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Research Article

COMPARISON OF PEDIATRIC INDEX OF MORTALITY (PIM)-3 AND PEDIATRIC SEQUENTIAL ORGAN FAILURE ASSESSMENT (pSOFA) SCORES TO PREDICT MORTALITY IN PEDIATRIC INTENSIVE CARE UNIT

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ABSTRACT

Objective: The objective of the study is to evaluate and compare the pediatric index of mortality (PIM)-3 and pediatric sequential organ failure assessment (pSOFA) scores to predict mortality in pediatric intensive care unit (PICU).

Methods: This cross-sectional study was conducted prospectively in PICU over 1 year. All consecutive patients admitted to the PICU aged 1 month to 12 years on designated study days were enrolled in the study (n=400). Mortality scores were calculated on the same day of admission using an Android calculator application.

Results: The mean PIM-3 score in the non-survivor group (n=48) was higher, i.e., −0.81 (−2.05 to −0.44) than in the survivor group (n=352), i.e., −4.67 (−5.83 to −4.05) with p<0.001. The pSOFA score was also found higher in the non-survivor group, i.e., 11 interquartile range (IQR) (8–11) as compared to the survivor group, i.e., 3 IQR (2–5) with statistically significant difference (p<0.001). The median value of sensitivity and specificity for PIM-3 was reported to be 97.46% and 86.67%, respectively. The median value of sensitivity and specificity for pSOFA was 97.72% and 85.11%, respectively. The area under-receiver operating characteristic (AU-ROC) 0.9145 (95% confidence interval [CI]: 0.8595–0.9695) for the PIM-3 was almost equal to the AU-ROC of pSOFA score, i.e., 0.9554 (95% CI: 0.918–0.992). Both scores were positively associated with each other (r=0.807, <0.0001)

Conclusion: Both PIM-3 and pSOFA scores were effective in predicting mortality in critically ill children.

Keywords: Pediatric index of mortality-3, Pediatric sequential organ failure assessment, Pediatric intensive care unit, Mortality scores.

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INTRODUCTION

The care of critically ill children remains one of the most demanding and challenging aspects in the field of pediatrics. The pediatric intensive care unit (PICU) aims at promoting early intervention and quality care with the objective of achieving good results and better prognosis. It is a fast-paced and special area in the hospital designed to provide care to critically ill children through a multidisciplinary approach [1]. Evaluation of the outcome of medical interventions can assess the efficacy of treatment and this helps in better decision-making, improving quality of care, and modifying the future management if required [2].

Several prognostic scores have been developed with the aim of objectively quantifying the severity of disease and predicting the risk of death at the time of PICU admission, which can be very useful in treatment planning and assessing the quality of care provided in PICU [3,4].

There are different mortality prediction scores available to predict mortality in PICU. These include the pediatric index of mortality (PIM) and its updated models, pediatric sequential organ failure assessment (pSOFA), pediatric risk of mortality (PRISM) and its updated models, pediatric multiple organ dysfunction score, pediatric logistic organ dysfunction score-2, etc. These scores are mathematical models, developed presuming a predictable relationship among various factors related to the severity of illness, physiologic alterations, patient characteristics, and risk of mortality. PIM-3 is one such score which is inexpensive and comprised of routine laboratory variables performed in PICU patients. It is an updated model, built using a larger dataset which improves the generalizability of the model to the population [3]. It uses data collected within the 1st h of admission. Recently, a pediatric version of the SOFA score, i.e., (pSOFA) was developed and validated retrospectively in critically ill children [5]. It was designed by adapting the original SOFA score with age-adjusted cutoffs for the cardiovascular and renal systems and by expanding the respiratory criteria to include non-invasive surrogates of lung injury. However, there are limited studies conducted to validate this score on a larger population, prospectively.

There are limited studies on mortality-predicting scores reported from developing countries. Moreover, none of the studies compared these two scores, so the aim of our study is to evaluate and compare PIM-3 and pSOFA scores to predict mortality in PICU patients.

Objectives

The objective of the study is to evaluate and compare PIM-3 and pSOFA scores to predict mortality in PICU.

METHODS

This cross-sectional study was conducted prospectively at a tertiary care PICU after obtaining approval from the institutional ethical committee. Patients ranging from 1 month to 12 years of age admitted to the PICU during the study period of 12 months (from 1st April 2020 to 31st March 2021) were enrolled in the study, after taking informed consent from parents/guardians of the child. Patients who died within 24 h of admission were excluded. Data were collected in the

pre-designed and pre-tested pro forma, which included demographic profile (age, gender, etc.), clinical features, laboratory investigations, diagnosis, and outcome.

In the nutritional status of children from 1 month to 5 years, severe acute malnutrition was defined according to the World Health Organization criteria [6]. For >5-year age patients, undernutrition is defined as BMI <3rd centile according to the IAP growth chart.

After that, two mortality prediction scores for PIM-3 and pSOFA were calculated through android score calculator application and used for predicting mortality in these cases. The outcome of the patient was noted as discharge or death.

Statistical analysis

Data were compiled using MS Excel and analyzed using IBM SPSS software version 20. Demographic variables were reported as counts and percentages or median and interquartile ranges. The Chi-squared (χ^2) test was used to determine statistically significant differences. Student t-test was used for categorical data. A $p<0.05$ was considered statistically significant. The performance of pSOFA and PIM-3 was assessed by discrimination. The sensitivity, specificity, and accuracy of the scores were calculated using two-by-two tables.

Discrimination is the ability of a model to distinguish accurately between survivors and non-survivors. Mortality discrimination was assessed using the area under the receiver operating characteristic (AU-ROC) curves. We defined acceptable discrimination as an AU-ROC between 0.70 and 0.79 and good discrimination as ≥0.80.

OBSERVATION AND RESULTS

Out of 400 patients, 352 survived and 48 patients (12%) died. The median age of the study group was 24 months. Fifty-six percent of patients were male. The most common underlying cause for PICU admission was found to be neurological (34%), followed by respiratory (20.3%), sepsis (15%), cardiovascular (12%), and others (18.7%). We observed that 157 patients (39.2%) belonged to <1 year of age group, 132 (33%) belonged to age group 1–5 years, 84 participants (21%) belonged to 5–10 years of age, and 27 (6.8%) of the patients belonged to the age group >10 years. The majority of mortality was seen in the central nervous system (29%) followed by the cardiovascular system (17%). Both infections and respiratory illnesses showed 15% mortality. Baseline demographic characteristics of the study population are depicted in Table 1. The PIM-3 score in the non-survivor group was −0.81 (−2.05, −0.44), and in the survivor group, it was reported to be −4.67 (−5.83, −4.05). This difference was found to be statistically significant with a $p<0.001$ and was higher in non-survivors in comparison to survivors. The pSOFA score in the non-survivor group was 11.0 interquartile range (IQR) (8.0, 11.0) and in the survivor group, it was observed at 3.0 IQR (2.0, 5.0). This difference was found to be statistically significant with a p-value (Table 1): Demographic and clinical characteristics of the study of <0.001 and similarly, it was also significantly high among non-survivors (Table 2) The AUC (area under the curve) score based on ROC curves and different performances values for ROC analysis for both score were calculated and reported in Table 2 and Fig. 1. In ROC analysis, the AUC for the PIM-3 score and pSOFA score were obtained to be 0.914 (95% CI: 0.882–0.940, $p<0.0001$) and 0.955 (95% CI: 0.930–0.973, $p<0.0001$), respectively, and had statistically significant difference with $p=0.0335$. For the assessment of predicted mortality at the respective cut-off value of PIM-3 ≥2.11, the sensitivity, specificity, +LR, −LR, PPV, NPV, and accuracy were 97.46% (95.23–98.83), 86.67% (73.21–94.95), 7.31 (3.47–15.40), 0.03 (0.02–0.06), 98.29% (96.47–99.18), 81.25% (69.24–89.30), and 96.23%, respectively. Whereas at the cut-off value of pSOFA score >7, the sensitivity, specificity, +LR, −LR, PPV, NPV, and accuracy were 97.72% (95.56–99.01), 85.11% (71.69–93.80), 6.56 (3.31–13.00), 0.03, (0.01–0.05), 98.0% (96.11–98.98), 83.33% (71.38–90.93), and 96.24%, respectively (Table 2). We also observed that the PIM-3 score and pSOFA scores were positively associated with each other (r=0.807, <0.0001) while no statistically significant correlation was found between PIM-3 and pSOFA scores with duration of hospital stay (Table 3).

DISCUSSION

Scoring systems assist health-care personnel to decide a patient's prognosis and support the decision-making steps as well as the patient's outcome. The ideal mortality prediction score must be simple, accurate, inexpensive, easy to use, and minimally invasive. To design and develop the optimal scoring approach for seriously sick children admitted to the PICU, is not a simple task [7]. Various strategies are used in PICUs for the prediction of the severity of illness and mortality risk, however, no pediatric mortality prediction score is completely satisfactory at present, and therefore researchers continue to devote significant effort to improve the accuracy of currently available scores and developing new ones [8]. In our study, we found both PIM-3 and pSOFA scores are good predictors of mortality. pSOFA score is ahead in ROC analysis showed with an AUC value of 0.9554 which is slightly higher than the AUC value of 0.9145 for PIM-3. A study done by Straney *et al*. in an international (Australia, New Zealand, Ireland, and the United Kingdom) multicenter, prospective cohort study of 53,112 children, evaluated the predictive ability of PIM-3 for mortality risk

Table 1: Demographic and clinical characteristics of the study population

Variable	Total, n (%)	Survivors, n (%)	Nonsurvivors, n (%)	p-value
Age (months)				
1–12	157 (39.2)	136 (86.6)	21 (13.4)	0.69
12–59	132 (33)	118 (89.4)	14 (10.6)	
60–119	84 (21)	74 (88)	10 (11.9)	
120–144	27 (6.8)	24 (88.9)	3 (11.1)	
Gender				
Male	225 (56.2)	193 (85.8)	32 (14.2)	0.07
Female	175 (43.8)	159 (90.8)	16 (9.2)	
Nutritional status				
Normal	325 (81)	304 (92.6)	30 (7.4)	<0.001
SAM	50 (12.5)	29 (78)	11 (22)	
Undernutrition	26 (6.5)	19 (74)	7 (26)	
Treatment				
Inotrops	71	33 (47)	38 (53)	<0.001
O^2 by face mask	216 (79.4)	198 (87.6)	18 (39.1)	<0.001
Ventilator CPAP	39 (14.3)	22 (9.7)	17 (37)	
Invasive ventilation	17 (6.3)	6 (2.7)	11 (23.9)	
Mean duration of stay (days)		6 (IQR: 5–8)	3 (IQR: 3–5)	<0.001

IQR: Interquartile range, SAM: Severe acute malnutrition, CPAP: Continuous positive airway pressure

Table 2A: Mean score among survivors and non-survivors

Mean score among survivors and non-survivors					
Scale	**Score/final outcome**				
	Survivors		**Non-survivors**		**p-value**
	Mean	**95% CI**	**Mean**	**95% CI**	
pSOFA	−4.67	−5.83–−4.05	−0.81	−2.05–−0.44	<0.001
PIM-3	3.0	2.0–5.0	11.0	8.0–11.0	<0.001

Table 2B: Diagnostic performance of two scores

Diagnostic performance of two scores				
Statistic	**Scale/cut-off value**			
	PIM-3 (≤2.11)		**pSOFA (<7)**	
	Value	**95% CI**	**Value**	**95% CI**
Sensitivity (%)	97.46	95.23–98.83	97.72	95.56–99.01
Specificity (%)	86.67	73.21–94.95	85.11	71.69–93.80
Positive LR	7.31	3.47–15.40	6.56	3.31–13.00
Negative LR	0.03	0.02–0.06	0.03	0.01–0.05
PPV (%)	98.29	96.47–99.18	98.00	96.11–98.98
NPV (%)	81.25	69.24–89.30	83.33	71.38–90.93
Accuracy (%)	96.23	93.88–97.88	96.24	93.86–97.88

PIM: Pediatric index of mortality, pSOFA: Pediatric sequential organ failure assessment, CI: Confidence interval, PPV; Positive predictive value, NPV: Negative predictive value, LR: Likelihood ratio

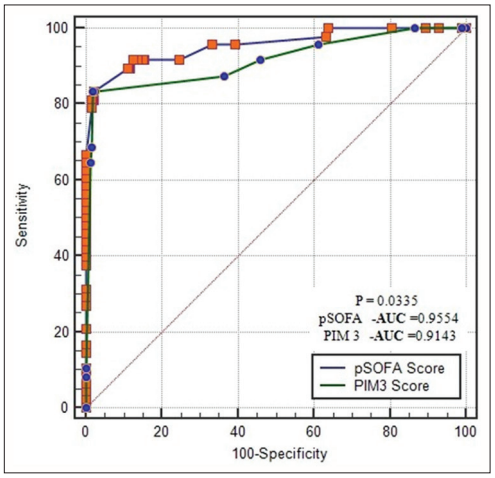

Fig. 1: Comparative receiver operating characteristic analysis of two scores

among children admitted to an ICU. They observed 0.88 (0.88–0.89) AUC, further, they observed superior performance of the model in Australia and New Zealand (AUC 0.91 (0.90–0.93) and 0.85 (0.84–0.86), respectively) as compared to Ireland and UK [3]. A similar result was reported in our study. The higher value of AUC for PIM-3 was noted in our study as compared to the study done by Sankar J (0.75; 95%CI: 0.67, 0.81) and Malhotra *et al*. 0.78 (95% CI 0.69–0.870) [9,10]. In a study by Lee *et al*., [18] the authors aimed to validate the PIM-3, the discrimination was acceptable (c-index = 0.76) [11,12]. Matics and Sanchez-Pinto evaluated the in-hospital mortality in a hospital in Chicago, using pSOFA scores and additional pediatric organ dysfunction scores. The maximum pSOFA score had excellent discrimination for in-hospital mortality, with an AUC of 0.94 (95% CI, 0.92–0.95) which is similar to our study AUC (0.9554) [5]. In another study in China by Mianling *et al*., ROC curve analysis showed that the AUCs of the pSOFA score for predicting the prognosis of children with sepsis in a PICU of a developing country was 0.937, (p<0.05) [9]. Mohamed El-Mashad *et al*. assessed the performance of the age-adapted SOFA score in children admitted into PICU in 2 hospitals in Egypt. The pSOFA score was higher in non-survivors (p<0.001). The ROC curve analysis revealed that the AUC of the SOFA score was 0.89 [10]. A study done by Baloch *et al*. for predicting 30-day mortality using pSOFA cut-off <2 reported lower values of all statistical parameters, i.e., AUC for pSOFA score (0.81, 95% CI=0.76–0.86, p=0.001), sensitivity (93.87%), specificity (38.21%), and accuracy (69.93%) as compared to our study which shows AUC 0.955 (95% CI: 0.930 to 0.973, p<0.0001) with cut off score >7 [8]. Similarly, Lalitha *et al*. also found that pSOFA had good capability (AUC=0.84) for the prediction of mortality [13]. In this study based on data, we used ≥2.11 and >7 as the optimum cut-off values for PIM-3 and pSOFA for the prediction of mortality compared to the cut-off of 8 points reported in a different reported pediatric study [5,8] and the cut off of more than 8 points described in a study in adults for SOFA [14]. The optimal cut-off value for PIM-3 was not found in other previous studies. We also conducted correlation analysis among PIM-3, pSOFA scores, and duration of hospital stay. It was observed that PIM-3 was positively associated with the pSOFA score (0.807, <0.0001). No statistically significant correlation was found between scores and duration of hospital stay. These findings were comparable to the study reported by Baloch *et al*. who reported a positive correlation between pSOFA score and PRISM III score while no statistical relationship between hospital stay and selected sores [8]. Although both scores, i.e., PIM-3, pSOFA had good AUC (>0.9), sensitivity (>97%), specificity (>85%), and accuracy (>96%), overall, our findings suggest that the pSOFA score had slightly better capability to predict mortality in children than the PIM-3 score. The PIM-3 was designed as a simple tool for the assessment of the risk of mortality in pediatric patients within the 1st h of contact of PICU admission. This score is validated in multiple countries [15]. Both models use score variables to get a percentage of mortality probability. An advantage of the PIM-3 is that the formula and coefficients of predicted mortality are presented and are freely available. The pSOFA score is also available for free and does not require special software for its calculation. pSOFA score requires measurement of fewer parameters than the PIM-3 (6vs10). Furthermore, the pSOFA may be calculated daily, offering a dynamic assessment of disease progression, while the PIM-3 is only calculated at admission. The pSOFA also does not require arterial blood gas measurements [16], which are difficult to obtain in children, and not easily available in all PICU in developing countries like US. pSOFA was adapted to use SpO_2 instead of PaO_2 values. On the other hand, one disadvantage of pSOFA is that it is not calculated immediately on PICU admission and there is a turnaround time of 24 h to get the worst value for each sub score. In this regard, the PIM-3 score offers an advantage over the pSOFA score, as the former is calculated within 1 h of PICU admission, allowing earlier identification of high-risk patients that need more aggressive management. In addition, the pSOFA score is relatively complex, which has led researchers to develop a quick version (qSOFA), but the latter seems to be less accurate as reported by studies done till now [17]. There is hope that the discovery of more accurate prognostic biomarkers may improve or replace the currently available scores. Even with such developments, it will remain difficult to perfectly predict the disease course of each patient owing to the extreme complexity of the underlying immune, metabolic, and endocrine mechanisms, in addition to the effect of the genetic makeup on the individual's response to treatment. In addition, there is no guarantee that mildly ill patients will not deteriorate as a result of health-care-related infections, adverse drug reactions, or other care-related problems. Our study is the first one to prospectively evaluate and compare these two scores. The limitations of our study are that it was a single-center study conducted at a tertiary hospital done with a small number of patients. Furthermore, we did not calculate the pSOFA score at serial intervals [10]. It makes sense for serial pSOFA scores to predict mortality more accurately, as changes in the score would parallel the progressive increase in severity that precedes death. The mortality in our study population was high, presumably due to the fact that our center is a referral center for other cities and registries of more serious diseases. Therefore, some of the findings of our study might not be generalizable to centers with low mortality rates. Validating

Table 3: Correlation analysis among pediatric index of mortality 3 score, pediatric sequential organ failure assessment score, and duration of stay (n=400)

Correlation	Duration of stay	PIM-3 score	pSOFA score
Duration of stay	-	−0.290 (<0.0001)	−0.133 (0.0079)
PIM-3 score	−0.290 (<0.0001)	-	0.807 (<0.0001)
pSOFA score	−0.133 (0.0079)	0.807 (<0.0001)	-

PIM: Pediatric index of mortality, pSOFA: Pediatric sequential organ failure assessment

PIM-3, pSOFA in a larger, multicenter sample of critically ill children in developing countries should be necessary to assess the generalizability of the scores.

CONCLUSION

The development of an ideal pediatric prognostic score remains a challenging objective. In this study, both scores, i.e., pSOFA and PIM-3 have proved their capability to predict mortality in children admitted to PICU. The diagnostic accuracy of pSOFA and PIM-3 were found equal in our study, and thus, both scores were good predictors for mortality in severely ill pediatric patients. It is recommended that by increasing the potential use of the various scoring models through proper education and calibration of assessments among different PICU, the existence of these models can be maintained in clinical practices.

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AUTHOR'S CONTRIBUTION

AKP: Acquisition and interpretation of data, data analysis, drafting the article, and literature review; RR: Concept, interpretation of data and data analysis, and revising the article critically for important intellectual content; GKP: Revising the article for important intellectual content; KC: Literature review and drafting the article. All the authors approved the final manuscript.

ETHICAL CLEARANCE

The approval was obtained from the Institutional Ethical Committee of the Gandhi Medical College, Bhopal (Letter No. 529/MC/IEC/2020, dated January 04, 2020).

CONFLICT OF INTEREST

None declared.

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