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# Diagnostic and predictive value of Respiratory Index of Severity in Children (RISC) scoring system in community-acquired pneumonia: a prospective cross sectional study

Mohamed Abdallah Abd El Megied[1*], Mohammad Abdel Fattah Abdel Motey[1], Miriam Magdy Aziz[1] and Mohammed Mohammedy Ebrahim[2]

## Abstract

**Background** Community-acquired pneumonia (CAP) exhibits high mortality rates among children, accounting for up to 50% in severe cases.

Respiratory Index of Severity in Children (RISC) score is a six-predictor standardized means for assessment of the severity of respiratory illness among children. The aim of this study was to validate the RISC score in evaluation of mortality outcome in hospitalized infants diagnosed with CAP.

**Methods** This prospective cross-sectional study was conducted on 150 Egyptian children who were diagnosed to have CAP, admitted to the general wards and pediatric intensive care units (PICUs) of Cairo University Children Hospital, Faculty of Medicine, Cairo University from September 2019 to June 2020.

**Results** Median RISC score was significantly higher in non-survivors compared with survivors ($p < 0.001$). There were significant direct correlations between RISC score and each of respiratory distress grade, C-reactive protein (CRP), PICU admission, mechanical ventilation (MV) and mortality ($p < 0.05$). The RISC score, assessed within 24 h of admission, had sensitivity of 85.71%, and specificity 89.51% in discriminating infants with CAP who survived from those who died (determined at a cut off > 3). The RISC score was a significant predictor for mortality in infants with CAP (Odds ratio = 5.17, $p < 0.001$).

**Conclusion** The RISC score helps in prediction of mortality among children with CAP. Future studies are needed to validate RISC score as a guide for effective management protocol.

**Keywords** Community-acquired pneumonia, Infants, Respiratory index of severity in children

## Background

Community-acquired pneumonia (CAP) is defined as an opacity that is consistent with the presence of acute pneumonia on chest radiographs (CXR) and is associated with respiratory symptoms in a previously healthy person who caught an infection outside the hospital, with lack of an alternative diagnosis [1]. CAP exhibits high mortality rates, up to 50% in severe cases.

The main risk factors for CAP include prematurity, age < one year, malnutrition, lack of breast feeding,

*Correspondence:
Mohamed Abdallah Abd El Megied
mohamed.abdallah@cu.edu.eg; mohnd8910@hotmail.com
[1] Department of Pediatrics, Faculty of Medicine, Cairo University, Cairo, Egypt
[2] Ministry of Health and Population, Cairo, Egypt

immunosuppression, overcrowding, passive tobacco exposure, exposure to indoor air pollution, winter season, and HIV infection [2]. Co-existing illnesses such as diarrhea and malaria are also important contributing factors to the increased CAP burden of disease in underdeveloped countries [3].

Management of CAP in children includes assessment of the severity of disease, and in many settings around the world, this relies mainly on clinical symptoms, signs and radiological results [4].

Inappropriate treatment of outpatients or delay of admission of CAP patients to ICU is associated with increased mortality [5]. Specific discrimination of children with CAP based on their risk of mortality outcome may help refine decisions about case management, such as the most appropriate site of treatment or the need for additional supportive care. Few similar methods have been developed to quantify the severity of pediatric pneumonia [6].

A simple pediatric severity score could aid predicting the probability of mortality outcome in a child who presents with CAP. One of these scores is the Respiratory Index of Severity in Children (RISC) which was developed in an attempt to predict the probability of mortality in a young child with lower respiratory tract infection (LRTI) [7].

The reviewed literature revealed that RISC was examined on south African infants presented with lower respiratory tract infection [7]. No study was conducted on Egyptian infants with CAP, specifically. In addition, one recent study [8] studied children under five (2 to 59 months) hospitalized due to severe CAP. We were interested in investigating infants with CAP, in particular, as they constitute the high percentage of mortality, and because this age group is the appropriate age of taking vaccines intended to protect against respiratory tract infections (as pneumococcal vaccine).

Moreover, in spite of the presence of guidelines targeting proper management of pneumonia among children, significant mortality exists. This indicates the presence of hidden factors that require further investigation. From this point, this study was conducted to examine the diagnostic and predictive capabilities of RISC in infants with CAP, in particular with the hope of reducing the mortality among this age group. We hypothesized that RISC would have good diagnostic and predictive capabilities in infants with CAP.

## Methods

### Study setting

This prospective cross-sectional study was conducted on 150 Egyptian children who were diagnosed to have CAP. They were admitted to the general wards and pediatric intensive care units (PICUs) of Cairo University Children Hospital, Faculty of Medicine, Cairo University from September 2019 to June 2020.

### Study population

The inclusion criteria specified for the study involved Egyptian children aged 1–24 months, hospitalized with diagnosis of CAP confirmed by chest X-ray. Criteria of diagnosis of CAP were set according to CAP definition [1]. Patients were excluded if they had congenital heart disease, or immunodeficiency disorders, refused to participate in the study, or died within 24 h of admission.

### Procedure

After taking informed consent, detailed child history was taken. This involved age, gender, residence, history of fever, wet cough, hemoptysis, shortness of breath, exposure to a source of infection, investigations and treatment given, and any complications.

Patients were physically examined. This included both general examination (level of consciousness, presence of cyanosis, temperature, heart rate, respiratory rate and grade of respiratory distress if present) and local chest examination. The chest shape, respiratory movements were inspected. The chest movements and trachea were palpated. Percussion for dullness or hyperresonance and auscultation for air entry, type of breathing, rhonchi and crepitations were carried out.

Laboratory investigations were carried out. These involved Complete blood count (CBC), total and differential leukocytic count, erythrocytic sedimentation rate (ESR), quantitative C-reactive protein (CRP). Blood and sputum cultures (obtained either by mini-BAL in mechanically ventilated infants or morning gastric aspirate in non-mechanically ventilated infants) were performed before initiation of the antimicrobial therapy.

Plain chest X-ray (posteroanterior and lateral views) were performed for all enrolled patients. CXR scoring was done by a single radiologist, as per the WHO interpretation of chest radiographs (Table 1) [9].

### The Respiratory Index of Severity in Children (RISC) score

The RISC score is a six-predictor standardized means for assessment of the severity of respiratory illness among children. The previously validated RISC score [7] was applied to all candidates within 24 h of admission to hospital (Table 2). Variables in the RISC score (hypoxia, chest indrawing, feed refusal, wheeze, malnutrition, age). Represent known risk factors for severe outcomes of pneumonia in children, with a maximum score of 6 points.

**Table 1** Radiological diagnosis of pneumonia in pediatrics

| |
|---|
| **Lober pneumonia** |
| Non-segmental, homogenous consolidation predominantly involving one lobe with air bronchograms (large bronchi remain patent and air filled in contrast to the adjacent non-aerated lung |
| **Bronchopneumonia** |
| Mild disease can manifest as peribronchial thickening and poorly defined air-space opacities; inhomogeneous patchy areas of consolidation involving several lobes reflect more severe disease |
| **Interstitial pneumonia** |
| Oedema and cellular infiltrates predominantly involving the interstitial tissue of the alveolar septa and surrounding small airways and vessels |

(Cherian et al., 2005) [9]

**Table 2** Respiratory Index of Severity in Children (RISC) scoring system

| **Severity of respiratory signs on physical exam:** | **If O2 ≤ 90%** | **3 Points** |
|---|---|---|
| 1. Oxygen Saturation = …% | Else | |
| 2. Does the child have chest indrawing? Yes/ No | Indrawing | 2 Points |
| 3. Does the child have wheezing? Yes/ No | Wheezing | -2 Points |
| 4. Does the child refuse feeding? Yes/ No | Refusal to feed | 1 Point |
| **Growth standards:** | | |
| 5. Weight for age z-score | Z ≤ -3 | 2 Points |
| | -2 ≤ Z < -3 | 1 Point |
| | Z > -2 | 0 Point |
| | Total points | |
| | Maximum | 6 Points |

(Reed et al., 2012) [7]

**Table 3** Frequency distribution of blood and sputum culture in infants with community acquired pneumonia

| | **Number of patients** | **Percent (%)** |
|---|---|---|
| **Blood culture** | | |
| No growth | 57 | 38 |
| E. coli | 1 | 0.67 |
| Not done | 92 | 61.33 |
| **Sputum culture** | | |
| No growth | 114 | 76 |
| E. coli | 1 | 0.67 |
| Pneumococci | 1 | 0.67 |
| Staph aureus | 3 | 2 |
| Not done | 31 | 20.66 |

### Data management and statistical analysis

Data involving participant history, basic clinical examination, laboratory investigations and outcome measures were collected, coded and analyzed. Data were first tested for normality with Kolmogorov–Smirnov test. They were found not to be normally distributed. Accordingly, nonparametric statistical tests were employed for analysis. Frequency distribution, percentage distribution, means ± standard deviation, chi-square test, Spearman's correlation, and logistic regression as well as receiver operating characteristic (ROC) analysis were conducted. *P*-values less than 0.05 were considered significant. Confidence intervals (95% CI) were calculated when appropriate. Statistical Package for the Social Sciences (SPSS version 20) software was used for analysis.

## Results

The enrolled patients involved 83 (55.33%) males and 67 (44.67%) females with male to female ratio 1.23:1, with a mean age of 7.2 ± 5.087 months. Thirty-four (22.67%) patients were living in rural regions, while the remaining 116 (77.33%) were living in the urban regions. General and systematic examinations were performed for all included patients. They revealed that the mean values for temperature, heart rate, and respiratory rate were 38.5 ± 0.8 $^{0}$C, 134 ± 15.8 beat/min, and 46.7 ± 10.4 breath/min, respectively. Cough and expectoration were present in 145 (96.67%), 103 (68.67%) patients respectively. Regarding the grades of respiratory distress, grade 'I'(tachypnea), 'II'(tachypnea & retraction) were recorded in 88 (58.67%), 22 (14.67), respectively; however, grade 'III'(tachypnea, retraction & grunting) and 'IV'(tachypnea, retraction, grunting & cyanosis) were recorded in 24 (16%), and 16 (10.67%) patients, respectively.

The radiological diagnosis of the enrolled patients were bronchopneumonia, interstitial pneumonia, and lobar pneumonia in 41 (27.33%), 75 (50%), and 34 (22.67%) patients, respectively. The mean value for hemoglobin, total leucocytic count, and C-reactive protein were 9.95 g/dl ± 1.3, 9.2 $10^{3}$/cmm ± 6.1, and 29.9 md/dl ± 27.1, respectively. Table 3 presents the results of blood and sputum cultures of the studied patients.

Throughout the study, 42 (28%) of the 150 patients were admitted to PICUs either due to initial severe respiratory distress or worsening of the respiratory condition.

**Table 4** Frequency distribution of RISC score and mortality in infants with community acquired pneumonia

| RISC score | Number of patients | Percentage (%) | Number of non-survivors | Percentage (%) |
|---|---|---|---|---|
| 0 | 27 | 18 | 0 | 0 |
| 1 | 23 | 15.33 | 0 | 0 |
| 2 | 50 | 33.33 | 0 | 0 |
| 3 | 29 | 19.33 | 1 | 0.67 |
| 4 | 14 | 9.33 | 2 | 1.33 |
| 5 | 4 | 2.67 | 2 | 1.33 |
| 6 | 3 | 2 | 2 | 1.33 |
| Total | 150 | | 7 | 4.67 |

*RISC* Respiratory index of severity in children

**Table 5** Comparison between survivors and non-survivors for demographic data and clinical course

| | Survivors (143) | Non-survivors (7) | *p*-value |
|---|---|---|---|
| **Residence** (Urban/Rural) | 114/29 | 2/5 | 0.006 |
| **Respiratory distress** (I&II / III&IV) | 110/33 | 0/7 | < 0.001 |
| **RISC score** (Median) | 2 | 5 | < 0.001 |
| **PICU admission** (Yes/ No) | 35/108 | 7/0 | < 0.001 |
| **Mechanical ventilation**(Yes/ No) | 19/124 | 7/0 | < 0.001 |

*RISC* Respiratory index of severity in children, *PICU* Pediatric intensive care

Of the 42 patients who were admitted to PICUs, 28 (66.6%) required mechanical ventilation (MV). Of the 150 patients enrolled in this study, seven patients (4.67%) died. The recorded RISC score and mortality in the studied patients are demonstrated in Table 4.

Survivors and non-survivors were compared as regard to the demographic, clinical, laboratory, need for PICU admission, and need for mechanical ventilation. Significant differences were demonstrated in Table 5.

Spearman's correlation coefficient test was performed. It revealed that there were significant positive correlations between RISC score and each of respiratory distress grade, CRP, PICU admission, mechanical ventilation and mortality (Table 6).

Regarding the discrimination performance of RISC score in infants with CAP, the receiver operating characteristic (ROC) curve showed that RISC score had a high sensitivity of 85.71%, and high specificity 89.51% in discriminating infants who survived from those who died with CAP (determined at a cut off > 3). Figure 1 presents the ROC curve.

Multivariate logistic regression test was performed for prediction of mortality in infants with CAP. Age, respiratory rate, CRP, and RISC score were used as predictors. Logistic regression revealed that RISC score was a significant predictor for mortality in infants with CAP (Odds ratio = 5.17, $p < 0.001$). Table 7 shows the above finding.

## Discussion

Males constituted 55.3% of the cases compared with females who constituted 44.7%. This male predominance agrees with what was reported by Musher and Thorner [10]. Farha and Thomson [11] assessed the risk factors of childhood pneumonia in the developing world, and

**Table 6** Spearman's correlation between RISC and laboratory/clinical data in infants with community acquired pneumonia

| | RISC | Age | RD | HR | TLC | PICU | MV |
|---|---|---|---|---|---|---|---|
| RD | $r = 0.64^*$ $p = 0.001$ | | | | | | |
| HR | | $r = -0.61^*$ $p = 0.001$ | | | | | |
| RR | | $r = -0.82^*$ $p = 0.001$ | | $r = 0.54^*$ $p = 0.001$ | | | |
| HB(%) | | $r = 0.2^*$ $p = 0.016$ | | | | | |
| CRP | $r = 0.17^*$ $p = 0.04$ | | | $r = 0.18^*$ $p = 0.02$ | $r = 0.38^*$ $p = 0.001$ | | |
| PICU | $r = 0.7^*$ $p = 0.001$ | | $r = 0.87^*$ $p = 0.001$ | | | | |
| MV | $r = 0.6^*$ $p = 0.001$ | | $r = 0.7^*$ $p = 0.001$ | | | $r = 0.73^*$ $p = 0.001$ | |
| Mortality | $r = 0.34^*$ $p = 0.001$ | | $r = 0.34^*$ $p = 0.001$ | | | $r = 0.36^*$ $p = 0.001$ | $r = 0.48^*$ $p = 0.001$ |

* Significant at $p < 0.05$, *r* correlation coefficient

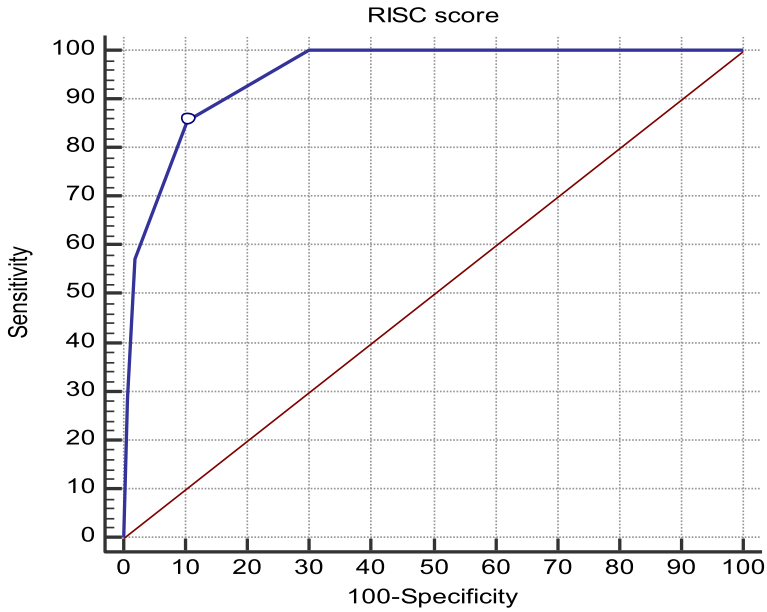


**Fig. 1** Receiver operating characteristic (ROC) curve of RISC score

**Table 7** Logistic regression of mortality prediction in infants with community acquired pneumonia

| Predictor | Odds ratio | 95% confidence interval | *p*-value |
|---|---|---|---|
| Age | 0.92 | 0.68–1.24 | 0.6 |
| Respiratory rate | 0.96 | 0.83–1.12 | 0.67 |
| CRP | 1 | 0.97–1.04 | 0.69 |
| RISC score | 5.17 | 2.13–12.52 | <0.001* |

* Significant at $p<0.05$

found that there was strong male predominance in those aged less than 5 years.

Cough was present in 96.76% of patients. This finding is consistent with Jain et al. [12] finding. They conducted a multicenter population-based study, on 2358 children hospitalized with radiographic evidence of pneumonia. They found that 95% of them had cough while expectoration was found in 68.67% of their participants.

Unfortunately, blood culture was available for 38.67% of our sample only, and missed in 61.33%. Of those who underwent blood culture, 98.27% showed no growth, while 1.73% showed positive results. This agrees with Youssef et al. [13] findings that revealed that 1.3% only of their blood cultures was positive. The sample was positive for E. coli. Our findings disagree with Mathew et al. [14] findings. The latter found that 30.6% of their blood culture demonstrated S. aureus, 20.4% S. pneumoniae, and 12.2% Klebsiella pneumoniae.

About 79.7% of our cases underwent sputum culture to delineate the causative organism. No growth was found in 95.8% of samples while 4.2% yielded positive results. The detected bacteria in sputum culture were Staphylococcus aureus (2.5%), Pneumococci and E. coli. Our findings did not agree with Shu et al. [15] findings. The latter examined children with CAP, and found that 65.63% of their study sample were positive. The top three dominant pathogens were Mycoplasma pneumoniae (43.64%), bacteria (15.12%), and respiratory syncytial virus (9.26%), and the rate of mixed infection was 16.02%. It appears that the difference between both studies is attributable to differences in age of children, antibiotic used, culture types, and detection techniques.

The mortality in our study was found to be 4.67%. McAllister et al. [16] found that the mortality rate among hospitalized children < 5 years in resource-limited countries ranged from 0.3% to 15%. The relatively low mortality rate may be due to excluding children with comorbidities. The mortality that occurred in our study is suggested to be related to respiratory failure related to pneumonia and/or other confounding factors, other than congenital heart disease, or immunodeficiency disorders as both disorders were excluded from the study. Further studies are required to elucidate these confounding factors.

Compared with that of Kapoor et al. [8], our mortality percentage was found to be less (4.67% vs 9.4%). This might be attributed to the different age group, and residency. They examined children up to five years old; however, we examined infants only (up to two years old). Moreover, they found that the mortality was higher in

children who lived in rural areas, whereas most of our sample were urban.

Respiratory distress was significantly higher in non-survivors compared with survivors. This is consistent with the study conducted by Nascimento-Carvalho [17]. They reported that hypoxemia and grunting are predictors of mortality in pediatric CAP. On the other hand, Lazzerini et al. [18] concluded that hypoxemia is a mortality risk factor in pediatric lower respiratory tract infections.

Our results showed that CRP was not a significant predictor of mortality, similar to what was reported by Pierrakos and Vincent [10]. They found that white blood cell count and CRP levels were not reliable predictors for assessing disease severity and mortality risk. The maximum RISC score (6 points) was found in about 2% of our participants, and 1.4% of Reed et al. [7] participants. Meanwhile, the minimum score (0 point) was found in about 18% of our participants, and 46.7% of Reed et al. [7] participants.

The current study revealed that the RISC score was higher in the non-survivors compared with survivors. This is consistent with Reed et. [7] finding. The high-risk score ($\geq 4$) was found in 14% of our participants and 11% of Reed et al. [7] participants. The high-risk participants accounted for 25% of our study mortalities, and 29.9% of Reed et al. [7] study mortalities.

Our study was one of the few studies that was conducted on children with CAP for evaluating RISC score as a scoring system for predicting mortality. This study focused on assessment of children admitted with lower respiratory tract infections age 1–24 months. The patients were followed up during the study duration and the observed outcomes (death, and need for ICU admission or mechanical ventilation) were compared with the predicted outcomes based on the RISC score. RISC score had a high sensitivity of 85.71% and a high specificity of 89.51% in discriminating infants who survived from those who died with CAP. Based on the reviewed literature, no evidence of the prevalence of CAP in Egypt was reported. Accordingly, the positive and negative predictive values were not calculated for our patients.

Comparing our ROC curve with that of Kapoor et al. [8], our study showed higher area under the curve, lower sensitivity, and higher specificity for mortality. Our area was 0.95 vs 0.91, sensitivity 85.7% vs 94.1%, and specificity 89.5% vs 73.6%. This indicates that our RISC score has better diagnostic performance.

Regarding mortality prediction, we found that RISC score was a significant predictor for mortality in infants with CAP (Odds ratio = 5.17, $p < 0.001$). Our study found that the RISC score is a good predictor of mortality in children hospitalized with CAP as found by other studies [6, 19].

As opposed to Kapoor et al. [8], we didn't find neither the respiratory rate nor the CRP to be significant predictors of mortality. They examined advanced stages of CAP (severe), in contrast to our study that examined variable stages of the disease. Thus, they had higher values for the respiratory rate and CRP.

Based on our findings, our hypothesis is accepted as RISC was found to have high sensitivity and specificity in discriminating infants who survived from those who died with CAP, in addition to being a significant predictor for mortality. It is recommended to apply RISC score within 24 h of patient admission with sequential daily application to determine patient progress, and predict mortality. In presence of high RISC score, it is highly recommended to optimize various aspects of the management plan; investigations (cultures), nonspecific supportive therapy (as mechanical ventilation), and specific therapy (as culture and sensitivity based antimicrobial therapy) from the first hours of admission. It worth implementing the RISC score on a wide scale especially in resource-limited countries to gain its benefit. It is recommended to repeat this study on different age groups within the pediatric population. The RISC score is highly recommended to be evaluated in the presence of other types of pneumonia (as ventilator associated pneumonia) and co-morbidities.

## Conclusion

In infants with CAP, the RISC score is significantly higher in non-survivors compared with survivors. The RISC score has high sensitivity (85.71%) and specificity (89.51%) in discriminating infants with CAP who survived from those who died. The RISC score is a significant predictor for mortality in infants with CAP with an odds ratio of 5.17. RISC score could identify high-risk children for targeted aggressive management to prevent adverse outcomes.

### Abbreviations

| | |
|---|---|
| CAP | Community-acquired pneumonia |
| RISC | Respiratory Index of Severity in Children |
| PICUs | Pediatric intensive care units |
| CRP | C-reactive protein |
| MV | Mechanical ventilation |
| CXR | Chest radiographs |
| LRTI | Lower respiratory tract infection |
| CBC | Complete blood count |
| ESR | Erythrocytic sedimentation rate |
| ROC | Receiver operating characteristic |
| CI | Confidence intervals |
| SPSS | Statistical Package for the Social Sciences |

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**Authors' contributions**
MAA drafted the work and revised it, being the major contributor in writing the manuscript. MAF made substantial contribution to the concept and design of the work and interpretation of data. MMA contributed to data interpretation. MME contributed to data acquisition. All authors read and approved the final manuscript. Each agreed both to be personally accountable for the author's own contributions and ensured that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

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**Availability of data and materials**
All data are available upon request.

## Declarations

**Ethics approval and consent to participate**
This study was approved by the Institutional Ethical Review Board, Faculty of Medicine, Cairo University, Approval number: MS 35–2020.

**Consent for publication**
Not applicable (no individual details, images or videos).

**Competing interests**
The authors declare that they have no competing interests.

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## Publisher's Note