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Original Article

Paediatrics Section

Association of Procalcitonin Level with the Severity of Pneumonia in Children under 5 Years of Age: A Prospective Cohort Study

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ABSTRACT

Introduction: Community Acquired Pneumonia (CAP) is a significant global health problem, with notable variations in incidence, causative pathogens, and outcomes across different regions and populations. Procalcitonin (PCT) has been established as a marker of bacterial infection to differentiate septic from other infections in paediatric patients.

Aim: To evaluate the severity of pneumonia in children under 5 years of age according to the parameters of Acute Illness Observation Scale (AIOS) and also to study its association with serum PCT level.

Materials and Methods: The present prospective cohort study was conducted in the Paediatric Intensive Care Unit (ICU) of BLDE deemed to be university, Shri BM Patil Medical College, Vijayapura, Karnataka, India, between March 2023 and October 2024. A total of 51 children aged between 2 to 59 months were included in the study who presented with fever, cough, and rapid breathing, along with any of the following symptoms: chest in drawing in a calm child, stridor, grunting, lethargy, convulsions, and decreased appetite. The AIOS was used to assess the children on Day 1, Day 2, and Day 5 of admission. On admission, venous blood was drawn and processed for serum PCT. The data collected was entered into a Microsoft Excel spreadsheet and analysed using Statistical Package for the Social Sciences (SPSS), Version 20.

Results: The age in the study group ranged from two months to 59 months, among them the majority were in the age group of 12 months- 5 years, i.e., 27 (52.9%) patients, followed by 24 (47.1%) patients in the age group of <12 months. A total of 33 (64.7%) patients were male children and 18 (35.3%) patients were female. It was found that 29 (56.9%) patients had moderate AIOS on day 1 and then 32 (62.7%) patients had mild AIOS on day 2 followed by 37 (72.5%) patients had mild AIOS on day 5. It was found that there was a significant association between AIOS score and PCT level and also with PCT and C-reactive Protein (CRP) level (p-value <0.05).

Conclusion: Both the AIOS and serum PCT levels demonstrate a strong ability to detect the severity level and determine clinical outcomes in paediatric patients with CAP.

Keywords: Acute illness observation scale, Biomarkers of severity, Calcitonin precursor, Community acquired infection

INTRODUCTION

The CAP is a significant global health problem. Globally, CAP leads to 1.4 million visits to the emergency department, 740,000 hospitalisations, and 41,000 deaths annually [1,2]. The annual incidence ranges from 5 to 11/1,000 individuals, with varying mortality rates based on the setting [2]. In India, studies have identified *S. pneumoniae*, *Klebsiella pneumoniae*, and *Staphylococcus aureus* as common causative agents [3,4]. Optimising triage, early referral, hospitalisation, and treatment criteria is crucial because India has one of the highest rates of pneumonia-related mortality. The technique known as Integrated Management of Neonatal and Childhood Illness (IMNCI) has made this easier by streamlining the process of classifying the severity of key acute childhood illnesses, such as pneumonia [3,4].

McCarthy PL et al., created the generic illness severity scale known as the AIOS in 1982, which is based on straightforward observations rather than intricate symptomatology. It has been proven to be helpful in this regard. Neuroendocrine cells found in the thyroid, lung, and intestine typically produce PCT, a protein precursor to the hormone calcitonin [5]. As part of the innate immune system's pro-inflammatory response, parenchymal cells release PCT, a precursor peptide of calcitonin, which is detectable 4 hours after endotoxin stimulation much sooner than CRP. PCT has been established as a marker of bacterial infection to differentiate septic from other infections in paediatric patients. Higher PCT concentration has been linked to the isolation of common bacterial species in numerous adult trials, particularly when it comes to bacterial CAP [6-8]. To the best of our knowledge, studies associating AIOS and PCT in pneumonia are sparse. Hence, the study was undertaken to evaluate the severity of pneumonia in children according to the parameters of AIOS and also to study its association with serum PCT level.

MATERIALS AND METHODS

The present prospective cohort study was conducted in paediatric intensive care Unit of BLDE deemed to be university, Shri BM Patil Medical College,Vijayapura, Karnataka, India, for a duration of 1.5 years (March 2023- October 2024). Study was approved by the institutional ethical committee of BLDE Deemed To Be University, Shri BM Patil Medical College (IEC Approval No.: BLDE(DU)/IEC/968/2022-23). Informed written consent was taken before including in the study.

Inclusion criteria: The children included in the study were aged between 2 to 59 months who present with fever, cough, and rapid breathing, along with any of the following symptoms: chest in drawing in a calm child, stridor, grunting, lethargy, convulsions, and decreased appetite.

Exclusion criteria: Children who were diagnosed with croup who presented with signs of a foreign body in the respiratory tract or who were already undergoing antibiotic treatment before their admission to our hospital were excluded from the study.

Sample size calculation: With anticipated mean±SD of bacterial pneumonia cases 12.0±6.7, the study would require a sample size of 44 patients with 95% level of confidence and a precision of 2.

Formula used [1,6]:

$$N=\frac{Z^2 \cdot S^2}{d^2}$$

Where:

Z= 1.96 (for 95% confidence level)

S= 6.7 (Standard deviation)

d= 2 (precision or absolute error)

$$N=\frac{(1.96)^2\times(6.7)^2}{(2)^2}$$

$$N=\frac{3.8416 \times 44.89}{4}=\frac{172.571824}{4}=43.14$$

Study Procedure

The children meeting the inclusion criteria admitted to the paediatric ICU were chosen for evaluation.

A detailed clinical history was obtained from all 51 children, including the duration of fever, cough, hurried breathing, and any previous hospital admissions for similar complaints. All children underwent a comprehensive clinical examination, which included measurement of respiratory rate, assessment of chest retractions, chest percussion, and auscultation, along with a systemic evaluation to follow the inclusion and exclusion criteria.

The AIOS was used to assess the children on Day 1, Day 2, and Day 5 of admission [Table/Fig-1] [5]. On admission, 3ml of venous blood was drawn using sterile technique and processed for total count, neutrophils, lymphocytes, haemoglobin, platelet count, CRP, and serum PCT. Blood was also sent for blood culture.

Observation item	1 (Normal)	3 (Moderate impairment)	5 (Severe impairment)
Quality of cry	Strong with normal tone or content and not crying	Whimpering or sobbing	Weak or moaning or high pitched
Reaction to parent stimulation	Cried briefly then stops or content and not crying	Cried on and off	Continual cry or hardly responds
State variation	If awake, stays awake or if asleep and stimulated, wakes up quickly	Eyes close briefly awake or awakes with prolonged stimulation	Falls to sleep or will not arouse
Color	Pink	Pale extremities or acrocyanosis	Pale or cyanotic or mottled or ashen
Hydration	Skin and eyes normal and mucous membrane moist	Skin and eyes normal and mouth slightly dry	Skin doughy or tented and dry mucous membrane and/or sunken eyes
Response (talk, smile) to social cues	Smiles or alert (<2 months)	Brief smile or alerts briefly (<2 months)	No smile or face is anxious, dull, expressionless or no alerting (<2 months)
Total score	6= best score 30= worst score		

[Table/Fig-1]: AIOS Scoring [5].

PCT levels are graded to reflect the severity of a potential bacterial infection or inflammatory response. Levels below 0.1 µg/L are considered normal, indicating a low likelihood of significant bacterial infection. Levels between 0.1 and 0.25 µg/L are classified as mild, suggesting a limited or early-stage response. Moderate elevation is defined by values between 0.25 and 0.5 µg/L, which may indicate a developing or localised bacterial infection. Levels greater than 0.5 µg/L are considered severe [6].

STATISTICAL ANALYSIS

The data collected was entered into a Microsoft Excel spreadsheet and analysed using SPSS, Version 20.

RESULTS

A total of 51 participants were included. In present study, most children were between 12 months and 5 years 27 (52.9%) and male 33 (64.7%). The majority presented with fever lasting less than five days and hurried breathing of one day duration. Clinical outcome was favorable in most cases, with 44 (86.3%) patients showing improvement [Table/Fig-2].

Category	Subcategory	Frequency (N=51)	Percentage (%)
Age group	<12 months	24	47.1
	12 months - 5 years	27	52.9
Sex	Female	18	35.3
	Male	33	64.7
Duration of fever	<5 days	46	90.2
	≥5 days	5	9.8
Duration of hurried breathing	1 day	35	68.6
	2 days	14	27.5
	3 days	2	3.9
Outcome	Improved	44	86.3
	Death	7	13.7

[Table/Fig-2]: Demographic, clinical characteristics and outcome of children with CAP.

[Table/Fig-3] shows that the study included 51 participants, with the majority presenting with fever and cough of less than five days duration, respectively. Hurried breathing was most commonly reported for one day. Co-morbidities were absent in 70.6% of cases. Clinical signs like grunt and retraction were observed in 23.5% and 60.8% of participants, respectively.

S. No.	Variables	Category	Frequency (n=51)	Percentage (%)
1	Duration of fever	<5 days	46	90.2%
		≥5 days	5	9.8%
		Total	51	100%
2	Duration of cough	<7 days	43	84.3%
		>7 days	8	15.7%
		Total	51	100%
3	Duration of hurried breathing	1 day	35	68.6%
		2 days	14	27.5%
		3 days	2	3.9%
		Total	51	100%
4	Co-morbidities present	Nil	36	70.6%
		Yes	15	29.4%
		Total	51	100%
5	Grunt	Absent	39	76.5%
		Present	12	23.5%
6	Retraction	Present	31	60.8%
		Absent	20	39.2%

[Table/Fig-3]: Clinical and symptom profile of study participants.

Nearly all children 50 (98%) required oxygen supplementation, reflecting significant respiratory compromise. Among those needing respiratory support, more than half 26 (52%) patients were managed with HFNC, while 7 (14%) patients required mechanical ventilation, indicating severe illness in a subset. Nasal prongs were used in 17 (34%) of cases [Table/Fig-4].

[Table/Fig-5] shows that the AIOS showed a clear trend of clinical improvement over the 5-day period. On Day 1, the majority of children (54.9%) presented with moderate illness, while only 27.5% had mild symptoms. By Day 2, there was a notable shift, with 64% of children categorised as mild and severe cases reducing slightly.

Variables		Frequency (n=51)	Percentages (%)
Oxygen requirement (n=51)	Yes	50	98.0
	No	1	2.0
Respiratory support (n=50)	High Flow Nasal Cannula (HFNC)	26	52
	Ventilation	7	14
	Nasal prongs	17	34
Surgical procedure (n=51)	Yes	5	9.8
	No	46	90.2

[Table/Fig-4]: Distribution of various treatment modalities among children with Community Acquired Pneumonia (CAP).

AIOS scale on day wise		Frequency (n=51)	Percentages (%)
AIOS on Day 1 (n=51)	Mild	14	27.5
	Moderate	28	54.9
	Severe	9	17.6
AIOS on Day 2 (n=50*)	Mild	32	64.0
	Moderate	8	16.0
	Severe	10	20.0
AIOS on Day 5 (n=41**)	Mild	35	85.4
	Moderate	4	9.8
	Severe	2	4.9

[Table/Fig-5]: Distribution of AIOS scale among children with Community Acquired Pneumonia (CAP).
*n is 50 since one death occurred before 2nd day of admission
**n is 41 since six deaths occurred and four children were discharged before 5th day of admission

By Day 5, 85.4% of children had mild scores, and severe cases dropped significantly to just 4.9%, indicating effective management and recovery in most patients.

On Day 1 of admission, the highest proportion of children 18 (35.3%) had PCT levels in Grade IV, indicating a greater severity of infection or systemic inflammation. Grade II and I followed with 12 (23.5%) and 11 (21.6%), respectively, while 10 (19.6%) fell under Grade III. This distribution suggests that a significant number of patients presented with moderate to high PCT levels, supporting the presence of substantial infectious or inflammatory processes [Table/Fig-6].

Procalcitonin (PCT) on Day 1	Frequency (n=51)	Percentage (%)
I	11	21.6
II	12	23.5
III	10	19.6
IV	18	35.3

[Table/Fig-6]: Distribution of Procalcitonin (PCT) grading among children with Community Acquired Pneumonia (CAP).

[Table/Fig-7] shows association between serum PCT level and AIOS on day 1 and day 2 and subjected to statistical test and Fisher's-Exact test was used and p-value was found to be <0.05 and found to be statistically significant and the association between serum PCT level and AIOS on day 5 was found to be not statistically significant.

DISCUSSION

The CAP is a significant contributor to childhood morbidity and mortality, particularly in low-resource settings. The present study investigated the effectiveness of the AIOS and serum PCT levels in assessing the severity and predicting the prognosis of CAP in children aged 2-59 months. The findings support the utility of these clinical tools in early identification of severe illness, appropriate triage, and monitoring therapeutic response.

In this cohort, more than half of the participants (56.4%) were aged 2-12 months. This age group demonstrated higher AIOS scores, consistent with the findings by Chinchu Mariyam C et al., suggesting greater disease severity in younger children [9]. Ratageri VH et al., reported a significantly higher incidence of CAP in infants aged 2-11 months compared to older age groups [10]. This increased susceptibility may be attributed to immature immune defenses, poor mucociliary clearance, and greater exposure to environmental risk factors such as indoor air pollution and poor nutrition [9,10].

Clinical presentations in this study population- fever (90.2%), cough (84.3%), hurried breathing (98.6%), and associated symptoms such as vomiting and poor feeding (31.4%)- highlight the non-specific yet consistent symptomatology of CAP in children [10,11]. Signs of respiratory distress, including elevated respiratory rate (47.1%), retractions (60.78%), grunting (23.5%), and adventitious lung sounds (86.3%), were frequent. These findings align with those from previous studies and reinforce their diagnostic value in routine clinical settings [12,13].

The AIOS score, initially developed by McCarthy et al., which integrates key clinical observations, proved effective in stratifying disease severity and monitoring progress [5]. On day 1, only 27.5% of children had scores <10, increasing to 62.7% on day 2 and 72.5% by day 5. This progressive improvement was statistically significant ($p<0.005$) and indicative of clinical recovery. Aarthy RV et al., similarly reported a significant reduction in AIOS scores over five days, validating its sensitivity in capturing dynamic clinical changes [11]. The ease of application and non-invasive nature of the AIOS tool make it particularly advantageous in primary care and low-resource settings [13].

Serum PCT levels were also found to be strongly correlated with AIOS scores and CRP values on days 1 and 2. Approximately one-third (33.3%) of participants had grade IV PCT levels, suggesting a high burden of bacterial infection and systemic inflammation., who observed elevated PCT levels in children with severe pneumonia. Don M et al., also reported that PCT levels were higher in hospitalised children and those with radiological evidence of alveolar involvement, confirming its value in predicting disease severity [14]. Combining AIOS scoring with PCT measurement can enhance clinical decision-making. In resource-constrained settings, where access to radiology and culture diagnostics may be limited, such dual assessment tools offer a practical and reliable alternative for early triage and risk assessment. Murali BH et al. also emphasised that AIOS, in comparison with IMNCI, provided more nuanced assessments of CAP severity [12].

Furthermore, the current study demonstrated a positive linear relationship between serum PCT and CRP levels (r=0.45), consistent

Serum Procalcitonin (PCT)	AIOS on day 1 (n=51)			AIOS on day 2 (n=50*)			AIOS on day 5 (n=41**)		
	Mild	Moderate	Severe	Mild	Moderate	Severe	Mild	Moderate	Severe
I	6 (54.5%)	3 (27.3%)	2 (18.2%)	9 (81.8%)	3 (9.1%)	1 (9.1%)	9 (81.8%)	1 (9.9%)	1 (8.3%)
II	5 (41.7%)	6 (50.0%)	1 (8.3%)	11 (91.7%)	0	1 (8.3%)	10 (83.3%)	2 (16.7%)	0
III	1 (10.0%)	8 (80.0%)	1 (10.0%)	7 (70.0%)	1 (20.0%)	1 (10.0%)	6 (85.7%)	1 (14.3%)	0
IV	2 (11.1%)	11 (61.1%)	5 (27.8%)	5 (27.8%)	4 (22.2%)	7 (50.0%)	10 (90.9%)	0	1 (9.0%)

[Table/Fig-7]: Association of serum Procalcitonin (PCT) with AIOS on Day 1 and Day 2.
p-value for day 1- 0.021, for day 2- 0.053, for day 5- 0.375; *n is 50 since 1 death occurred before 2nd day of admission; **n is 41 since six deaths occurred and four children were discharged before 5th day of admission.

with the work of Yadav M et al., when using cut-off values of >2 ng/mL for PCT and >50 mg/dL for CRP, PCT exhibited higher specificity (86.4%) compared to CRP (63.6%) while maintaining the same sensitivity (92.9%) [15]. These findings suggest that PCT may serve as a more reliable biomarker in distinguishing between severe and very severe cases of pneumonia [14].

The research links a widely accepted clinical scoring method called AIOS to the objective biomarker PCT for better paediatric pneumonia diagnosis and severity evaluation. The disease progression kinetics became visible through the study's use of multiple day-to-day AIOS score checks, which help validate treatment efficacy. The relationship between AIOS and the well-known bacterial infection biomarker PCT enhances its clinical value for decision-making in medical contexts.

Limitation(s)

The generalisation of research findings becomes difficult because the study took place in only one medical center, and a larger sample size might strengthen the precision and accuracy of the study.

CONCLUSION(S)

Both the AIOS along serum PCT levels demonstrate a strong ability to detect the severity level and determine clinical outcomes in paediatric patients with CAP. Hence, combining the AIOS scoring system with serum PCT levels results in a better clinical decision. The mortality risk increases when patients have high AIOS scores and their PCT levels remain elevated.

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