RESEARCH PAPER

Comparison of Outcomes using Pediatric Index of Mortality (PIM) -3 and PIM-2 Models in a Pediatric Intensive Care Unit

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Objectives: To compare patient outcomes using the Pediatric Index of Mortality-3 (PIM-3) model with PIM-2 model for children admitted to the intensive care unit. **Methods:** We prospectively recorded the baseline characteristics, variables of PIM-3 and PIM-2 at admission, and outcomes of children ≤17 years over a period of 11 months. We used Area Under Receiver Operating Characteristics (AU-ROC) curves and Goodness-of-fit (GOF) tests to determine which of the two models had better discrimination and calibration. **Results:** Out of 202 children enrolled, 69 (34%) died. Sepsis and pneumonia were the common admitting diagnoses. The AU-ROC was better for PIM-3 (0.75) as compared to PIM-2 (0.69; *P*=0.001). The GOF-*P* value was 0.001 for both models, that indicated poor calibration of both (*P*<0.001). The AU-ROC curves were acceptable across different age and diagnostic sub-groups. **Conclusion:** PIM-3 had better discrimination when compared to PIM-2 in our unit. Both models had poor calibration across deciles of risk.

Keywords*: Critical Illness, Outcomes, Prognosis, Scoring system.*

Severity of illness scoring systems are an integral part of providing intensive care. The two commonly used mortality risk scoring systems in pediatric intensive care units (PICU) include the Pediatric Risk of Mortality (PRISM) and the Pediatric Index of Mortality (PIM) scores [1,2]. PIM-3 is the latest revision of PIM that has been validated in Australia, New Zealand, Ireland and UK [3]. It has the same number of variables as PIM-2 [4] with two major changes – the variable 'recovery post-procedure' is further divided into three categories, and an additional 'very high-risk diagnosis' variable has been added. Only few studies have validated PIM-3 so far [5-7], and very few from developing countries [7]. We therefore aimed to compare the discriminative ability and calibration of PIM-3 and PIM-2 models, calculated within 1 hour of admission.

METHODS

We conducted this observational study in our 8-bedded tertiary-care PICU between September 2015 and July 2016.

The protocol was cleared by the Institutional Ethics Committee. All children aged 2 months to ≤17 years admitted to the ICU were eligible for enrolment. Children were enrolled after obtaining written informed consent from one of the parents**.** Children dying within 1 hour of admission were excluded. The data collected included demographic variables, diagnosis, variables of PIM-3 and PIM-2, clinical course, and outcome. The data collected were obtained as part of the routine workup of these children.

The variables of PIM-3 and PIM-2 were collected within 1 hour of admission. Data collection was done by three researchers, and the intra-observer as well as inter-observer reliability was good with kappa statistic of 0.92 (95% CI: 0.90-0.94) and 0.94 (0.91 -0.96), respectively.

Statistical analyses: Data were analyzed using Stata 11.2 (StataCorp, College Station, TX). The performance of PIM-2 and PIM-3 was assessed by discrimination and calibration. Discrimination is the ability of a model to distinguish accurately between survivors and non-survivors. Mortality discrimination was assessed using Area Under the Receiver Operating Characteristics (AU-ROC) curves [8,9]. We defined acceptable discrimination as an AU-ROC between 0.70 and 0.79, and good discrimination as ≥0.80 [8,9]. Calibration is the correlation between predicted and actual outcomes over the entire range of risk. A good calibration is represented by a $P \geq 0.05$ (as assessed by the GOF test) [10].

RESULTS

The final data set comprised of 202 children [median

(IQR) age, 3 (0.5,7)], of whom 69 died (34%). The major reasons for ICU admission were severe sepsis and respiratory illnesses **(*Web Table* I).** The major causes of death were refractory shock (56%) and refractory hypoxemia. The mean probability of death by PIM-3 was 15% and by PIM-2 was 16%.

The AU-ROC was higher for PIM-3 (0.75; 95%CI: 0.67, 0.81) as compared to PIM-2 (0.69; 0.62, 0.77) (*P*=0.005) **(*Fig*. 1)**. Calibration was poor across deciles of risk for both scores with GOF *P* value being <0.0001 for PIM-3 and <0.001 for PIM- 2. PIM-3 had good AU-ROC across all age and diagnostic categories as compared to PIM-2**.** Discrimination (AU-ROC) was best for respiratory illnesses for the two scores **(*Table* I)**.

DISCUSSION

The results of the present study demonstrate that PIM-3 had better AU-ROC curve than PIM-2 in the current PICU setting; however, none of the scores had good calibration.

In comparison to the development set (in which PIM-3 was developed) and the multicenter study from Italy in which it was validated, the median risk of mortality was higher in our study population with both PIM-3 and PIM-2. The median probability of death with PIM-3 was 3.5% and 3.9% and 5.3% and 4.9% with PIM-2 in the development [3] and validation sets [5], respectively. This clearly demonstrates that the children admitted to our unit were sicker at admission and probably late in their course of illness. The mortality rates in the development and validation sets, respectively were also much lower (3.7% and 5%) [3,5] as compared to our study. This could probably explain the difference in AUROC curve between these two studies and ours with AUROC curve being >0.80 for both PIM-2 and PIM-3 in these studies [3,5]. The other possible reasons for this disparity is the difference in disease patterns between these units and our unit. Both PIM-3 and PIM-2 models have been developed and validated in mixed ICU units catering to both medical and surgical patients (one-third of admissions in the development sets were post-surgical) including those undergoing cardiac bypass and post-transplant [3,5]. In contrast, our unit mostly caters to acute infectious or medical conditions and only occasionally admits post-surgical patients. These factors could not be accounted for by the variables used to calculate the scores. Not surprisingly therefore, the case mix and the severity of illness at admission resulted in regression coefficients that are quite different from the development set for some of the items of the scores.

In contrast to discrimination which was acceptable for PIM-3, calibration was poor for both PIM-3 and PIM-2. In comparison to our study, PIM-3 had better calibration than PIM-2 in the Italian cohort [5]. The results of our study for PIM-3 and PIM-2 are similar to previous studies from developing countries that reported the models to be under-predicting deaths in their set-up [11-14]. The poor calibration of the scores observed in these units and ours could be attributed to the differences in the patient profile, need to manage large numbers of severely ill children with less than optimal human resources, and possible differences in standard of care between these units and the units where the models where developed [6,7,11-14].

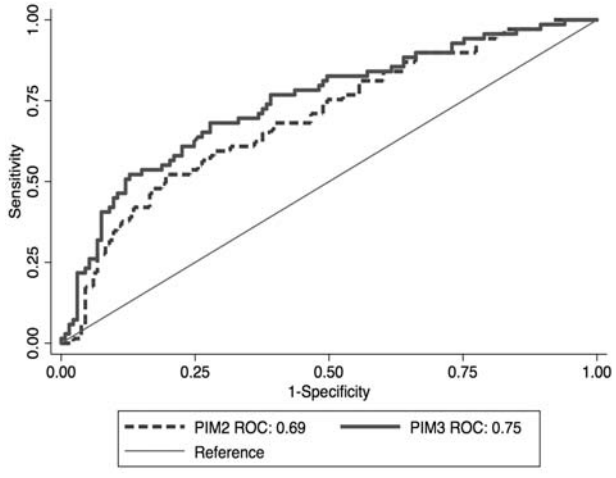

FIG. 1 *Comparison of ROC curves – PIM3 and PIM2.*

TABLE I AREA UNDER ROC CURVES OF PIM-3 AND PIM-2 (*N*=202)

Category	*Area Under ROC Curve*	
	PIM-3	*PIM- 2*
Age range		
<1 y (*n*=74)	0.74	0.75
1-<5 y (*n*=39)	0.70	0. 67
5-<10 y (*n*=58)	0.74	0.65
≥10 y (*n*=31)	0.80	0.67
Diagnoses		
Severe sepsis (*n*=91)	0.73	0.69
Respiratory illness (*n*=41)	0.86	0.80
Neurological illness (*n*=30)	0.74	0.69
Cardiac illness (*n*=13)	0.78	0.79
Liver failure (*n*=3)	-	-
Other conditions (*n*=24)	0.71	0.53

PIM: Pediatric index of mortality.

WHAT THIS STUDY ADDS?

- PIM-3 as a severity of illness score has better discrimination as compared to PIM-2; though both have poor calibration.

A limitation of this study was that it was a single clinical unit study and applicability of the results is limited due to poor calibration, and low sensitivity and specificity. Multi-unit studies in developing country settings are required to address these problems.

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WEB TABLE I BASELINE CHARACTERISTICS OF THE CHILDREN ADMITTED TO THE PEDIATRIC INTENSIVE CARE UNIT (*N*=202)

Variables	*All patients*
Age range	
<1 y	74 (37)
1-<5 y	39 (19)
5-<10 y	58 (29)
≥10 y	31 (15)
Male gender	123 (61)
*PIM-2 probability (%)	7.2 (3.3, 14)
*PIM-3 probability (%)	6 (3, 12)
Elective admission	14 (7)
Moderat to severe undernutrition	52 (26)
Diagnoses	
Sepsis	91 (45)
Respiratory illness	41 (20)
Neurological illness	30 (15)
Cardiac illness	13 (6.44)
Others	27 (13.5)
Underlying chronic illness	113 (56)
PIM-3 Low Risk Diagnosis	8 (4)
PIM-3 High Risk Diagnosis	7 (3.5)
PIM-3 Very High Risk Diagnosis	18 (9)
PIM-2 Low Risk Diagnosis	5 (2.5)
PIM-2 High Risk Diagnosis	19 (9)

*PIM: Pediatric index of mortality; Data expressed as number (%), or *median (IQR).*