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Validation of PRISM III (Pediatric Risk of Mortality) Scoring System in Predicting Risk of Mortality in a Pediatric Intensive Care Unit

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Abstract: *Many scoring systems have been used in various PICUs to predict mortality, also to compare functioning of different PICUs and assess their manner of resources consumption. Patient mortality is affected by many factors i.e. clinical condition of the patient, demographic profile and clinical characteristics of population, hospital management and organization, case mix and admission practices. It is desirable that these scoring systems should be independent of time and place. Therefore, there is a need of testing scoring systems in settings different from the one in which they were originally developed. PRISM scoring system was developed by Pollack et. al. based on physiological variables. This prospective analytical study was carried out to validate PRISM III scoring system in predicting mortality outcome in PICU of a tertiary care hospital in Jodhpur in year 2014. This study included 145 patients who met inclusion criteria. The final outcome was recorded as death or discharge. It was observed that mortality increased with increasing PRISM III score approaching almost 100% by PRISM III score of 19 and more. Length of stay in PICU increased with increasing PRISM III score upto score of 14 thereafter length of stay decreased gradually with increasing score. In this study the predictive value of PRISM III score was good in our PICU setup.*

Keywords: *Pediatric Risk of Mortality (PRISM), Pediatric Intensive Care (PICU)*

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I. Introduction

The main purpose of pediatric intensive care unit (PICU) is to prevent mortality by intensively monitoring and treating critically ill who are considered at risk of dying. It is extremely important to estimate patient's risk of death as it would be useful in achieving many different goals such as assessing patient's prognosis, ICU's performance, ICU's resource utilization and also evaluating therapies, controlling and matching severity of illness in clinical studies and deciding access to medical resources (1,2,3).

Predictive modeling can provide an estimate of risk of mortality faced by a patient upon entry into an ICU. Such predictive models have been designed and used for all age groups (4,5,6).

Diverse scoring systems have been used in various PICUs (17). The PRISM *(Pediatric Risk of Mortality*) scoring systems is a modified form of PSI *(Physiologic Stability Index*) that can assess the severity of disease in a given population of sick children, its third revision PRISM-III has also been used to compare the functioning of different PICUs or same PICU over a period of time and assess their manner of resources consumption (7).

PRISM scoring system, first presented by **Pollack *et al.*** is based on Physiologic variables which are subdivided to various parameters. In a given PICU, there is a close correlation between PRISM score, the number of patients' impaired organ systems during the first 12-24 h of admission and risk of mortality(8).

It is important to know the accuracy of these scoring systems to estimate the mortality risk in ICUs of different groups and countries. The desired predictor model must be independent from time and place. Patient's mortality is not only affected by PICU's performance but also depends upon many other factors such as demographic profile and clinical characteristics of population, hospital management and organization, case mix and admission practices. Therefore there is need for field testing of these scoring systems in settings different from the one in which they were originally developed. This study was planned to apply, assess and validate PRISM III scoring system in predicting mortality outcome in PICU of a tertiary care hospital in Jodhpur, India and to compare with similar studies (16,18).

Table 1: PRISM III score

Variables	Age restrictions and Range		Score
Systolic blood pressure in mm Hg	Infants 130-160 55-65 >160 40-54 < 40	Children 50-200 65-75 >200 50-64 <50	 2 6 7
Diastolic blood pressure in mm Hg	All ages >110		6
Heart rate in beats per minute	Infants > 160 <90	Children > 150 < 80	 4 4
Respiratory rate in breaths per minute	Infants 61-90 >90 apnea	Children 51-70 > 70 apnea	 1 5 5
PaO2/FiO2	All ages	200-300 <200	2 3
PaCO2 in torr (mm Hg)	All ages	51-65 >65	1 5
Glasgow coma score	All ages	<8	6
Pupillary reactions	All ages	Unequal or dilated Fixed and dilated	4 10
PT/PTT	All ages	1.5 times control	2
Total bilirubin mg/dL	>1 month	> 3.5	6
Potassium in mEq/L	All ages	3.0-3.5 6.5-7.5 < 3.0 > 7.5	1 1 5 5
Calcium in mg/dL	All ages	7.0-8.0 12.0-15.0 <7.0 >15.0	2 2 6 6
Glucose in mg/dL	all ages	40-60 250-400 <40 >400	4 4 8 8
Bicarbonate in mEq/L	all ages	<16 >32	3 3

II. Methods And Materials

This Prospective analytical study was conducted at Pediatric intensive care unit of a Tertiary care Hospital in Jodhpur, Rajasthan during 1st March 2014 to 31st August 2014. All the patients admitted in PICU of Umaid Hospital, Jodhpur aged from one month to 12 years who consented were included in the study. Patients with duration of stay <24 hours in PICU, patient less than one month or more than 12 years old, patients who were not provided the required care e.g. non-availability of complicated cardiac surgery or neurosurgery or were admitted in a state of continuous cardiopulmonary resuscitation and never achieved stable vital signs for at least 2 hours were excluded from study.

A precoded Performa was filled which included demographic profile, history, clinical examination, diagnosis, PICU outcome (survival/death), length of stay, ventilated or not, 14 parameters of PRISM III scoring system. The PRISM III score evaluation was done as per recommendation of **Pollock et al**. Clinical assessment was done continuously for 12 hours and most abnormal value was considered for scoring. The patients were followed up during PICU stay and the outcome was recorded as "survived" or "died" at the end.

Statistical Method: The expected mortality was calculated by using formula

$\mathbf{p = e^r / 1+e^r}$

Where, **p** = probability of PICU mortality

Here **r** (risk of death) = **a** x PRISM III score + **b** x Age (in months) + **c** x Operative Status + **d**

- Where, **a, b** and **c** are logistic regression coefficients for the PRISM III score, age and operative status (postoperative = 1, non-operative = 0), and d is constant.
- Where, **e** is a constant value and **r** stands for empirical function of PRISM-III scores, that is calculated by a non-linear method of curve-fitting using the observed results.

Software used for statistical analysis was Microsoft Office Excel. The association between the study variables namely, age, sex, PRISM III score and length of stay with the PICU mortality was tested using contingency/ Pearson chi- square / Fischer's exact test, as appropriate.
Multiple logistic regression models were constructed to assess the influence of PRISM III score and age on mortality. Further, the predictive accuracy of the model was assessed using the receiver operating curve analysis and expected mortality was compared with observed mortality by using Hosmer-Lemeshow test.

- Studied patients are classified in 10 groups according to their PRISM-III scores: 1-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44 and 45-49.

Observations and Results
166 patients were admitted in the PICU from March 2014 to 31st August 2014 out of which only 145 met inclusion criteria and were enrolled in the study. There were 87 males and 58 females, mortality among different sexes was not statically significant (P value 0.223). Table no. 2 shows the diagnosis with which patients were admitted in PICU.

Table 2: Diagnosis of patients admitted to PICU

Respiratory System	**No. / Died**	**Cardiovascular System**	**No./ Died**	**Central Nervous System**	**No. / Died**	**Gastrointestinal and Hepato-biliary System**	**No. / Died**	**Renal**	**No. / Died**	**Misc.**	**No. / Died**
Pneumonia	46/13	**Congenital Heart disease**	20/7	**TBM**	4/3	**Hepatic encephalopathy**	3/2	**HUS**	3/2	**Sepsis**	22/12
Pulmonary Kochs	9/3	**Rheumatic Heart Disease**	6/2	**Other meningo-encephalitis**	21/9	**Liver abscess**	2/0	**AGN**	2/0	**Shock**	36/23
Empyema/ Lung abscess	3/2	**Cardiomy-opathy /myocardit-is**	2/0	**Status Epilepticus**	5/0	**Diarrhoeal diseases**	3/1	**AKI**	13/9	**DIC**	6/5
Asthma	3/0	**Arrythmia**	3/1	**GBS**	5/0			**CRF**	1/1		
Pyo/Hydro/ Pneumothorax	6/2										
ARDS	3/2									**Others**	12/4
Total	**76**	**Total**	**31**	**Total**	**35**	**Total**	**8**	**Total**	**19**	**Total**	**76**
% of Total	52.41		21.4		24.13		5.51		13.10		52.41
Died	22		10		12		3		9		44
Mortality	28.94		32.25		34.28		37.5		47.36		57.89

Cases included 51 infants (35%) and 95 children (65%). Infant mortality was 45.09% as compared to 27.65% in children, but difference was not statistically significant. Median age was less than mean in all categories as there were younger patients and mortality was more in these patients. **:** Mean age of admitted patients was **3.75yrs**, Mean PRISM III score was **10.2** and mean length of stay was **10.7** days**,** 54 (37.24%) patients were ventilated. Mortality in ventilated patients was 68.51% and in non ventilated patients was 13.18%. This difference was statistically highly significant (p value < 0.01). **(χ^2 = 43.93, DOF= 1)**

The mean PRISM III score in survivors was **5.63** (range of 0-26) and in non survivors was **19.16** (range2-48).

It was found that PRISM III had a biphasic effect on the length of stay (LOS). Length of stay increased with increasing PRISM III score up to the score of 14. Thereafter length of stay decreased gradually with increasing severity of illness (higher PRISM III score) thus it was found that PRISM III score had a biphasic effect on the length of stay (LOS). Length of stay increased with increasing PRISM III score up to the score of 14. Thereafter length of stay decreased gradually with increasing severity of illness (higher PRISM III score), after score of 19 the length of stay is much shorter. This decrease is a reflection of the progressively larger fraction of early deaths in a population with increasing severity of illness (higher PRISM III score). It was seen that as the PRISM III score increases, mortality increases and beyond a score of 19, mortality reaches almost 100%. Only 1 child survived beyond score of 19 (score of 26).
Of the 145 patients observed, there were 96 (66.2%) survivors and 49(33.8%) deaths.
It was seen that as the PRISM III score increases, mortality increases and beyond a score of 19, mortality reaches almost 100%. Only 1 child survived beyond score of 19 (score of 26).
Of the 145 patients observed, there were 96 (66.2%) survivors and 49(33.8%) deaths.

Table 3: Mortality in different PRISM III score groups

PRISM III Score	Death	Survival	Total	Observed mortality (%)
0-4	4	44	48	8.16
5-9	8	35	43	18.6
10-14	8	11	19	42.1
15-19	6	4	10	60
20-24	8	0	8	100
25-29	5	1	6	83.4
30-34	4	0	4	100
35-39	3	0	3	100
40-44	1	0	1	100
45-49	2	0	2	100

PICU Mortality In Relation To Various Parameters In The Study

It was observed in this study that Systolic blood pressure (SBP), respiratory rate (RR), mental status (GCS), pupillary reaction, PaCO2, PaO2/ FiO2, blood sugar level, total bilirubin, bicarbonate level showed significant association with mortality but remaining variables like diastolic blood pressure (DBP), heart rate (HR), PT/APTT, serum potassium and serum calcium did not show significant association with the mortality.

Table 4: Different variables of PRISM III score with their p values in our study

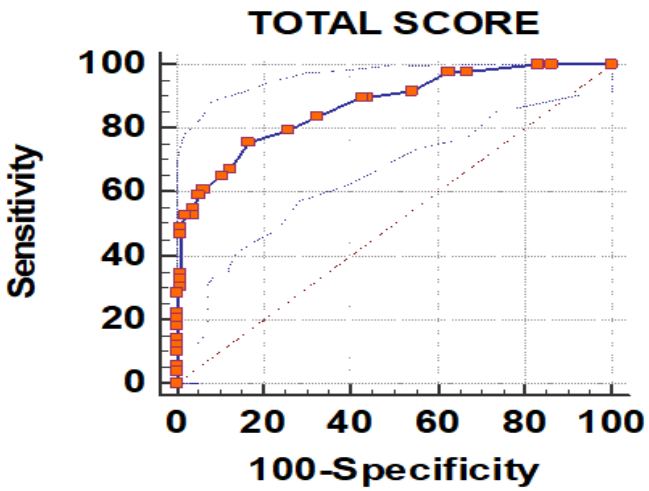
Statistically significant variables	P value	Statistically non-significant variables	P value
Systolic Blood Pressure (SBP)	<0.001	Diastolic Blood Pressure (DBP)	>0.05
Respiratory Rate (RR)	<0.001	Heart rate (HR)	0.25
Mental Status (GCS)	<0.001	PT/APTT	>0.2
Pupillary Reaction	<0.001	Serum Potassium	>0.5
PaO2/ FiO2	<0.001	Serum Calcium	0.2
Total Bilirubin	<0.001		
Blood Sugar Level	<0.01		
Bicarbonate Level	<0.02		
PaCO2	0.04		

Table 5: Predicted and observed outcome

PRISM III Score	Death		Survival		Total No
	Observed	Predicted	Observed	Predicted	
0-4	4	5.0	45	43.9	49
5-9	8	10.7	35	32.3	43
10-14	8	8.6	11	10.4	19
15-19	6	7.6	4	2.4	10
20-24	8	6.9	0	1.1	8
25-29	5	5.8	1	0.2	6
30-34	4	3.9	0	0.05	4
35-39	3	2.9	0	0.0	3
40-44	1	0.9	0	0.0	1
45-49	2	1.9	0	0.0	2

The results on **Goodness of the prediction model as seen by the Hosmer – Lemeshow goodness of fit chi square test** are presented in above table. We can see that the variation among observed and predicted mortality across the 10 PRISM III score strata are not significant.

Figure : ROC curve for PRISM III score area under curve = 0.871



ROC curve for PRISM III score area under curve = 0.871

Area under the ROC curve (AUC)	**0.871**
Standard Error	**0.0314**
95% Confidence interval	**0.806 to 0.921**
Significance level P (Area=0.5)	**<0.0001**

Area under the curve
Test result variable: PRISM III SCORE

Area	Std. Error	P Value	95% CI	
			Lower bound	Upper bound
0.871	0.031	<0.001	0.814	0.934

It was seen that area under the receiver operating curve for PRISM III score is 0.871 which shows that it is a good predictor in our set up.
The overall sensitivity is 75.51 and specificity 83.33 while positive predictive value is 89.8 and negative predictive value is 87.

III. Discussion

This study was carried out in PICU of Umaid Hospital, Dr. S.N. Medical College, Jodhpur to assess validity of PRISM III scoring system in our set up.

Survival and death were recorded as outcome variables. We used PRISM III score-12 (i.e. PRISM III score at 12 hours) as this is considered to be better for risk assessments, by shortening data acquisition time, it is also better as this separates the observation from treatment period. However till now no score is precise enough to be able to predict individual patient's risk so accurately as to enable us to make a decision on individual patient.

Mortality was found to be 33.8% in our study as compared to another Indian study in which mortality was 18%. This could be attributed to the fact that only 15% patients were ventilated in that study as compared to severity of illness and **Tilford et al** reported mortality of 4.5% again from USA (7,10,11,12). However it is futile to compare mortality in different studies without comparing the degree of sickness of admitted patients, case mix and admission practices.

In our study 97.9% patients had a PRISM III score of < 39 and 83.4% had a score of <19. This may be due to the fact that Patients with much higher scores may be dying before reaching the hospital or PICU.

In our study the mean length of stay in PICU with PRISM III score between 0-4 was 10.11 days, between the score of 10-14 was 17.05 days and between the score of 40-44 was 2 days. Thus it was found that PRISM III had a biphasic effect on the length of stay (LOS). Length of stay increased with increasing PRISM III score up to the score of 14, thereafter length of stay decreased gradually with increasing PRISM III score i.e. increasing severity of illness. **Ruttimann UE et al** found similar biphasic effect, leading to an increase in the LOS up to a score of 20, thereafter a decrease caused by a progressively larger number of early deaths as disease

severity increased further (9).In our study the mortality increased with increasing PRISM III score, approaching almost 100% by score of 19 and above.

Among the different variables Systolic blood pressure (SBP), respiratory rate (RR), mental status (GCS), pupillary reaction, PaCO2, PaO2/ FiO2, blood sugar level, total bilirubin, bicarbonate level showed significant association with mortality but remaining variables like diastolic blood pressure (DBP), heart rate (HR), PT/APTT, serum potassium and serum calcium showed no significant association with the mortality, which is similar to study by **Pollack MM et al** where they found that the variables with the greatest importance in outcome prediction, as indicated by the highest PRISM III scores, were minimum systolic blood pressure, abnormal pupillary reflexes and altered mental status (GCS<8) because these three variables reflect status of two vital organs (heart and brain) of the body **Shann et al** also did not find significance of heart rate and PT/APTT on univariate analysis of mortality(8,6).

Table no. 6: Logistic Regression Model for predicting mortality

Variable	Coefficient	Std. Error	P Value	OR(95% CI)
Constant	-2.811	0.5063		
PRISM III	0.2266	0.4080	<0.001	1.254(1.158-1.359)
Age	-0.0034	0.06	0.3973	0.94(0.82-1.07)

A logistic regression analysis was done on the outcome status (died/survived), taking PRISM III score as a predictor of mortality.

The analysis yielded a logistic r = PRISM III x 0.2266- (Age x 0.0034)-2.811.
The probability of death was calculated by formula:
Probability of death $\mathbf{p = e^r / 1+e^r}$
Where r = PRISM x 0.2266 – (age x 0.0034) – 2.811(in our study). Here -2.811 is a constant.
The odds ratio corresponding to the PRISM III score is 1.254 with the 95% CI (1.158-1.359).
For a given PRISM III score, if age increases by 1 month, the odds of death decrease by 1%.
Our study showed that the AUC for ROC of PRISM III is 0.871 which means it has a good discriminating capability (correct prediction of deaths and survival) in our PICU and is valid for our set up. Looking into the regression coefficients, PRISM III has a coefficient of -0.2266 and age has a very low regression coefficient of -0.0034. The score can be used for comparing changes in PICU mortality risk over a period of time i.e. We can compare present data of our unit with earlier data or data to be acquired later on i.e. **Tilford JM et al** compared PRISM score with mortality in 16 ICUs for the period 1980-85 and again in 1992-93(10).
Table 5 shows that, mortality rises with increasing PRISM III scores. A remarkable agreement exists between the expected mortality calculated by PRISM III score and observed mortality in all levels of PRISM III score. If they are higher or lower in different ranges in a non systematic manner the test would not be valid.
PRISM III score can be used to compare mortality of any two units. Comparison can also be made with the reference unit where it was originally developed. Standardized mortality rate (SMR), i.e. observed deaths divided by expected death according to PRISM III coefficients of reference PICU of less than one show that given PICU is performing better than reference PICU and vice versa.

IV. Conclusions

1. The mortality increases with the increase of PRISM III score i.e. higher the PRIM III score, higher the mortality.
2. The mean length of stay in PICU is the longest with PRISM III score of 10-14 (17.05 days). The length of stay decreases with further increase in PRISM III score. This is attributed to early deaths in the high PRISM III score patients due to increasing severity of illness.
3. The overall performance of the PRISM III score is good with AUC of 0.871 (good discrimination) and reasonable agreement between observed and expected mortality across most mortality risk intervals (good calibration).
4. However till further validation of PRISM III score, it should not be used for making decisions in individual patient's life, treatment cost benefits etc. as some patients with high scores may also survive i.e. one patient in our study with PRISM score of 26 survived. For this purpose even more accurate scores would be required.

Overall it appears that PRISM III score has good discriminating and calibration in our PICU and more studies should be carried out in more institution of India on a larger number of patients to see its performance. However scope of further improvement of score with decrease in time required for calibration and greater accuracy still remains.

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List of abbreviations and acronyms

ARDS	Acute Respiratory Distress Syndrome
AGN	Acute Glomerulus Nephritis
AKI	Acute Kidney Injury
CRF	Chronic Renal Failure
GBS	Gullian Barre Syndrome
GCS	Glasgow Coma Scale
HUS	Hemolytic Uremic Syndrome
LOS	Length of Stay
PRISM	Pediatric Risk of Mortality
PSI	Physiologic Stability Index
PT/aPTT	Prothombin time/ Activated partial thromboplastin time
ROC	Receiver Operating Curve
SMR	Standardized Mortality Rate
TBM	Tubercular Meningitis