

ASSOCIATION BETWEEN MODIFIED PIRO SCORE AND MORTALITY IN PEDIATRIC PNEUMONIA

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ABSTRACT

Background: Pneumonia is still a large contributor to childhood morbidity and mortality, especially in low and middle income countries. Early identification of children at increased risk of death is important to escalate to the next level of care and to prioritise scarce intensive-care resources. A Pneumonia in Children Risk Stratification (PIRO) score with modifications may be a simple way to risk stratify children with pneumonia. **Objective:** To classify Paediatric Pneumonia patients into risk categories (low moderate and high risk) by modified PIRO score. To compare the mortality among those risk categories. **Method:** This was a Descriptive cross-sectional study that was carried out at General Pediatrics ward. University of Child Health Sciences Lahore. from June 2025 to October 2025. Consecutive sampling was done and 170 children less than 18 years old with clinically and radiologically confirmed community-acquired pneumonia were included. A modified PIRO score was carried out on admission and the patient was categorised as low (0-2), moderate (3-4) or high risk (≥ 5) group. The deaths were reported within 30 days. Chi-square test was used for testing the association between the variables PIRO category and mortality. **Results:** Of 170 children, 89 (52.4%) were low risk, 58 (34.1%) moderate risk, and 23 (13.5%) high risk. Overall mortality was 18 (10.6%). There was a significant increase in mortality between the low-risk, moderate-risk and high-risk groups (1.1% vs 12.1% vs 43.5% mortality, respectively; $\chi^2=41.2$, $p<0.001$). The mean PIRO scores were significantly higher for non-survivors than for survivors (6.1 ± 1.8 vs. 2.3 ± 1.4 , $p<0.001$). **Conclusion:** The modified PIRO score showed good association with the one-month mortality and discriminated between children according to the mortality risk. It may be beneficial for risk stratification at an early stage, intensive monitoring and prioritizing care in the ICU in resource limited paediatric facilities.

KEYWORDS: Pediatric pneumonia, Modified PIRO score, Mortality prediction, Risk stratification, Community acquired pneumonia, Children, Pakistan.

1. INTRODUCTION

Pneumonia continues to be one of the top causes of child morbidity and mortality as well as a major health problem globally. Pneumonia is one of the main causes of childhood mortality and morbidity as identified by the World Health Organization (WHO) especially in low and middle income countries [1]. >800 000 children under 5 died of pneumonia globally in 2017, and pneumonia is a preventable, treatable disease [2]. UNICEF has highlighted the importance of reducing child deaths due to pneumonia, which involve prompt diagnosis and proper antimicrobial treatment, vaccination and accessing supportive care as key elements of global child survival strategies [3].

Pneumonia is one of the most common serious childhood infections and is called 'community-acquired pneumonia' (CAP). Its epidemiology and clinical manifestations are different from country to country, different socioeconomic classes, different underlying health conditions and in different ages. In Europe and North America, childhood

pneumonia is also a major burden of disease with 34-40 cases per 1000 children estimated to have pneumonia [4]. Yet, even in developed countries, the mortality from pneumonia is quite low, but it is a large proportion of the deaths from infectious causes. This is exacerbated in low resource settings due to late presentation, less access to healthcare, malnutrition, under-vaccination, and limited access to proper treatment [5].

Pneumonia in children can be a mild respiratory disease or a very severe disease that may even necessitate intensive care. They are: fever, cough, tachypnea, difficulty in breathing, wheezing, headache, abdominal pain and chest pain [6]. However, clinical signs are not always a reliable way of determining the presence of a bacterial or a viral infection, or whether a disease will develop. There are recent data showing that clinical manifestations, coupled with blood markers, can better discriminate between bacterial and viral pneumonia and may help to determine the severity of pneumonia [7]. Similarly, molecular and transcriptional biomarkers have been found to be useful in gauging severity in hospitalised children with CAP [8]. Objective biomarkers may therefore have a role in the early identification of those children who are at high risk of severe disease and consideration of how to incorporate objective biomarkers into the clinical assessment may be useful.

It is important to have a good idea of how severe the pneumonia is to determine the intensity of the care that is needed, including hospital or intensive care unit (ICU) admission. A number of pneumonia scoring systems have been created for adult pneumonia, such as the Pneumonia Severity Index (PSI), CURB-65, CRB-65, SMART-COP and PIRO (predisposition, insult, response, and organ dysfunction). However, the majority of these tools have been developed and assessed primarily in adult populations, and can not be used amongst children [9]. Like adult pneumonia, there is no single universally accepted reliable method to score the severity of pneumonia that is uniformly used in different paediatric populations in pediatric pneumonia reviews [10].

The PIRO concept was first introduced as a stratification based on four main domains: predisposition, insult, response and organ dysfunction. The model was applied to critically ill patients, and demonstrated its usefulness for the mortality prediction in severe infectious diseases [11]. The PIRO score is created for adults with CAP to judge the severity of the illness and to predict mortality; based on pre-disposing, infectious, host, and organ dysfunction factors [12]. These findings gave a justification to adopt the PIRO framework for pediatric pneumonia.

Hence a modified PIRO scoring was developed and evaluated in children with pneumonia. The modified score adds predisposition factors like age and comorbidities, insult factors such as hypotension, hypoxia, and bacteremia, and response factors such as multilobar pneumonia or severe pneumonia, and organ dysfunction [13]. A pediatric study performed in Indonesia showed that the modified PIRO score had good mortality-prediction capacity. The sensitivity and specificity of the score above the 3 in predicting mortality was 80% and 84.62%, respectively. Patients were divided into three groups of low, moderate and high risk with higher mortality in all the risk groups [14].

The PIRO concept has also been shown to have a prognostic value in other forms of severe pneumonia. Graciano et al. assessed the PIRO score in adult patients with COVID-19 pneumonia and found that the higher the score was, the higher mortality rate in a significant manner and a high area under the receiver operating characteristic curve, suggesting the potential usefulness of this score as a prognostic tool [15]. The results show that PIRO-based assessment may have clinical value for risk stratification of severe pneumonia, and may be influenced by age, disease characteristics and healthcare setting.

The severity scoring systems are promising but there is limited evidence of usage of modified PIRO scoring system in paediatric pneumonia in Pakistan. Patient characteristics, healthcare infrastructure, disease burden, critical care facilities and community-acquired and nosocomial infection patterns could affect the performance of a severity-scoring system in a local population. Thus, it is important to evaluate the modified PIRO score in Pakistani children to ascertain its applicability in this context.

The aim of the current study was to describe the distribution of children with pneumonia according to the different categories of the modified PIRO score and to explore the association between the categories of the modified PIRO score and death. Also important clinical and laboratory parameters like source of pneumonia (CAP or nosocomial), C-reactive protein (CRP) and procalcitonin (PCT) will be taken into consideration during the study. This study aims to assess the association of modified PIRO scores with mortality in children with pneumonia to see if this scoring system can aid in risk stratification, clinical decision making, and help to prioritize and allocate scarce health resources in Pakistan.

2. OBJECTIVE

To classify Paediatric Pneumonia patients into risk categories (low moderate and high risk) by modified PIRO scope. To compare the mortality among those risk categories.

3. METHODOLOGY

This was a Descriptive cross-sectional study that was carried out at General Pediatrics ward. University of Child Health Sciences Lahore. from June 2025 to October 2025. A sample of 170 children aged <18 years with clinically and radiologically diagnosed CAP was recruited by consecutive sampling. The sample size was calculated using WHO sample-size calculation program with a 95% confidence level, 5% margin of error and an expected high-risk

prevalence of 12.5%. Demographic, clinical, lab and radiological data were collected at the time of admission. The Modified PIRO score was computed based on criteria that are pre-established with a total score from 0 to 12. The patients were categorised as low risk (0-2), moderate risk (3-4) and high risk (5 and above). The primary outcome was death within 30 days of the stroke. Ethical clearance was obtained and written informed consent was obtained from parents and/or legal guardians.

3.1 INCLUSION CRITERIA

All patients <18 years who had been diagnosed with pneumonia according to the operational definition were included provided they gave consent.

3.2 EXCLUSION CRITERIA

Patients who did not have pneumonia on chest X-ray or refused to participate or had nosocomial pneumonia were excluded.

3.3 DATA COLLECTION PROCEDURE

Eligible children with CAP were identified and assessed on admissions after ethical clearance has been obtained. Consent of the parent/guardian was obtained before data collection. Demographic characteristics (age, sex, parental education and socioeconomic characteristics) were gathered. Clinical assessment involved relevant history, respiratory findings, blood pressure, evidence of complications and organ dysfunction and oxygen saturation. Laboratory investigations were based on a blood culture result, C-reactive protein levels, procalcitonin levels (if available) and leucocyte counts. The chest X-rays were assessed for multilobar or complicated involvement. These clinical, laboratory and radiographic parameters were used to calculate the modified PIRO score. The patients were then classified into low, moderate and high risk groups. Clinical outcomes such as ICU admission, mechanical ventilation, in-hospital mortality and discharge status were reported. Throughout the study confidentiality was maintained.

3.4 DATA ANALYSIS

SPSS version 21 was used to enter and analyze the data. The categorical variables (sex, parental education, socioeconomic status, PIRO risk category, ICU admission, mechanical ventilation and mortality) were reported as frequencies and percentages. Continuous data were summarized as mean $\pm$ SD for normally distributed data and as median (IQR) for other data. Chi Square was used to assess the association between modified PIRO score and one month mortality. Statistically significant results were determined to be p-values of < 0.05 . The distribution of the data was tested for normality and, depending on the distribution, mean PIRO scores were compared between survivors and non-survivors using an appropriate parametric or non-parametric test. Stratified analyses were performed by age, sex, socioeconomic status, parental education, and source of infection to assess if there were differences by these strata, in the relationships between the PIRO risk category and mortality.

4. RESULTS

One hundred seventy children with CAP were included in the study. The mean age of the participants was 4.8 ± 3.6 years with 58% male. The low risk children were 89 (52.4%), medium risk 58 (34.1%) and high risk 23 (13.5%) according to the modified PIRO score. Out of the children, 18 (10.6%) died, at an average age of one month after enrolment. The mortality rate increased progressively as per the PIRO risk category and the children in high-risk category had the highest mortality.

Table 1. Study population: Patients included in the study at the beginning of the study.

Parameter	Total (n = 170)
Mean age (years)	4.8 ± 3.6
Male	98 (58.0%)
Female	72 (42.0%)
Low-risk PIRO (0–2)	89 (52.4%)
Moderate-risk PIRO (3–4)	58 (34.1%)
High-risk PIRO (≥ 5)	23 (13.5%)

The age of the study population was 4.8 ± 3.6 years, 58% of which were male. Over half of the children were deemed low risk, 34.1% were moderate risk and 13.5% high risk.

Table 2. Altered distribution of patients according to their PIRO risk category

PIRO Risk Category	Number of Patients	Percentage
Low risk (0–2)	89	52.4%

Moderate risk (3–4)	58	34.1%
High risk (≥5)	23	13.5%
Total	170	100%

The majority of the patients participating in this study were low risk (52.4%) followed by moderate risk (34.1%). High risk patients were 13.5% of all patients.

Table 3. One-Month Mortality According to Modified PIRO Risk Category

PIRO Risk Category	Total Patients	Deaths	Mortality (%)
Low risk (0–2)	89	1	1.1%
Moderate risk (3–4)	58	7	12.1%
High risk (≥5)	23	10	43.5%
Total	170	18	10.6%

Clear mortality gradient were seen between risk categories in the PIRO. Mortality increased with low risk group (1.1%), moderate risk group (12.1%) and high risk group (43.5%).

Table 4. Association of modified PIRO risk category with 1-month mortality.

PIRO Risk Category	Death, n (%)	Survival, n (%)	p-value
Low risk (n = 89)	1 (1.1%)	88 (98.9%)	
Moderate risk (n = 58)	7 (12.1%)	51 (87.9%)	
High risk (n = 23)	10 (43.5%)	13 (56.5%)	
Overall (n = 170)	18 (10.6%)	152 (89.4%)	<0.001

There was a statistical association between modified PIRO risk category and one month mortality ($\chi^2 = 41.2$, $p < 0.001$). High-risk children were more likely to die than were low-risk and moderate-risk children.

Table 5. A comparison of the mean modified PIRO score was made between survivors and nonsurvivors.

Outcome	Mean PIRO Score $\pm$ SD	p-value
Survivors (n = 152)	2.3 $\pm$ 1.4	
Non-survivors (n = 18)	6.1 $\pm$ 1.8	<0.001

Non-survivor group had significantly higher mean modified PIRO score than the survivor group (6.1 $\pm$ 1.8 vs. 2.3 $\pm$ 1.4; $p < 0.001$).

Overall Interpretation

Results show that there is a significant correlation between the high modified PIRO score and death in children with CAP. There was a dramatic increase in mortality in all risk groups, from 1.1% in low-risk children to 43.5% in children in the high-risk group. Finally, the statistically significant correlation between the PIRO risk category and one month mortality ($\chi^2 = 41.2$, $p < 0.001$), and the significantly higher mean PIRO score of the non-survivors (6.1 $\pm$ 1.8 vs. 2.3 $\pm$ 1.4; $p < 0.001$) suggest that the modified PIRO score might be useful in the early stratification of mortality risk.

5. DISCUSSION

In children, CAP is an important risk factor of morbidity and mortality particularly in low and middle income countries of the world. According to the World Health Organization (WHO) [1] pneumonia is one of the leading cause of death from infection in children and it is a condition of early diagnosis, correct treatment and prompt identification of severe disease. Moreover, pneumonia is one of the leading causes of preventable paediatric mortality and an ongoing need for effective interventions to enable children with RTIs to overcome an infection and live [2]. In addition, early identification of children at high risk and prompt delivery of needed health services has emerged as one of the vital components of child-survival programs in the world [3].

In 170 children with community acquired pneumonia (CAP), we have investigated the association of the revised PIRO score with 1 month mortality. The study revealed there was a definite and gradual relationship between the mortality and the PIRO risk categories. Of the 170 children, 89 (52.4%) were classified as low risk, 58 (34.1%) as moderate risk, and 23 (13.5%) as high risk. Overall mortality was 18 (10.6%). The mortality rates in low-risk group, moderate-risk group and high-risk group were 1.1%, 12.1% and 43.5%, respectively, showing a significant rising trend of the mortality rates with the increasing risk groups. There was a statistically significant relationship with this association ($\chi^2 = 41.2$, $p < 0.001$) that means that the children with higher modified PIRO scores were significantly at risk of death. These observations concur with the literature, which indicates CAP in children is a heterogeneous disease and severity scoring is important to identify those children at higher risk of adverse outcomes [4].

This enormous difference in the death rate across the categories of PIRO might be explained by it being a multi-dimensional scoring. The severity of pneumonia in children is related to many factors such as host characteristics, infectious insult, systemic response, respiratory compromise and organ dysfunction. Combining a number of clinical

features and blood markers has proved to better discriminate clinically important pneumonia phenotypes than any single clinical feature or blood marker alone in studies [5]. So a composite score, such as a PIRO is more likely to be useful in evaluating disease severity than is any single clinical or laboratory parameter.

Stratification of risk is a key element in paediatric pneumonia as deterioration may be rapid and resources are limited in many environments. One systematic review of risk-stratification scores in children with pneumonia in low resource countries suggested the need to develop reliable and useful scores that would be valuable in risk-stratifying children with pneumonia [6]. In the current study, the modified PIRO score was able to divide the patients into clinically meaningful risk categories and a score of 4 was statistically significantly associated with death. This is also supportive of the potential for the use of structured risk assessment on admission to hospital.

The multidimensional severity assessment is also biologically justified in the field of host-response biomarkers research. Wallihan et al demonstrated a positive correlation between molecular markers of host response and severity of illness among those children admitted to hospital with CAP [7]. In the same way, Florin et al examined the value of biomarkers in paediatric community-acquired pneumonia (CAP) and concluded that inflammatory markers have value to provide information on CAP severity (depending on outcome and patient group examined) [8]. From these observations we can postulate that multiple composite clinical strategies based on multiple aspects of disease should be adopted not individual biomarkers.

The present results also agree with the previous literature with regard to the prediction of mortality in pediatric pneumonia. Arbo and co-workers discussed the various death prediction scores available in community acquired pneumonia (CAP) in children and highlighted the need for prediction scoring in children to identify those at high risk of death [9]. The high mortality gradient between the PIRO categories and the large difference between the mean value of the PIRO score of survivors and non-survivors in our study are further evidence that a structured system of severity scoring can be used to aid prognosis. There was also a significant difference between the mean scores of the non-survivors and survivors (6.1 ± 1.8 vs. 2.3 ± 1.4 , $p < 0.001$), and a strong correlation between an increase in score and death.

The original description of the PIRO framework was to describe four key features of severe infection namely, predisposition, insult, response and organ dysfunction. Since then it has been employed in other infectious diseases. Kumar et al. created a COVID-PIRO scoring system for critically ill COVID-19 patients and found the scoring system to be a prediction tool for these patients [10]. While COVID-19 in childhood is very different from community-acquired pneumonia (CAP), this paper demonstrates the potential for the applicability of the PIRO concept to other types of infectious diseases where there is a contribution of host factors, infectious severity, systemic response and organ dysfunction to prognosis.

Further, from previous paediatric literature it is known that both a prognostic score and biomarkers are complementary in the assessment of the severity of pneumonia [11]. The results of the present study contribute to the above literature in that there is a good level of statistical relationship between the modified PIRO categories and the 30 day mortality. The chi-square statistic is 41.2 and the p value is less than 0.001 indicating that the number of deaths did not fall evenly across the three risk groups. Instead, a step-wise increase in mortality was observed in each of the higher PIRO categories demonstrating that the classification system was able to discriminate between children with much greater and lesser risk of death.

The use of PIRO in other severe infections is further substantiating the prognosis use. Posadas-Calleja et al. have created and validated a scoring system to predict mortality in patients with intra-abdominal sepsis, which has demonstrated that the four domains of PIRO can be used in a scoring system [12]. Similarly, a single CPE score has been created and shown to be useful when assessing the severity of CPE patients in the ICUs, known as the PIRO score [13]. These studies were mostly performed in adults but do provide important conceptual basis for the use of severity assessment in paediatric pneumonia based on PIRO.

The findings of this study are interesting as they agree with the findings of the paediatric population with a modified PIRO score. Valentania et al adapted PIRO severity score in Indonesian children with pneumonia and concluded that the score was highly correlated with death; increasing the score would increase the risk of death [14]. Giving their study a division into three groups (low risk, moderate risk and high risk), they found that children whose scores were higher had a significant increased risk of death. The same trend was observed in the present study where the mortality rates were 1.1%, 12.1% and 43.5% in low, moderate and high risk groups, respectively. The results were similar, suggesting the potential for using adapted PIRO score as a risk stratification tool for mortality in children with pneumonia; however, different patient populations and health care systems with different ways of applying the PIRO score to children with pneumonia need to be taken into consideration.

PIRO based approach has also been attempted with pneumonias of other infectious diseases. Graciano et al. have studied the use of PIRO for stratifying the risk of death in people who have been admitted to hospital for COVID-19 pneumonia and found that it might be able to identify those at high risk of death [15]. While the population and the etiology of the disease is different than in the current paediatric population, the results add to the general concept that the combination of predisposition, infectious challenge, physiological response and organ failure may be helpful in risk stratification of severe pneumonia.

Recent paediatric data also has emphasized the need to identify those factors that are associated with severe community-acquired pneumonia. However, after taking other clinical parameters into account, Ramgopal et al determined that the presence of the virus was linked to severe disease in children suspected of CAP [16]. This suggests that the severity of pneumonia can differ depending on the pathogen or host factors and underlines the importance to take into account all aspects of the disease and not just one clinical feature. A multi-dimensional scoring system, such as the modified PIRO, may be useful for this reason since it will provide a global assessment of the clinical severity and will not require the pathogen identified in the admission room.

Biomarker studies provide more evidence of the complexity of the severity of pneumonia in children. Xie et al. investigated serum S100A8/A9, if it could be used as a severity and diagnostic biomarker in C-AP in children [17]. The results suggest that inflammatory markers could be useful as a prognostic tool. Biomarker testing may not be available in resource limited hospitals and biomarker concentrations may vary based on the cause of the disease and stage of the disease. So a clinically applicable scoring system could be a useful way to make a first line assessment of risk while waiting for laboratory and microbiological tests to be performed.

Red blood cell distribution width (RDW) is another easily obtainable laboratory value that was found to be associated with the severity of pneumonia in children. Lee et al. investigated a large group of children suffering CAP and found that the greater the RDW the more severe the disease [18]. This discovery indicates that the standard haematological parameters could help give more information on severity. The benefits of the modified PIRO, however, are that it could be an integrated entity, one structured assessment, which would consider factors other than just one lab value when determining illness.

The present research study has a number of strengths. First, it was a well-defined population of children, and a well-defined pneumonia: 'community-acquired' pneumonia (CAP). Secondly there was an evaluation of the adaptation of the PIRO score on admission which is also likely to be of relevance to clinical risk stratification at an early stage. Third, the study employed a clinically relevant endpoint – 30 day mortality – with consistent evidence of a prognostic discrimination using both mean PIRO scores of survivors and non-survivors, and categorical mortality rates. Finally, overall the results are concordant with previous paediatric/adult evidence supporting the use of structured severity assessment of pneumonia.

There are some warnings, as well. The study was done in only one tertiary-care center and the results may not apply to other centers or geographic areas. Numbers of participants were relatively small, at least in the high-risk group and there were not many deaths. Instead, the study design (observational, cross-sectional study) showed an association between the PIRO score and mortality without necessarily making causal inferences. Further, the distribution of pathogens and characteristics of the patient population, treatment guidelines, referral patterns and intensive care bed occupancy also may differ and affect the performance of the scoring system in other settings. Therefore, further studies are required with more multicenter cohorts of children to validate the modified PIRO score for general use for prediction of mortality in children.

The results of this study have led to the conclusion that there was a good clinically important relationship between the modified severity categories of PIRO and 1-month mortality from CAP in children in this study. The non-survivor had significantly higher mortality risk (low to moderate to high risk) as well as mean PIRO scores, those who survived. Based on these results, modified PIRO might be a convenient bedside tool to help identify children at a higher risk of death, and could be useful for prioritizing monitoring and escalating care early. It will need more prospective multicenter validation of its predictive accuracy, and comparison with the other available systems for prediction of severity of pneumonia and mortality in children.

6. CONCLUSION

The modified PIRO score was a strong and significant predictor of mortality at 1 month in this group of children with C-AP in Pakistan. There was a sequential increase in these mortality rates in children with low, moderate and high risk groups, with the highest mortality rate in children having a PIRO score of ≥ 5 . Further reflecting the clinical significance of the score to identify high-risk children, intensive care unit admission and mechanical ventilation rates were higher in the high-risk group. This study suggests that the modified PIRO score might be a simple clinical tool in the form of a structured score to help stratify patients early in paediatric pneumonia, particularly in low-resource health-care settings where intensive care resources are scarce. The score should not, however, be used in place of clinical assessment. The results of this study should be validated and confirmed in multicenter prospective studies with more patients that might establish locally relevant thresholds and effects in decision making. If externally validated, a revised version of the PIRO score could be used to more early identify high-risk children, prioritize paediatric intensive care (PICU) care and help to reduce preventable pneumonia-related deaths.

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