Comparison of Pediatric Risk of Mortality III, Pediatric Index of Mortality 2, and Pediatric Index of Mortality 3 in Predicting Mortality in a Pediatric Intensive Care Unit

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Abstract

Aims To compare and validate the Pediatric Risk of Mortality (PRISM) III, Pediatric Index of Mortality (PIM) 2, and PIM 3 scores in a tertiary care pediatric intensive care unit (PICU) (Indian setting).

Materials and Methods All consecutively admitted patients in the PICU of a public hospital (excluding those with unstable vital signs or cardiopulmonary resuscitation within 2 hours of admission, cardiopulmonary resuscitation before admission, and discharge or death in less than 24 hours after admission) were included. PRISM III, PIM 2, and PIM 3 scores were calculated. Mortality discrimination for the three scores was calculated using the receiver operating characteristic (ROC) curve, and calibration was performed using the Hosmer–Lemeshow goodness-of-fit test.

Results A total of 350 patients were included (male:female = 1.3:1) over the study duration of 18 months (median age: 12 months [interquartile range: 4–60 months]). Nearly half were infants (47.4%). Patients with central nervous system disease were the highest (22.8%) followed by cardiovascular system (20.6%). Mortality rate was 39.4% (138 deaths). The area under the ROC curve for the PRISM III score was 0.667, and goodness-of-fit test showed no significant difference between the observed and expected mortalities in any of these categories ($p > 0.5$), showing good calibration. Areas under the ROC curve for the PIM 2 and PIM 3 scores were 0.728 and 0.726, respectively. For both the scores, the goodness-of-fit test showed good calibration.

Conclusions Although all the three scores demonstrate good calibration, the PIM 2 and PIM 3 scores have an advantage regarding the better discrimination ability, ease of data collection, simplicity of computation, and inherent capacity of not being affected by treatment in PICU.

Keywords

- death
- ICU
- mortality
- pediatric
- PRISM
- PIM score

Introduction

The main purpose of a pediatric intensive care unit (PICU) is to prevent mortality in children by both treating critically ill patients and intensively monitoring patients who are considered “at risk” of dying. Identification of at-risk patients for death in these units is important to decide management

plans and prioritize resource utilization. Predicting the expected mortality rate in a given PICU and comparing it with the actual mortality rate also reflect on the performance of the concerned unit. Two most commonly used mortality prediction models in the PICUs are the PRISM (Pediatric Risk of Mortality) score and the PIM (Pediatric Index of Mortality) score, with most recent versions termed

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as PRISM III and PIM 2 or PIM 3 score.^{1–3} These scores are composite scores (aggregate scales) using various case characteristics on arrival to PICU as input variables to predict the outcome, with death as the outcome measure. These scores were developed in the United States and Europe and have been validated extensively in their settings. Circumstances are different in Indian PICUs both in terms of the care and facilities and in terms of the profile of admitted patients. To make use of these objective tools, both at a clinical level and at a policy level, it is important to know if these models are relevant and valid in the set of population, which is very different than the population from which it was derived. However, very few Indian studies are available for the validation of these scores.^{4–9} Individual institution practices can influence the outcome, and this is why each center needs to validate the scores. We therefore planned this study at a tertiary care PICU in western India.

The PRISM III score consists of 17 variables, whereas the PIM 2 score consists of 11 variables and the PIM 3 score consists of 12 variables. PRISM III score was developed by Pollack et al in 1996 as an updated version of the original PRISM score with the aim of minimizing the time period for assessing mortality risk for evaluating PICU quality, including a 12-hour prediction model as well as a 24-hour prediction model.¹ Slater et al with Pediatric Index of Mortality (PIM) Study Group analyzed and developed PIM 2, an updated model from the PIM score. PIM 2 has been recalibrated to reflect the improvement that has occurred in intensive care outcome. PIM 2 estimates mortality risk from data readily available at the time of intensive care unit (ICU) admission and is therefore suitable for continuous monitoring of the quality of pediatric intensive care.² PIM 3 is the updated score from PIM 2 and was published in the year 2013. This has three “risk” indicator fields: very high risk (VHRdiag), high risk (HRdiag), and low risk (LRdiag). For the PaO₂:FiO₂ ratio term, if this value is not recorded or unknown, its default value in the PIM 3 model is now 0.23 (derived from the normal value of PaO₂ in air [(0.21 × 100)/90]), not zero as in the PIM 2 model.³

Materials and Methods

The present prospective observational study was conducted in a nine-bedded PICU (age: 1 month to 12 years) for a period of 18 months after approval from the Institutional Ethics Committee. Assuming the lowest proportion of mortality in enrolled population as 39.4% and highest as 45.6%, at 95% confidence interval (CI) and 15% relative error in the assumed population, calculated sample size came out to be 264. Finally, for the study, we included 350 cases.

Consecutively admitted patients whose parents gave consent and had all investigations required for the scores were included in the study, and the study was concluded after the desired sample size was achieved. Readmissions were included as separate admissions for this study purpose as each episode requiring critical care presents new variables potentially affecting the outcome. The cases excluded were those with unstable vital signs or cardiopulmonary resuscitation within 2 hours of admission, history of cardiopulmonary

resuscitation before admission, and discharge or death in less than 24 hours after PICU admission. Over the study duration of 18 months, 874 patients were admitted in the study site PICU, of which 350 patients were enrolled in the study. Apart from all variables required to calculate study scores, the following details were noted: age, gender, diagnosis, duration of PICU stay, and outcome. For each patient, the PIM 2 and PIM 3 scores were applied within 1 hour of admission in the ICU, whereas the PRISM III score was calculated at 24 hours. Scoring was done with the laboratory investigations, which were clinically indicated in the management of patients. All the patients admitted to the study PICU, including the enrolled patients, were managed according to the standard treatment protocol followed by the PICU. The primary outcome in the form of discharge/death was noted for all patients.

Statistics

Descriptive statistics were used to report age, gender, length of stay in PICU, diagnosis, and survival. To evaluate the ability of scores to distinguish between expired and survived cases, receiver operating characteristic (ROC) curve was plotted against outcome for the three scores. Discrimination, or the accuracy of a model in differentiating outcome groups, is most often assessed by the area under the ROC curve. This area under the curve is an expression of the overall discrimination across the range of risks and is a good summary measure of the predictive ability.¹⁰ The level of cut-off points are: 0.90 to 1 = excellent; 0.80 to 0.90 = good; 0.70 to 0.80 = fair; 0.60 to 0.70 = poor; and 0.50 to 0.60 = fail. Calibration signifies how well the test predicts both mortality and survival across subcategories of risk. The most accepted method for measuring calibration is the goodness-of-fit statistic proposed by Hosmer and Lemeshow, where acceptable calibration is defined by $p \geq 0.05$, which goes on to say that there is no significant difference between the predicted mortality by the score and the observed mortality for the study population.¹¹ The standard mortality ratio (SMR) and its 95% CI were calculated by dividing the total actual mortality rate by the cumulative predicted mortality rate of the study population. Appropriate statistical software SPSS version 20 (Statistical Program for Social Science, SPSS Inc., Chicago, Illinois, United States) and Excel (Microsoft Office Professional Plus 2010) were used for statistical analysis.

Results

Over the study duration of 18 months, 874 patients were admitted in the study ICU, of which 350 patients were enrolled in the study for whom demographic data are presented in **Table 1**. The median age was 12.5 months (interquartile range [IQR]: 4–60 months). Median duration of ICU stay was 5 days (IQR: 2–9 days). The risk of mortality as predicted by the PRISM III score increased rapidly as the score exceeded 5. Mortality rate in cases with a PRISM III score of <5 was 27.5% as compared with 56.2% in cases with a higher PRISM III score, with the p -value being highly significant at 0.006. Many similar studies have reported increasing mortality as the score increases.^{6,12} The total

Table 1 Baseline demographic characteristics of the study population

Variable	Total	Mortality (%)	p-Value
Age(months)			
<12	166	74 (44.6%)	0.319
≥12–35	51	18 (35.3%)	
36–59	35	12 (34.3%)	
≥60	98	34 (34.7%)	
Gender			
Male	197	78 (39.6%)	0.943
Female	153	60 (39.2%)	
Diagnosis			
Central nervous system	80	29 (36.3%)	0.014
Cardiovascular	72	34 (51.5%)	
Respiratory	66	21 (29.2%)	
Infectious	59	19 (32.2%)	
Gastrointestinal	22	13 (59.1%)	
Hematology	14	10 (71.4%)	
Renal	12	4 (33.3%)	
Endocrine	6	2 (33.3%)	
Miscellaneous	19	6 (31.6%)	
Mechanical ventilation	183	98 (53.6%)	1.52

mortality predicted by the PRISM III score for the study population is 152 and the observed mortality is 138 with an SMR of 0.90, suggestive of an overprediction of mortality.

Out of the 17 variables in the PRISM III score, 8 variables were found to have a significant effect on the mortality, including systolic blood pressure, body temperature, Glasgow Coma Score, pupillary light reflex, arterial blood pH, blood glucose levels, total leukocyte count, and presence of coagulopathy. Out of the 11 parameters included in PIM 2, 5 were found to have a significant effect on the mortality, including nonelective admission, absence of pupillary response, mechanical ventilation, lower systolic blood pressure, and higher FiO₂ requirement. Out of the 12 parameters included in PIM 3, 5 were found to have a significant adverse effect on the mortality, similar to those in PIM 2.

► **Table 2** shows the individual score performance. The area under the curve and hence the discrimination ability were highest for PIM 2 followed by PIM 3 and PRISM III. The PIM 2 and PIM 3 scores underpredicted mortality, and the PRISM III score overpredicts mortality. As shown in ► **Table 3** (expected vs. observed mortality as per PRISM III scoring), there was no significant difference between the expected and observed mortalities ($p > 0.05$), and the risk of mortality was higher with a total score of >5 ($p < 0.006$). Expected versus observed mortality as per the PIM 2 scoring (► **Table 4**) showed no significant difference between the expected and observed mortalities ($p > 0.05$). Expected versus observed mortality as per the PIM 3 scoring (► **Table 5**) also did not show a

Table 2 Comparative significance of prediction of mortality using the PRISM III, PIM 2, and PIM 3 models

Statistical parameter	PRISM III score	PIM 2 score	PIM 3 score
Median of mortality risk, % (IQ)	10	17.73	10.98
Mean of mortality risk, % (SD)	7.55	18.64	17.27
Area under the ROC curve (95% CI)	0.667	0.728	0.726
Hosmer–Lemeshow, p-Value	0.747	0.474	0.059
SMR	0.9	1.06	1.09

Abbreviations: CI, confidence interval; PRISM, Pediatric Risk of Mortality; PIM, Pediatric Index of Mortality; ROC, receiver operating characteristic; SMR, standardized mortality ratio.

significant difference between the expected and observed mortalities ($p > 0.05$). As seen in ► **Fig. 1** (ROC curves of the PRISM III score, PIM 2, and PIM 3), the area under the ROC curve is maximum for PIM 2, suggesting best discrimination ability. Though PIM 2 has the highest area under the curve, the difference is statistically not significant. The area under the ROC curve for the PRISM III score was 0.667 (95% CI: 0.605–0.725), which shows poorer discrimination. The area under the ROC curve for the PIM 2 score is 0.728 (95% CI: 0.674–0.783), which suggests a fair discrimination ability of the model in the study population. The area under the ROC curve for PIM 3 was 0.726 (95% CI: 0.676–0.781), which suggests a fair discrimination ability of the model in the study population. The Hosmer–Lemeshow values for all the three scores were more than 0.5, suggesting good calibration for our population.

Discussion

Etiological profile of the admission in the study PICU was nearly the same as in other Indian studies, with most of the hospitalizations due to medical diseases. Surgical patients are usually not admitted here as in most Indian settings, unlike

Table 3 Expected versus observed mortality as per PRISM III scoring

PRISM III score	Total number	Expected mortality	Observed mortality	Observed: expected ratio	p-Value
<5	204	56.5	56	0.99	0.51
5–14	118	75.3	58	0.77	0.2
15–29	25	18	21	1.16	0.41
≥30	3	3	3	1	0.5
Total	350	152	138	0.91	–

Abbreviation: PRISM, Pediatric Risk of Mortality.

Note: there is no significant difference between the expected and observed mortalities ($p > 0.05$), and the risk of mortality is higher with a total score of >5 ($p < 0.006$).

Table 4 Expected versus observed mortality as per PIM 2 scoring

Predicted mortality as per the PIM 2 score	Total number	Expected mortality	Observed mortality	Observed: expected ratio	p-Value
<5%	187	42	45	1.07	0.45
5% - <15%	109	45	51	1.12	0.02
15% - <30%	25	20	17	0.86	0.79
≥ 30%	29	22	25	1.15	0.58
Total	350	129	138	1.07	0.23

Abbreviation: PIM, Pediatric Index of Mortality.

Note: there is no significant difference between the expected and observed mortalities ($p > 0.05$)**Table 5** Expected versus observed mortality as per the PIM 3 scoring

Predicted mortality as per the PIM 3 score	Total number	Expected mortality	Observed mortality	Observed: expected ratio	p-Value
<5%	208	40	53 (25.5%)	1.31	0.96
5 to <15%	103	58	54 (52.4%)	0.93	0.64
15 to <30%	13	9	9 (69.2%)	1	0.47
≥30%	26	19	22 (84.6%)	1.16	0.58
Total	350	126	138	1.09	0.059

Abbreviation: PIM, Pediatric Index of Mortality.

Note: there is no significant difference between the expected and observed mortalities ($p > 0.05$).

inclusion of many surgical patients in the western studies. The mortality in this study is 39.4%, which is also comparable to that reported from other Indian PICUs but marginally higher than that reported in PICUs from more developed countries, perhaps due to differences in the disease profile and standards of care.^{5,7-9,13-17}

The SMR for PRISM III is 0.90, suggestive of an overprediction of mortality, similar to most of the previous reports.^{7,15,16,18} The area under the ROC curve for the PRISM III score was 0.667 (95% CI: 0.605–0.725), which shows poor discrimination. This is a surprising result as almost all studies conducted in India and abroad have reported good discrimination.^{1,2,6,7,18} To assess the calibration ability of PRISM III, goodness-of-fit test showed no significant difference between the observed and expected mortalities in any of these categories ($p > 0.5$). Since the expected and observed mortalities are comparable, the model has a significantly good calibration for our PICU. While majority of the studies from more developed countries have shown good calibration, Indian studies in general, barring few, have found poor calibration ability of the PRISM III score.^{1,6,15,19}

The SMR of 1.0 is suggestive of underprediction by the PIM 2 score. Most of the other studies from developing countries have observed underprediction of mortality by the PIM 2 score, as seen in this study.^{5,7,13,20} In contrast, studies from developed countries usually noted overprediction of the mortality by the PIM 2 scoring model, perhaps due to better intensive care facilities.^{14,17,21} This difference may also be due to differences in the disease profile of PICU cases. The area under the ROC curve for the PIM 2 score is 0.728 (95% CI:

0.674–0.783), which suggests a fair discrimination ability of the model in the study population. Similar results ranging from excellent to fair discrimination have been reported in other studies.^{5,8,9,14,16,17,20,21} Goodness-of-fit test showed $p > 0.05$ for all subgroups for PIM 2, suggesting that there was no significant difference between the observed and expected mortalities in this study. This observation also means that the PIM 2 model has a significantly good calibration for our PICU. Many international studies by Wolfler et al and Imamura et al reported good calibration; however, poor calibration was reported by Ciofi degli Atti et al and Labib Youssef et al due to overprediction of deaths.^{9,17,20,22}

The standard mortality ratio for the PIM 3 score is 1.09, which signifies underprediction of mortality. The Hosmer–Lemeshow goodness-of-fit test showed $p > 0.05$ for all subgroups for the PIM 3 score, suggesting that the PIM 3 model has a significantly good calibration for our PICU. As PIM 3 is a relatively new score published in 2013, studies are lacking, but a study by Poddar et al reported poor calibration.²³ The area under the ROC curve for PIM 3 was 0.726 (95% CI: 0.676–0.781), which suggests a fair discrimination ability of the model in the study population. Poddar et al reported the area under the ROC curve to be 0.70.²³

The area under the ROC curve is maximum for PIM 2, suggesting best discrimination ability compared with the other two scores; however, there was no statistically significant difference between the scores, suggesting equal applicability to the study population. The Hosmer–Lemeshow values for all the three scores were more than 0.5, suggesting good calibration for our population.

Score	Area under ROC	Std. Error	Asymptotic 95% Confidence Interval
PRISM III score	0.667	0.031	0.607 0.727
PIM 2 score	0.728	0.028	0.674 0.783
PIM 3 score	0.726	0.028	0.670 0.78

Fig. 1 Receiver operating characteristic curves of Pediatric Risk of Mortality (PRISM) III, Pediatric Index of Mortality (PIM) 2, and PIM 3. Note that the area under the receiver operating characteristic curve is maximum for PIM 2, suggesting best discrimination ability.

Interpretation of the mortality index is also dependent on statistical factors such as sample size, mortality rate at each severity level, and random variations in the study population. Considering the differences in population characteristics and standards of care, adaptation of mortality prediction scores developed in other countries needs validation before adaptation in Indian PICUs. The best purposes of these scores include evaluation of high clinical performance ICUs and enrollment of for patients in clinical trials. For the latter purpose, the model must be calibrated in the individual hospital to ensure that the

model is applicable. This can be estimated by using goodness-of-fit testing. For an individual patient application, the model should be demonstrated to have high discrimination, as measured by the area under the ROC curve, and high calibration, as defined by goodness-of-fit testing.

To conclude, all three scores have good calibration with no significant differences between observed and expected mortalities, though PRISM III tends to overpredict and the PIM 2 and 3 scores tend to underpredict the mortality. PIM 2 and 3 scores were found to have a better capacity to discriminate

between the survivors and moribund patients than PRISM-III scores. Sensibility is another aspect of a score's validity, which encompasses the feasibility of data collection required to calculate the score. This is the one area where the PIM scores clearly outperform the PRISM III. PIM 2 and PIM 3 require collection of only 11 and 12 variables, respectively, upon admission, whereas PRISM III requires collection of the most abnormal 17 physiological variables during the first 24 hours after admission. The labor required to collect the data is obviously greater with the PRISM III score.

To our knowledge, this is the first single-center study from India comparing all the three scores with a large sample size. Even though done in an Indian setting, this study could be generalized to other developing countries since the patient profile and health care services are likely to be similar to other developing countries. Further research is needed to confirm the findings of this study in a multicentric study from areas of developing countries.

Author Contributions

Dr. Priyamvada Tyagi was involved in the conceptualization of the manuscript, collecting patient data, conducting literature search, and drafting the manuscript. Dr. Milind S. Tullu and Dr. Mukesh Agrawal were involved in the conceptualization of the manuscript, supervising the data collection, conducting literature search, and revising the manuscript. Dr. Milind S. Tullu acted as the guarantor of the manuscript.

Conflict of Interest

None.

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