Scholars Journal of Applied Medical Sciences
Abbreviated Key Title: Sch J App Med Sci
ISSN 2347-954X (Print) | ISSN 2320-6691 (Online)
Journal homepage: www.saspublishers.com

OPEN ACCESS

Pediatrics

Comparison of Two Prognostic Scores PRISM III and PIM 3 in a Pediatric Intensive Care Unit

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| **Received:** 01.04.2019 | **Accepted:** 11.04.2019 | **Published:** 30.04.2019
DOI: 10.36347/sjams.2019.v07i04.016

Abstract **Original Research Article**

Objective*:** To compare the performance of recent versions of prognostic scores PRISM III (Pediatric risk of mortality) & PIM 3 (Pediatric index of mortality) scores at general pediatric intensive care unit, investigating the relation between observed mortality & survival & predicted mortality & survival. ***Methods: A prospective cohort study was undertaken at pediatric intensive care unit (PICU) of SVPPGIP, Cuttack during period of 1st July 2015 to 30th June 2016. Study was approved by institution's Ethics committee. A total of 416 patients were enrolled out of 450 admissions during study period. Within first hour of admission PIM 3 was assessed & at 24 hours PRISM III was assessed. Patients were followed up for outcome measured in form of survivors & non survivors. Statistical analysis for model evaluation included Hosmer- Lemeshow goodness of fit test, receiver operating characteristics (ROC) curve & spearman's correlation test. ***Results***: A total of 416 patients were enrolled, 28 patients were excluded as their outcome was not known. Among the 388 patients 310 were survivors & 78 were no survivors. The overall number of estimated mortality was 65.86(16.97%) with PRISM III & 62.74% (16.17%) with PIM 3 compared to observed mortality of 78(20.1%).PIM 3($\chi 2$= 3.71 P <0.05) & PRISM III ($\chi 2$= 2.23 p <0.05) had poor caliberation. PRISM III showed the better discrimination (ROC=0.893) followed by PIM 3 (ROC= 0.870). PIM 3 & PRISM III (0.851 to 0.927) revealed positive & significant correlation with spearman's rank correlation (r= 0.318 P <0.0001). ***Conclusion:*** In this study PRISM III & PIM 3 under predicted mortality & also had poor caliberation with good discrimination. Overall both scores exhibited good capacity to discriminate between survivors & non survivors. They are tools with comparable performance at the prognostic evaluation of pediatric patients.

Keywords: Intensive care units, pediatric; Mortality; PRISM III (Pediatric Risk of Mortality); PIM 3(Pediatric Index of Mortality); Prognostic scores.

INTRODUCTION

Pediatric intensive care unit (PICU) is an important component of tertiary pediatric care services. Pediatric intensive care units (PICU) aim at promoting qualified care with the objective of achieving the best results and better progress for critically ill children. These units are points of major technology transfer and constitute one of the main consumers of hospital budgets. Pediatric intensive care units (PICU) aim at promoting quality care with the object of achieving the best results and better prognosis for critically ill children [1]. These units are points of major technology transfer and constitute one of the main consumers of hospital critical care segment.

However, when patients with varying prognosis and degrees of clinical severity are being treated the final results of employing the resources available at such units are often uncertain [2]. Scoring systems have been developed in response to an increasing emphasis on the evaluation and monitoring of health services [2]. In this context the incorporation of technology does not always follow strict analytical rules with respect of supporting scientific evidence or, even less frequently, cost-efficiency relationships[3]. The evaluation of severity of illness in the critically ill patient is made through the use of severity scores and prognostic models [4].

Severity scores are instruments that aim at stratifying patients based on the severity of illness, assigning to each patient an increasing score as their severity of illness increases, predict a certain outcome (usually the vital status at hospital discharge) based on a given set of prognostic variables and a certain modelling equation [5]. Pediatric ICUs compare

components that are related with disease severity and the resources available with the outcomes of specific types of patients. Mortality and length of hospital stay are examples of the most used outcomes. In order to measure severity risk of mortality scores are employed that establish a numerical scale and in this way they compare estimated mortality in percent with the observed mortality.

Severity of illness scoring systems could be used to assess the impact on patient outcomes of planned changes in the ICU, such as changes in bed number, staffing ratios, medical coverage [6] & also to assess the prognosis of individual patients in order to assist families and caregivers in making decisions about ICU care. All existing models aim to predict an outcome (vital status at hospital discharge) based on a given set of variables. The outcome of a patient with a certain clinical condition (defined by the registered variables), is estimated by treating in a hypothetical reference ICU.

Pediatric ICUs compare components that are related with disease severity and the resources available with the outcomes of specific types of patients. Mortality and length of hospital stay are examples of the most used outcomes. In order to measure severity risk of mortality, scores are employed that establish a numerical scale and in this way they compare estimated mortality in percent with the observed mortality. Known as prognostic scores, these can be used to evaluate the quality of medical care and to optimize the employment of resources, aiming at improving the cost-benefit relationship. Since they compare mortality adjusted by disease severity, these scores can also be used for comparisons between clinical trials and for planning technological resources. The principal scores that have been developed for the pediatric population are the PRISM (Pediatric Risk of Mortality) [7] and PIM (Pediatric Index of Mortality), with their most recent versions being PRISM III [8] and PIM 3[9]. These scores were developed by identifying variables relevant to mortality risk and scoring them after a multivariate statistical analysis by logistic regression.

The PRISM score was published in 1988 by Pollack *et al*. and exhibited an excellent discriminatory and predictive performance [10]. It is still the most widely known and used at PICU and is used in clinical trials as a standard prognostic score for evaluation of disease severity in pediatric patients. A revised version of the PRISM score, PRISM III, has been available since 1996 [11] which, according to its authors, offer better predictive capability [12].

The results of the original PIM article, published in 1997 by Shann *et al*. provided evidence that the model was capable of good predictions and classifications of mortality in groups of children hospitalized in intensive care units [13]. The authors suggest that one advantage of the PIM over the PRISM is the fact that the PIM is based on just 8 variables, all of which are collected at the point of admission, which facilitates data collection and avoids any impact on the results from 24 hours of intensive management strategies [14]. Several articles that have evaluated the PIM have shown that is performs well at predicting death [14-19].

The performance of the PRISM and PIM systems have been compared a number of times by the authors who developed the scores themselves, but have rarely been compared independently. To date, those studies that have been performed independently have not used heterogenic groups of patients from PICUs, but have investigated certain specific disease categories, new versions of the methods [20, 21] or homogenous groups of high mortality patients. In this independent study, our objective is to compare the performance of the PRISM III and the PIM 3 at a general PICU. In this study, we are investigating the relationship between observed mortality and survival and the predicted mortality and survival rates as estimated by the two scores.

Objectives

To compare the performance of the PIM II (Pediatric Index of Mortality) and PRISM III (Pediatric Risk of Mortality) scores at a general pediatric intensive care unit, the relation between observed mortality and survival and predicted mortality and survival.

METHODS

The present prospective cohort study performed between 1st July 2015 to 30th June 2016 was carried out at Pediatric Intensive Care Unit of Sardar Vallabhbhai Patel Post Graduate Institute of Pediatrics (SVPPGIP), Cuttack. All children of 1 month – 14 years age group admitted to PICU are included in the study. Patients expired within first eight hours and patients discharged within 24 hours after admission or Patients who left against medical advice are excluded from the study. It is a 12 bedded PICU which is well equipped with all monitors and mechanical ventilators, facilities of portable X ray, bedside ultrasound and ABG machine.

After admission to PICU detailed history was taken and data collected an age, sex, weight, duration of illness prior to admission. The presence and duration of fever, altered sensorium, convulsion, respiratory distress, abnormal bleeding was elicited. Demographic data was collected in order to characterize the sample, including age, admission, sex, and origin. The outcomes assessed were length of hospital stay at the unit and patient progress (discharge or death).Clinical examination will be performed on all the admitted children to select the study population according to inclusion criteria. Within the first hour of admission PIM 3 was assessed and all the precautions required for

the calculation of the PIM 3 score was followed. Further at 24 hours admission to the PICU PRISM III score was assessed. The calculated PIM 3 scores were converted to expected mortality rate by using software developed by MOA systems. PRISM III scores which were calculated converted to estimated mortality rate. Patients were followed up for the outcome. The outcome was measured in the form of survivors and non survivors. Simple descriptive analysis was utilized for the groups and subgroups under study (mean median, standard deviation). Comparison of the general similarity between observed mortality and that expected mortality by standardized mortality ratio (SMR) was calculated. In order to calibrate the scores, the Hosmer Lemeshow goodness-of-fit test was employed to test the agreement between observed and expected mortality, at five different risk intervals [22]. The capacity for discrimination between survivors and moribund patients was made using the typical area under a receiver operating characteristic curve (ROC curve) [23, 24] and quantitative correlation between the results of the scores was analyzed using the Spearman test.

RESULTS

A total of 416 patients were enrolled out of 450 admissions during the study period, after applying the exclusion criteria (14 expired within 24 hrs after admission, rest were discharged within 24 hours after admission). A total of 388 patients were analyzed as 28 patients were discharged against medical advice, they were excluded from the study as their outcome was not known. Maximum numbers of patients were infants (52%). Patients with Infectious diseases (34.2%), Neurological (22.4%) and Respiratory system (21.4%) constituted most of the present study population (Graph 1). The mean duration of PICU stay in survivors was 108.3 ± 121.6 hours and in non-survivors was 150.5 ± 122.1 hours. This difference was statistically significant (t = -2.26, p = 0.024). Thus, longer duration of the PICU stay of the patient was associated with higher mortality. The general sample characteristics are given in (Table 1).

Among the 388 patients analyzed, 310 were survivors and 78 were non survivors, with the overall observed mortality rate of 20.1%. Estimated mortality according to the PRISM III was 65.86 (16.97%) and by the PIM 3 this figure was 62.74 (16.17%) patients. This corresponds to an SMR (CI= 95%) of 1.18(1.10-2.30) for the PRISM III and 1.24 (1.20-2.90) for the PIM 3. (Table 2) synthesizes the performance of the models.

Table 3 & 4 evaluates similarities in observed and expected mortality, at different mortality risk intervals according to the Hosmer-Lemeshow goodness-of-fit test for the PRISM and the PIM (Table 3 & 4).

PRISM III underestimated mortalities compared to the observed mortalities which was statistically significant ($p<0.05$). PRISM III underestimated the mortality so had poor calibration for various level of probability of death (Table 3 & Graph 2).

PIM 3 underestimated mortalities compared to the observed mortalities which was statistically significant ($p<0.05$). PIM 3 underestimated the mortality so had poor calibration for various levels of probability of death (Table 4 & Graph 3).

As the area under the curve was 0.87 (CI - 0.77 to 0.92) for PIM 3 and 0.89 (CI - 0.81 to 0.93) for PRISM III, both discriminated probability of death and survival well. But when pair wise comparison of ROC curve was done p value was 0.696, there was no statistical difference between these scores for discrimination (Figure 1).

Table-1: Characteristics of the general sample

Characteristics	Value
Number of patients(n)	416
Mortality: n(%)	78(20.1%)
Male:Female	1.32:1
Age(months);mean(median)	52.1(26%)
Length of stay(hours);mean(median)	118.6(122.7)
Diagnosis	
Infectious	133 (34.2%)
Neurological	87 (22.4%)
Cardiovascular	58 (15.0%)
Respiratory	83 (21.4%)
Hepatic	12 (3.2%)
Miscellaneous	15 (3.9%)

Table-2: Performance of the model

	PRISM III	PIM 3
Mean of mortality risk;%(SD)	14.18±9.23	3.43±1.03
Median of mortality risk;%(IQ)	11.0(7.0-17.0)	3.77(3.26-4.05)
Estimated mortality; n	65.86	62.74
Standardized mortality (SMR)(CI-95%)	1.18(1.10-2.30)	1.24(1.20-2.90)
Hosmer- Lemeshow of goodness- of- fit test	$\chi2 = 2.23$, $p < 0.05$	$\chi2 = 3.71$, $p<0.05$
Area under a ROC (IQ-95%)	0.893(0.810-0.930)	0.870(0.772-0.925)

SD = standard deviation; IQ = interquartile interval; SMR = standard mortality ratio; CI = confidence interval; ROC = receiver operating characteristic curve

Table-3: PRISM III calibration model across various level of probability of death

Probability of death	Total (no.)	Survival		death	
		OBS.	EXP.	OBS.	EXP.
0-1	122	105	106. 56	17	15.44
>1-5	190	164	164.6	26	25.4
>5-10	28	20	22.6	8	5.4
>10-15	19	12	14.32	7	4.68
>15-20	4	3	3.5	1	0.5
>20-25	7	5	5.2	2	1.256
>25-30	1	0	0.744	1	0.256
>30-50	4	1	1.767	3	2.233
>50	13	0	2.265	13	10.735
Total	388	310	321.55	78	65.86
$\chi2 = 2.23$ CI= 95% p<0.05					

Table-4: PIM 3 calibration model across various level of probability of death

Probability of death	Total (no.)	Survival		Death	
		OBS.	EXP.	OBS.	EXP.
0-1	16	16	15.95	0	0.05
>1-5	292	242	247.4	50	44.6
>5-10	46	33	36.74	13	9.26
>10-15	11	6	8.01	5	2.99
>15-20	7	5	7.2	2	0.8
>20-25	5	2	2.1	3	1.9
>25-30	1	1	0.705	0	0.295
>30-50	7	4	4.67	3	0.99
>50	3	1	1.1	2	1.9
Total	388	310	323.87	78	62.74
$\chi2 = 3.71$ CI= 95% p<0.05					

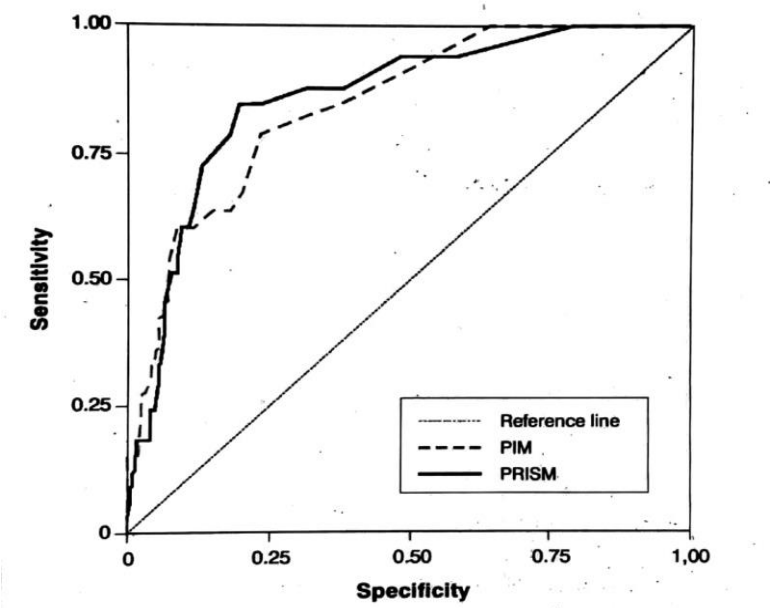
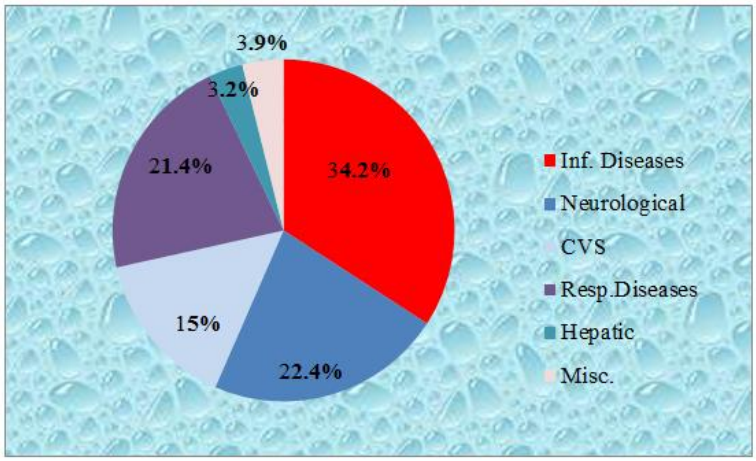
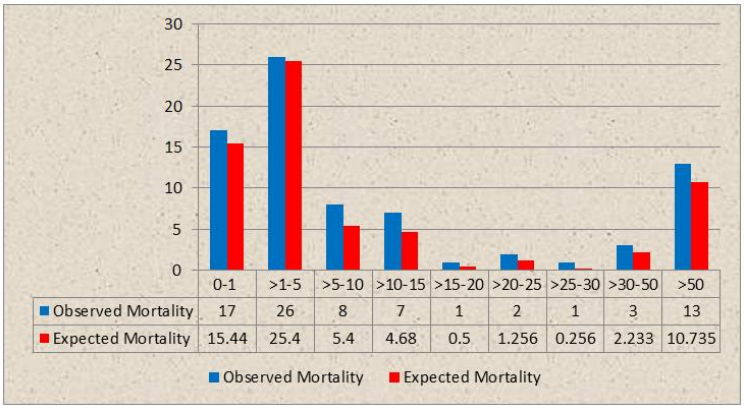


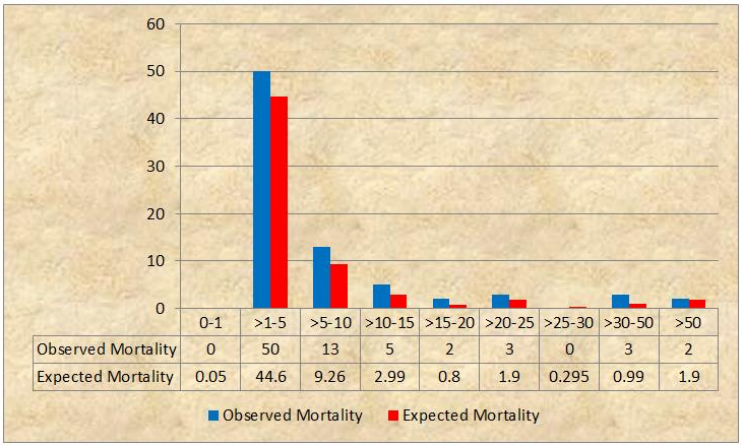
Fig-1: Superposition of two receiver operating characteristic curves (ROC). The area under the ROC curve was 0.89 for PRISM (CI 95% 0.81-0.93) and 0.87 (CI 95% 0.77-0.92) for PIM, both discriminated probability of death and survival well



Graph-1: Morbidity patterns in study population



Graph-2: Comparison of observed & expected mortality by PRISM III



	0-1	>1-5	>5-10	>10-15	>15-20	>20-25	>25-30	>30-50	>50
Observed Mortality	0	50	13	5	2	3	0	3	2
Expected Mortality	0.05	44.6	9.26	2.99	0.8	1.9	0.295	0.99	1.9

Graph-3: Comparison of observed & expected mortality by PIM 3

DISCUSSION

We evaluated the risk of mortality in PICU (of SVPPGIP, Cuttack) in this study by means of PRISM III & PIM 3. The principal scores that have been developed for the pediatric population are the PRISM (Pediatric Risk of Mortality) and PIM (Pediatric Index of Mortality), with their most recent versions being PRISM III and PIM 3. The performance of the PRISM III and PIM 3 systems have been compared a number of times by the authors who developed the scores themselves, but have rarely been compared independently.

To date, those studies that have been performed independently have not used heterogenic groups of patients from PICUs, but have investigated certain specific disease categories, new versions of the methods or homogenous groups of high mortality patients. The PIM 3 and PRISM III scores were first validated in developed countries. In this independent study, our objective is to compare the performance of the PRISM III and the PIM 3 at a general PICU. In this study, we are investigating the relationship between observed mortality and survival and the predicted mortality and survival rates as estimated by the two scores.

In the present study, the observed mortality rate was 20.1%. PRISM III and PIM 3 underestimated the mortality with a predictive mortality rate of 16.9% (SMR 1.18) and 16.1% (SMR 1.24) respectively. Similar observations of under prediction of mortality by the scores were shown in studies from both developed and developing countries [25-29]. In an Indian study where the characteristics of the study population and ICU setting were similar to the present study PIM 3 and PRISM III under predicted the mortality with an predictive mortality rate of PRISM 29% (SMR 1.2), PIM II 22% (SMR 1.57) and PIM 22 % (SMR 1.57) respectively against the observed mortality rate of 35% [25] Leteurte *et al*. [30] also demonstrated the under prediction of mortality by the scores. Contrary to these observations, studies from developed countries have shown accurate prediction of mortality using these scores, a Korean study showed the predictive mortality rate of 13.9% (SMR 1) and with 14.1% (SMR 0.99) using PIM II and PRISM III respectively versus the observed mortality rate of 14%[31].

The discriminatory power was evaluated using ROC, with PRISM III (AUC being 0.893) having better discriminatory power than PIM 3 (AUC being 0.870) with the positive and significant correlation using spearman's rank correlation ($r=0.315$; $p<0.0001$ value). Similar observations of positive correlation were seen in studies done by Qureshi *et al*. [32] ($r=0.74$; $p=0.001$) and Martha *et al*. [33] ($r=0.65$; $p<0.001$).

Various studies have also shown similar good discrimination and poor calibration both from developed and developing countries. The Indian study with the similar characteristics of study population and ICU setting as the present study, evaluating the performance of the scores, under predicted mortality with SMR for PRISM, PIM and PIM II been 1.2, 1.57 and 1.57 and documented AUC of 0.80, 0.82 and 0.81 respectively[34].

Contrary to our observation, good calibration and good discrimination of the scoring systems with accurate prediction of mortality was observed in most of the studies from developed countries [33, 35, 36,37, 38, 39]. Gemke *et al*. [37] demonstrated that PRISM III at 12 hours ($p=0.21$, AUC=0.78) and PRISM III at 24 hours ($p=0.214$, AUC=0.78) and PIM ($p=0.77$, AUC=0.74) had good calibration and good discrimination [37] Similar findings were noted by Korean [36] and Spanish [40] studies. Studies which were conducted in developing countries also showed that PRISM III had good calibration and good discrimination ($p=0.16$, AUC=0.89) [41].

It is desirable that scoring systems should be devised in such a way that they work in both developed and developing countries. This may involve or adapting existing scoring systems in a way that may not affect their current functioning in the developed world but

may appropriately modify their use within the developing world. The modification could take into account difference in the patient profile, difference in PICU practice and importantly, difference in resource allocation.

CONCLUSION

PIM 3 and PRISM III under predicted the mortality in the pediatric intensive care unit and also had poor calibration with good discrimination. Likely reasons for poor calibration underestimation in this present study could be difference in patient's profile, greater load of severity of illness being managed with lesser resources both physical and human; and differences in the quality of care.

PRISM III & PIM 3 score can help to concentrate efforts on those who can benefit more in PICU and can help to manage better with optimal utilization of limited resources. As the observed mortality is high compared to expect mortality (as predicted by both PRISM III & PIM 3) indicates more intense monitoring improvement needed to reduce mortality in current set up.

Although we had poor calibration, when the results were taken as whole both the scores exhibited good capacity to discriminate between survivors and non survivors and can be used as a tool with comparable performance for prognostic evaluation of pediatric patients admitted in a PICU setup.

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