | | | | |
| 1 | 50 (22.5%) | 22 (22%) | 28 (23%) | – | 0.89 |
| 2–3 | 125 (56.3%) | 60 (60%) | 65 (53.2%) | | |
| 4 + | 47 (21.1%) | 18 (18%) | 29 (23.8%) | | |
| Birth weight (Kg) | | | | | |
| <2.5 | 46 (20.7%) | 24 (24%) | 22 (18%) | 1.4 (0.7–2.7) | 0.2 |
| ≥2.5 | 176 (79.3%) | 76 (76%) | 100 (82%) | | |
| Prematurity | | | | | |
| Yes | 42 (18.9%) | 25 (25%) | 17 (13.9%) | 2.1 (1.04–4) | 0.03[a] |
| No | 180 (81.1%) | 75 (75%) | 105 (86.1%) | | |
| Delivery | | | | | |
| CS | 175 (78.8%) | 95 (77.9%) | 80 (80%) | 0.9 (0.5–1.7) | 0.7 |
| Normal | 47 (21.2%) | 27 (22.1%) | 20 (20%) | | |
| BF practice | | | | | |
| Exclusive BF | 68 (30.6%) | 30 (30%) | 38 (31.1%) | 0.9 (0.5–1.6) | 0.8 |
| Non-exclusive BF | 158 (71.2%) | 71 (71%) | 87 (71.3%) | 0.9 (0.5–1.7) | 0.96 |
| Lack of BF | 64 (28.8%) | 29 (29%) | 35 (28.7%) | 1 (0.6–1.8) | 0.9 |
| Vaccination | | | | | |
| Vaccinated | 209 (94.1%) | 92 (92%) | 117 (95.9%) | 2 (0.6–6.4) | 0.2 |
| Incomplete vaccination | 13 (5.9%) | 8 (8%) | 5 (4.1%) | | |
| Previous history | | | | | |
| ALRI | 18 (8.1%) | 10 (10%) | 8 (6.6%) | 1.6 (0.6–4.2) | 0.35 |
| Pneumonia | 35 (15.8%) | 12 (12%) | 23 (18.9%) | 0.6 (0.3–1.2) | 0.2 |
| Paternal smoking | | | | | |
| Yes | 138 (62.2%) | 63 (63%) | 75 (61.5%) | 1.1 (0.6–1.8) | 0.82 |
| No | 84 (37.8%) | 37 (37%) | 47 (38.5%) | | |
| Family history | | | | | |
| Asthma | 30 (13.5%) | 11 (11%) | 19 (15.6%) | 0.7 (0.3–1.5) | 0.32 |
| No | 192 (86.5%) | 89 (89%) | 103 (84.4%) | | |

ARTI, acute lower respiratory infection; BF, breastfeeding; CAP, community-acquired pneumonia; CI, 95% confidence interval; CS, caesarian section; $n$ (%), number (percentage); OR, odds ratio.

[a] Statistically significant *$P < 0.05$.

*Table 2. Comparison between the studied groups regarding children's characteristics.*

| Characteristics | Total cases $N = 222$ | Severe CAP group $n = 100$ | CAP group $n = 122$ | $P$ |
|---|---|---|---|---|
| Age (months) | 4 (6.5) | 3 (4) | 5 (14) | <0.001[b,a] |
| WAZs | −0.76 (1.7) | −0.86 (2) | −0.61 (2) | 0.02[b,a] |
| RR (breaths/min) | 58 ± 8.4 | 59.7 ± 8 | 56.6 ± 8.5 | 0.007[c,a] |
| HR (beats/min) | 136.7 ± 13.4 | 139.6 ± 14.7 | 134.4 ± 11.8 | 0.004[c,a] |
| Temperature (°C) | 37.6 ± 0.6 | 37.7 ± 0.6 | 37.6 ± 0.6 | 0.26[c] |
| Oxygen saturation (%) | 92.2 ± 5.6 | 90.5 ± 7.4 | 93.5 ± 3 | <0.001[c,a] |
| Hemoglobin (g/dl) | 10.14 ± 1.28 | 10 ± 1.3 | 10.2 ± 1.3 | 0.17[c] |
| Total leukocyte count ($10^3$/μl) | 11.9 (7.5) | 12.6 (8.7) | 11.3 (7.7) | 0.14[b] |
| Neutrophil count ($10^3$/μL) | 4.9 (5.4) | 5.4 (5.4) | 4.5 (5.5) | 0.15[b] |
| Lymphocyte count ($10^3$/μl) | 5.5 (4.3) | 5.6 (4.3) | 5.3 (4.3) | 0.7[b] |
| NLR | 0.9 (1.28) | 0.89 (1.29) | 0.9 (1.28) | 0.4[b] |
| Platelet count ($10^3$/μl) | 420.8 ± 149.2 | 451.9 ± 154.5 | 395.4 ± 140.3 | 0.005[c,a] |
| Serum sodium (mmol/l) | 136.1 ± 4.85 | 136.4 ± 6 | 135.9 ± 3.6 | 0.47[c] |
| Serum potassium (mmol/l) | 4.7 ± 0.67 | 4.8 ± 0.6 | 4.7 ± 0.7 | 0.29[c] |
| RBG (mg/dl) | 98.3 ± 24.3 | 96.5 ± 27.3 | 99.8 ± 21.6 | 0.32[c] |
| Blood pH | 7.34 ± 0.1 | 7.33 ± 0.1 | 7.36 ± 0.09 | 0.048[c,a] |
| Chest radiograph $n$ (%) | | | | |
| Interstitial infiltrates | 121 (54.5%) | 50 (50%) | 71 (58.2%) | 0.06[d] |
| Alveolar infiltrates | 79 (35.6%) | 35 (35%) | 44 (36.1%) | |
| Consolidation (lobar) | 22 (9.9%) | 15 (15%) | 7 (5.7%) | |

CAP, community-acquired pneumonia; HR, heart rate; IQR, interquartile range; $n$ (%), number (percentage); NLR, neutrophil–lymphocyte ratio; RBG, random blood glucose; RR, respiratory rate; SD, standard deviation; WAZs, weight-for-age z scores.
[a] Statistically significant *$P < 0.05$.
[b] Values are expressed as Median (IQR) 'Mann–Whitney test'.
[c] Values are expressed as mean ± SD 'Student's t test.'
[d] Values are expressed as number (%) 'Chi-square test.'

underweight (OR = 2, $P = 0.04$), oxygen saturation <90% (OR = 2.9, $P = 0.002$), altered level of consciousness (GCS<15) (OR = 9.1, $P = 0.01$), anemia for age (OR = 2, $P = 0.03$), CRP>6 mg/l (OR = 3.3, $P < 0.001$), blood pH < 7.3 (OR = 2, $P = 0.03$), partial pressure of carbon dioxide (PCO2) >50 mm Hg (OR = 2.5, $P = 0.02$), and positive sputum culture (OR = 3.2, $P < 0.001$) were significantly associated with increased risk of severe CAP. All enrolled children experienced RD, and the most common presentation in both groups was RD grade II; however, severe CAP cases were more likely to present with RD grades III and IV when compared with the CAP group ($P < 0.001$).

Of the 222 patients enrolled in this study, 80 (36%) children required admission to the PICU, with a median (IQR) length of hospital stay of 6 (3), and five (2.3%) patients died. As shown in Table 4, children

*Table 3. Children's characteristics and the risk of severe CAP.*

| Characteristics | Total cases $n = 222$ $n$ (%) | Severe CAP group $n = 100$ $n$ (%) | CAP group $n = 122$ $n$ (%) | OR (CI) | $P$ |
|---|---|---|---|---|---|
| Underweight | 46 (20.7%) | 27 (27%) | 19 (15.6%) | 2 (1.04–3.9) | 0.04[a] |
| Oxygen saturation <90% | 44 (19.8%) | 29 (29%) | 15 (12.3%) | 2.9 (1.5–5.8) | 0.002[a] |
| GCS <15 | 8 (3.6%) | 7 (7%) | 1 (0.8%) | 9.1 (1.1–75.3) | 0.01[a] |
| Anemia for age | 170 (76.6%) | 83 (83%) | 87 (71.3%) | 2 (1.02–3.7) | 0.04[a] |
| CRP >6 mg/l | 109 (49.1%) | 65 (65%) | 44 (36.1%) | 3.3 (1.9–5.7) | <0.001[a] |
| Sodium <135 mmol/L | 71 (32%) | 33 (33%) | 38 (31.1%) | 1.1 (0.6–1.9) | 0.77 |
| Blood pH < 7.3 | 46 (20.7%) | 27 (27%) | 19 (15.6%) | 2 (1.04–3.8) | 0.04[a] |
| PCo2 >50 mm Hg | 28 (12.6%) | 18 (18%) | 10 (8.2%) | 2.5 (1.08–5.6) | 0.03[a] |
| Positive sputum culture | 63 (28.4%) | 41 (41%) | 22 (18%) | 3.2 (1.7–5.8) | <0.001[a] |
| Grade of RD | | | | | |
| Grade I | 16 (7.2%) | 4 (4%) | 12 (9.8%) | | |
| Grade II | 143 (64.4%) | 51 (51%) | 92 (75.4%) | 4.7 (2.5–8.9) | <0.001[b,a] |
| Grade III | 48 (21.6%) | 33 (33%) | 15 (12.3%) | | |
| Grade IV | 15 (6.8%) | 12 (12%) | 3 (2.5%) | | |

CAP, community-acquired pneumonia; CI, 95% confidence interval; CRP, C-reactive protein; GCS, Glasgow coma scale; $n$ (%), number (percentage); OR, odds ratio; PCO2, partial pressure of carbon dioxide; RD, respiratory distress.
[a] Statistically significant *P < 0.05.
[b] Respiratory distress (grades III and IV versus grades I and II).

*Table 4. Comparison between studied groups regarding outcomes.*

| Outcomes | Total cases $n = 222$ | Severe CAP group $n = 100$ | CAP group $n = 122$ | OR (CI) | $P$ |
|---|---|---|---|---|---|
| Complication $n$ (%) | 21 (9.5%) | 20 (20%) | 1 (0.8%) | 30.3 (4–229.9) | <0.001[a] |
| PICU admission $n$ (%) | 80 (36%) | 54 (54%) | 26 (21.3%) | 4.3 (2.4–7.8) | <0.001[a] |
| Death $n$ (%) | 5 (2.3%) | 5 (5%) | 0 (0%) | 2.3 (2–2.7) | 0.01[a] |
| Hospital stay (days) | 6 (3) | 7 (5) | 5 (2) | – | <0.001[b,a] |

CAP, community-acquired pneumonia; CI, 95% confidence interval; IQR, interquartile range; n (%), number (percentage); OR, odds ratio; PICU, pediatric intensive care unit.

[a] Statistically significant *$P < 0.05$.

[b] Values are expressed as median (IQR) 'Mann–Whitney U.'

with severe CAP were more likely to have adverse outcomes compared with CAP cases in terms of mortality (5% vs 0%, OR = 2.3, $P = 0.01$) and morbidity including complications (20% vs 0.8%, OR = 30.3, $P < 0.001$), PICU admission (54% vs 21.3%, OR = 4.3, $P < 0.001$), and length of hospital stay (7 (5) vs. 5 (2), $P < 0.001$). Complications among severe CAP patients were in the form of sepsis (6%), pneumothorax (3%), aspiration (3%), pleural effusion (3%), heart failure (3%), and empyema (2%), while only one patient (0.8%) developed sepsis in the CAP group.

## 5. Discussion

Despite effective vaccination, nutritional, and environmental interventions, pneumonia remains one of the top causes of death in under-five children [9]. Evaluation of disease severity and which children are more vulnerable to severe pneumonia is challenging [10]. This study identified key factors that could determine children at risk of developing severe CAP during early clinical assessment, thus helping guide the clinical practice and result in better outcomes.

In the this study, we evaluated various factors including demographic data, history-related, and characteristics either clinical, laboratory, or radiological, and its association with the risk of severe CAP among under-five children who were hospitalized with CAP. As for demographic characteristics, it was found that younger children (≤12 months) had an increased risk of developing severe CAP (OR = 2.6, $P = 0.007$), whereas gender had no predictive value for pneumonia severity. This is following the findings of Kasundriya et al. [11] and Chen et al. [12]. These results may be explained by the fact that infants tend to be more susceptible to severe disease due to their underdeveloped immune systems and immature respiratory systems.

Apart from premature children who had twice the risk of developing severe CAP (OR = 2, $P = 0.03$) in our study, the severity of CAP was not significantly associated with low birth weight, birth order, mode of delivery, lack of breastfeeding, incomplete immunization, previous episode of pneumonia or ALRI, paternal smoking, or family history of asthma among the studied patients ($P > 0.05$). This was consistent with the findings of Kasundriya et al. [11], who found an association between severe pneumonia and premature birth. These findings might be attributed to decreased immunity and defects in lung function in preterm infants. However, Kasundriya et al. [11] revealed that nonexclusive breastfeeding in the first 6 months of life, as well as incomplete immunization, increased the risk of severe pneumonia in contrast to our findings. Nevertheless, Chen et al. [12] showed in their study that formula feeding predicted a higher chance of having severe CAP in infants under 6 months of age only, and justified this by explaining that the feeding approach loses its influence on immunity once immunity matures. In addition, Azab et al. [13] have demonstrated that parental smoking seems to be an important predictor for severe CAP and hospitalization, contrary to our findings.

In our study, severe CAP cases were found to have significantly higher respiratory rates and heart rates but lower oxygen saturations compared with CAP patients. In addition, patients with severe CAP were shown to have significantly higher platelet counts and serum CRP levels but lower blood pH than the CAP group. This is in line with the findings of Muljono et al. [14], who observed that elevated respiratory rates were associated with pneumonia severity and may be an indicator for recognizing children at risk of mortality. Williams et al. [15] also showed that tachycardia was associated with severe pneumonia. These findings demonstrated the association of these characteristics with the severity of CAP.

Regarding radiological characteristics, we did not find a significant association between radiographic findings and the severity of CAP. This is in contrast to the Chen et al. [12] findings, who found that abnormalities on radiographs were significantly

associated with a higher risk of contracting severe CAP or needing for PICU among childhood CAP cases.

Regarding clinical characteristics, malnutrition (underweight), oxygen saturation <90%, and altered conscious level (GCS<15) upon admission were found to be significant predictors for the severity of CAP among studied children (OR = 2.9, $P = 0.002$; OR = 2, $P = 0.04$; OR = 9.1, $P = 0.01$, respectively). The present findings were endorsed by Bhat et al. [2], who reported that malnourished children had an increased risk and severity of CAP. Caggiano et al. [16] also observed that increased oxygen demand was associated with severe pneumonia. So, when assessing a child with CAP, it is crucial to detect hypoxemia using pulse oximetry to determine pneumonia severity and the need for hospitalization [2]. Furthermore, Williams et al. [15] noticed that altered mental status was associated with severe pneumonia.

Among laboratory characteristics, anemia for age and acidosis (blood pH < 7.3 and Pco2 >50 mm Hg) was shown to be at twice the risk of developing severe CAP. This finding was consistent with Muljono et al. [14], who observed that a normal level of hematocrit was linked with a reduced risk for severe CAP, indicating that anemia may boost children's vulnerability to pneumonia and raise the risk of death. Also, a hemoglobin level of less than 10 g/dl was found to be a predictive risk factor for progressive pneumonia according to Huang et al. [17]. Metabolic acidosis was found by Wang et al. [18] to be a risk factor for death in children hospitalized with pneumonia. Likewise, blood pH < 7.30 was found to be a predictor of severe CAP by España et al. [19].

Furthermore, we found that CRP levels >6 mg/l and positive sputum cultures upon admission were significant predictive factors for severe CAP. These findings were supported by findings from Huang et al. [17] and Shan et al. [5], who observed that high CRP levels were significantly correlated with a higher likelihood of severe CAP, particularly in younger patients. On the contrary, Wu et al. [20] found that CRP levels were not related to WHO severity criteria in children admitted with pneumonia.

In our study, children with severe CAP were found to have adverse outcomes including increased mortality and increased morbidity such as complications, PICU admission, and longer hospital stay, compared with CAP patients. This was in agreement with the findings of Champatiray et al. [21], who reported that higher mortality rates were observed with severe pneumonia, and Feinstein et al. [10], who noticed that infants with severe CAP had a higher incidence of PICU transport within 48 h of hospitalization. These results indicate the poor prognosis of severe CAP and thus the importance of early assessment of CAP severity.

In conclusion, severe CAP was found to have an increased risk of mortality and morbidity among under-five children. And, the severity of CAP in hospitalized children was found to be significantly associated with several factors, including prematurity, young age, clinical characteristics on admission, such as malnutrition, low oxygen saturation, and altered level of consciousness, as well as laboratory characteristics, such as anemia, acidosis, and elevated CRP. These findings suggest that these factors could be potential predictors for the risk of severe CAP in under-five children. Therefore, the early identification of children with severe CAP who are found to be at risk of adverse outcomes, along with providing them with timely and proper management, can result in a reduction in under-five morbidity and mortality. Thus, further research is required to elucidate the association between these factors and mortality among under-five children hospitalized with severe CAP.

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### Conflicts of interest

The authors have no conflicts of interest to disclose.

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