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The Performance of Modified Pediatric Index of Mortality-2 Scoring System in a Pediatric Intensive Care Unit in Ethiopia

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Abstract

Background: *The mortality rate remains high in pediatrics intensive care units. Hence, predicting mortality in a pediatric intensive care unit (PICU) is vital for improving the quality of care and survival of children. The pediatric index of mortality-2 (PIM-2), is one of the most used prediction models in resource-limited setups, which does not need extensive laboratory investigation. Thus, this study aimed at assessing the performance of the modified PIM-2 score in a pediatric intensive care unit at the University of Gondar Comprehensive Specialized Hospital, Ethiopia.*

Method: *A single-centered prospective cohort study was conducted among 313 children admitted to the pediatrics intensive care unit at the University of Gondar Comprehensive Specialized Hospital. Data were collected by structured checklists adapted from different pieces of literature, through history taking, patient document review, and physical examination. The modified PIM-2 was scored within the first hour of admission. The standardized mortality ratio (SMR) was calculated using the Mid-P exact method. The discriminatory function was assessed by the area under the receiver operating characteristic (ROC) curve. The Hosmer-Lemeshow goodness of fit test was used for calibration.*

Result: *A total of 313 participants with a median age of 48 months (IQR: 12–122) at admission were included in this analysis. Of those 59.7% were males. The median duration of hospital stay was three days (IQR: 1–6).A total of 102 (32.6%) children died during the study period. The overall predicted mortality rate by the PIM-2 score was 11.1%, giving an SMR of 2.93 (95% CI: 2.11, 3.95). The area under receiver operating characteristics (AUROC) of PIM-2 was 0.79 (95% CI: 0.76, 0.86), and the Hosmer-Lemeshow goodness of fit test across deciles of risk strata showed good calibration (X^2=7.45, df=8, p=0.489) as well as across subgroups by age, diagnosis, and nutritional status.*

Conclusion: *The modified PIM-2 had a fair discriminatory function and good calibration in the study setting. Though it can be used to prioritize care and for the assessment of the quality of care, we recommend developing and validating another parsimonious risk score with a better discriminatory function.*

Background

Appropriate prediction of outcomes in pediatric intensive care units improves the quality of care and outcome of patients. The Pediatric Logistic Organ Dysfunction (PELOD), Pediatric Index of Mortality (PIM), and Pediatric Risk of Mortality (PRISM) scoring systems are the commonly used models for the prediction of death in children admitted to intensive care units. These models could be used to compare the standard of care between the units and within the unit at different times by adjusting the severity of illness and diagnoses(3–5).

The PIM scoring system is the best tool for predicting the probability of death in resource-limited settings like Ethiopia, where high child mortality and low facility for child care (8). This scoring system was originally developed in 1997(5), and revised to PIM-2 in 2003(6) and PIM-3 in 2013(7).

Although studies show that PIM-2 has been validated in many pediatric critical care settings across the globe(9–11). We did not find a published study that shows the validation of the PIM-2 scoring system in Ethiopia. Thus, validating the PIM-2 scoring system for the prediction of mortality in Ethiopia could help to improve the outcome and quality of care.

The difference in the case mix in our setting and in the setting where the model is developed can affect the performance of the PIM-2 score. Therefore, validating PIM-2 in our population before using it in clinical practice is crucial. We preferred to validate PIM-2 instead of PIM-3 since we could not access the PIM-3 Android application for free.

Thus, this study aimed at assessing the performance of the PIM-2 scoring system to predict the probability of death among critically ill children admitted to the pediatric intensive care unit to come up with better outcomes and improved quality of child care.

Method

Study design, period, and setting

A prospective cohort study was conducted among children aged one month to 18 years who are admitted to the pediatric intensive care unit (PICU) at the University of Gondar Comprehensive Specialized Hospital from February 2018 to July 2019.

The PICU has six beds with cardiorespiratory monitors and one mechanical ventilator, which have an average of 25 pediatric patients admissions per month. Team composition in the PICU is limited to a general pediatrician, resident, interns, and a handful of senior-level nurses.

Study participants and sampling

The source populations for this study were all pediatric patients aged 1 month to 18 years admitted to the PICU, whereas, the study populations were all pediatric patients admitted to PICU between February 2018 and July 2019. Patients who stayed for more than 2 hours in the PICU were included in the study, and patients having incomplete data, and surgical patients admitted for recovery only were excluded from the study. The sample size was calculated using a single population proportion formula by assuming p=21%, from a previous study conducted in Bangladesh (12) with a 5% margin of error at 95% CI. After adding 10% contingency, the total sample was279. A simple random sampling technique was used to select the study participants.

Data collection procedure

Data were collected through a structured data extraction checklist adapted from different literature and expert opinions by physicians working at the PICU. Clinical characteristics such as systolic blood pressure, the pupillary light reflex to bright light, oxygen saturation, any indication for mechanical ventilation (MV) within the first hour of admission, and primary admission diagnoses according to the tenth version of the World Health Organization (WHO) International classification of diseases (ICD-10) were documented within the first hour of admission. The primary diagnoses for the ICD-10 assignment in patients having multiple diagnoses were used. We also checked and documented patients for having 'high risk' diagnoses (i.e., cerebral hemorrhage, cardiomyopathy/ myocarditis, hypo plastic left heart syndrome, neurodegenerative disorders, leukemia/lymphoma at first induction, Human immunodeficiency virus infection, liver failure as the main reason for ICU admission, cardiac arrest preceding ICU admission, severe combined immunodeficiency) or 'low-risk diagnoses (asthma, bronchiolitis, croup, obstructive sleep apnea, diabetic ketoacidosis, seizure disorder)(6). The patients were assigned to the highest possible risk group if they had multiple risk groups. Elective admissions, admissions only for recovery from surgery or admission following cardiac bypass are also identified and recorded. Since there was no arterial

blood gas analyzer during the study period, we took partial arterial oxygen pressure by imputation from the saturation of oxygen measured by a pulse oximeter. Base excess and fraction of inspired oxygen were unavailable, subsequently, 0 and 0.21 were entered respectively for unknown values, as to the recommendation from the PIM-2 calculator. Thus, the modified PIM-2 from nine parameters was calculated using an android app QxMD. The collected data were double-checked by the data collector and the principal investigator. half day orientation was given for the data collectors before the actual data collection about the study's objectives, data abstractions, and ethical issues. The principal investigator supervised the overall data collection process but was not involved in patient care directly.

Statistical Analysis

After checking the data for its consistency and completeness, it was entered into Epi Data version 3.1 and exported to STATA version 14 for cleaning, coding, and analysis. Descriptive statistics such as mean, median, and proportions were carried out to summarize baseline characteristics and admission patterns.

The discriminatory function of the modified PIM2 score between death and survival was calculated by the area under the curve of the receiver operating characteristic curve (AUROC). The AUROC value>0.70,>0.80, and >0.90 were taken as fair, good, and excellent discrimination respectively(13). The model calibration was done using the Hosmer Lemeshow goodness of fit test for the entire sample population, as well as across deciles of risk strata. The performance of the modified PIM-2 score across age, diagnoses, and nutritional status was compared using a standardized mortality ratio (SMR), which is calculated from the observed and expected mortality rate using the Mid-P exact method and AUROC. A p-value >0.05 on the Hosmer Lemeshow goodness of fit test was considered as well-calibrated.

Ethical approval and consent to participate

Ethical clearance was obtained from the Institutional Ethical Review Board of the College of Medicine and Health Sciences, University of Gondar (ref.no 20/12/2018). Informed verbal consent was obtained from the caretakers. The name or any other identifying information was not recorded on the questionnaire and all information taken from the chart was kept strictly confidential and in a safe place. The information retrieved was used only for the study purpose.

Result

Socio-demographic and clinical characteristics

A total of 376 patients were admitted to the PICU during the study period, but only 327 patients fulfilled the inclusion criteria. Fourteen participants were excluded from the study due to incomplete data and 313 patients were included in this analysis.

The median age at admission was 48 months (IQR:12-122 months) with 28.1% infants and 21.4% adolescents. Of the total patients studied, 59.7% were males.

The primary source of admissions in the PICU was the emergency room (60.4%), inpatient pediatrics wards (13.1%), and referrals from other facilities (11.8%).

Neurologic disorders (22.7%), infectious diseases (17.3%), and injuries/poisonings (11.8%) accounted for the top three admission diagnoses in the ICU **(Table 1).** The median duration of stay at PICU was three days (IQR: 1–6).

Mortality and performance of the modified PIM-2 score

Nearly one-third of patients (32.6%) died in the PICU, and the mean predicted mortality rate based on the modified PIM-2 score was 11.14%, making an SMR of 2.93(95%CI: 2.11, 3.95). The modified PIM-2 score has a 'fair' discriminatory function (AUROC =0.79,95% CI: 0.76-0.86) **(Figure 1)** and good calibration on the Hosmer Lemeshow Goodness of fit test across deciles of risk strata (χ^2=7.452, df=8, p=0.489) **(Table 2).** The calibration and discriminatory function across subgroups by age, diagnosis, and nutritional status were also good **(Table 3).**

Table 1: Socio-demographic and clinical characteristics of children admitted to the pediatric intensive care unit (N=313)

Characteristics	Frequency (n)	Percentage (%)
Age in months		
≤12	88	28.1
13-24	29	9.3
25-60	66	21.1
61-132	63	20.1
>132	67	21.4
Sex		
Male	187	59.7
Female	126	40.3
Primary Diagnoses		
Neurologic	71	22.7
Cardiovascular	21	6.7
Respiratory	18	5.8
Endocrine and metabolic	28	8.9
Gastrointestinal and hepatobiliary	20	6.4
Renal	20	6.4
Hematologic-oncologic	21	6.7
Infectious	54	17.3
Injury and poisoning	37	11.8
Congenital malformations	23	7.3
Nutritional status, z-score		
Normal	163	52.1
Moderate acute malnutrition	50	16
Severe acute malnutrition	100	31.9
Vaccination status		
Complete	203	64.9
Incomplete	110	35.1
Comorbid illness*		
Yes	43	13.7
No	270	86.3

**Defined as a concomitant chronic illness which is not a reason for the current admission.*

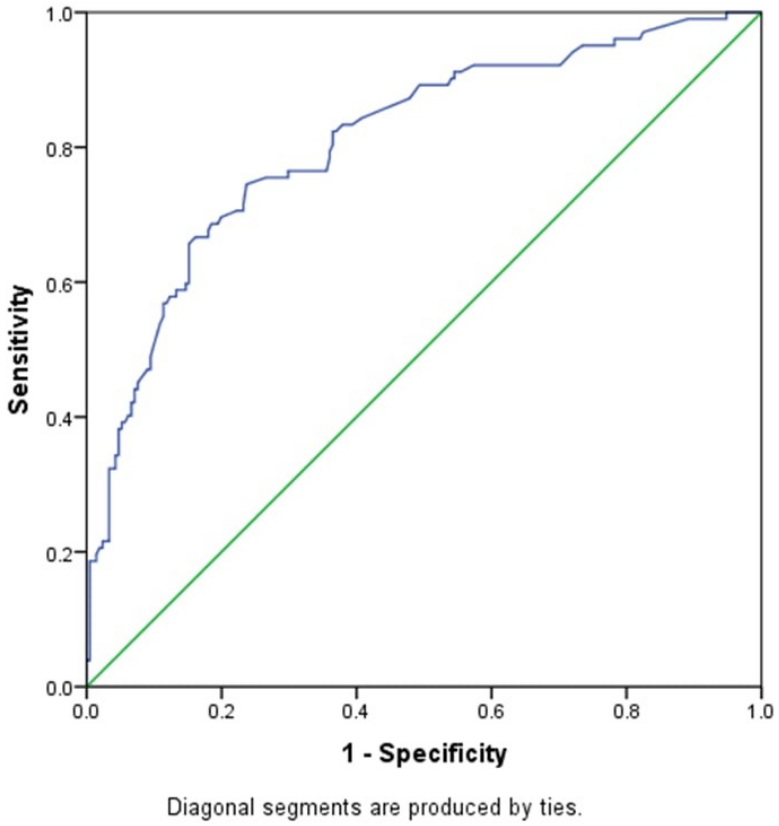

Figure 1: *Receiver operating characteristics curve for the performance of modified PIM2 (AUC 0.79 (95% CI: 0.76-0.86).*

Table 2: Table 2; performance across deciles of PIM 2 score Hosmer Lemeshow Goodness of fit test (x^2=7.452, df=8, p=0.489)

Decile of PIM 2	n	Survival		Death		SMR
		Observed	Expected	Observed	Expected	
1	24	23	22.872	1	1.128	0.887
2	37	32	34.351	5	2.649	1.888
3	33	30	29.450	3	3.550	0.850
4	29	24	24.400	5	4.600	1.087
5	33	25	25.487	8	7.513	1.065
6	31	26	21.220	5	9.780	0.511
7	32	18	18.598	14	13.402	1.045
8	32	17	15.046	15	16.954	0.885
9	32	9	11.586	23	20.414	1.270
10	30	7	7.989	23	22.011	1.045
Total	**313**	**211**	**210.999**	**102**	**102.001**	**1.000**

Table 3: Performance of PIM2 across Subgroups (N=313)

Subgroup	n	Mean PIM 2	Survival		Death		SMR (95% CI)	AUROC (95% CI)
			Observed	Expected	Observed	Expected		
Age in months								
≤12	88	12.42	60	77.1	28	10.9	2.57(1.74-3.66)	0.795(0.741-0.850)
13-24	29	6.65	19	27.1	10	1.9	5.26(2.67-9.38)	0.807(0.755-0.858)
25-60	66	15.35	40	55.9	26	10.1	2.57(1.72-3.71)	0.810(0.759-0.861)
61-132	63	10.36	43	56.5	20	6.5	1.93(3.08-4.67)	0.811(0.759-0.862)
>132	67	8.00	49	61.6	18	5.4	2.04(3.33-5.16)	0.804(0.751-0.858)
Primary Diagnosis								
Neurologic	71	11.32	45	62.9	26	8.10	3.20(2.14-4.63)	0.810(0.759-0.862)
Cardiovascular	21	17.78	13	17.3	8	3.73	2.14(1.00-4.07)	0.807(0.755-0.859)
Respiratory	18	9.78	12	16.2	6	1.76	3.41(1.38-7.09)	0.807(0.754-0.860)
Endocrine and metabolic	28	4.77	22	26.7	6	1.33	4.51(1.83-9.38)	0.807(0.754-0.860)
Gastrointestinal and hepatobiliary	20	18.67	7	16.3	13	3.73	3.49(1.94-5.81)	0.807(0.763-0.90)
Renal	20	3.99	17	19.2	3	0.80	3.75(0.95-10.20)	0.815(0.763-0.867)
Haemato-oncologic	21	22.81	15	16.9	6	4.12	1.46(0.59-3.03)	0.805(0.752-0.859)
Infectious	54	10.15	32	48.2	22	5.78	3.80(2.45-5.67)	0.798(
Injury and poisoning	37	3.43	35	35.7	2	1.27	1.57(0.26-5.20)	0.823(0.775-0.871)
Congenital malformations	23	15.92	13	19.3	10	3.66	2.73(1.38-4.87)	0.798(0.745-0.851)
Nutritional status								
Normal	163	11.35	118	144.5	45	18.50	2.43(1.80-3.23)	0.771(0.713-0.829)
Moderate acute malnutrition	50	8.87	33	45.56	17	4.44	3.83(2.30-6.00)	0.790(0.736-0.845)
severe acute malnutrition	100	11.95	60	88.05	40	11.95	3.35(2.42-4.51)	0.777(0.721-0.833)

Discussion

This is the first prospective follow-up study that assessed the performance of the PIM 2 score in the Ethiopian setting. The findings in this study showed that PIM 2 scoring system had a fair discriminatory function between death and survival and good calibration) across deciles of risk strata in 313 patients admitted to an intensive care unit. The standardized mortality rate (SMR) was 2.93 (95%CI: 2.11, 3.95) for the entire sample population and as high as 5.26 in some subgroups. The model has fair discrimination and calibration across subgroups by age, diagnosis, and nutritional status.

These findings will help clinicians and administrators in a resource-limited setting like ours use the PIM2 tool for risk-based stratification of interventions and for the assessment of the overall quality of intensive care.

A PIM-2 score is a tool used to assess the baseline disease severity, which is simple to calculate, freely available, and not affected by subsequent interventions. It is validated and practiced in several developing and developed countries across the globe (10,11,14,15).

Discrimination, assessed by measuring the area under the Receiver Operating Characteristics Curve, is the ability of the model to categorize patients into two outcome groups such as survivors and non-survivors. Calibration of a model, assessed by Hosmer and Lemeshow goodness of fit test, measures the

correlation between the predicted outcomes and actual outcomes over the entire range of risk prediction(16). The standardized mortality ratio is the ratio of the observed number of deaths to the expected number of deaths, which is a very important surrogate comparator of quality of care between different settings. But, differences in case mix can influence the comparison of standardized mortality ratios even with optimal risk adjustment (17).

The discriminatory function of the PIM 2 score in our PICU was found to be similar to the findings of prospective follow-up studies done in Nepal, Barbados, and Egypt (11,18,19), but it was lower than the findings in the settings where the model was developed (6). This discrepancy could be attributed to the difference in the case mix.

The PIM 2 score is well-calibrated across deciles of risk strata, and subgroups by age, diagnosis, and nutritional status in our study (Hosmer Lemeshow Goodness of fit test x2=7.452, df=8, p=0.489). Good calibration of this scoring system is also found in studies done in Egypt ((χ^2=5.58, *P*=0.34), Japan (X^2= 4.8, p = 0.44) , Italy (χ^2 =9.86, p∀∇.26) and Barbados (X^2=5.64, p=0.58) (10,14,20,21) .

The observed mortality was significantly higher than that of predicted and that of the finding in the original study for the development of the tool (6) and prospective follow-up studies done in Argentina (SMR=0.85), Hong Kong (SMR = 0.52), and Spain (SMR=1.0)(22–24). The variation in SMR may be attributed to differences in patient profiles, medical resources, and quality of intensive care in our PICU, the threshold for initiating and timing of intensive care.This finding is an excellent indicator for hospital administrators to focus on quality improvement works.

We used the modified PIM 2 score where base excess and FiO_2 were not accounted for, and PaO_2 was entered by imputation from peripheral oxygen saturation measured by a pulse oximeter. Had there been a measurement of exact FiO2 and PaO2 values, the mean PIM-2 and predicted mortality would have been higher and hence, would have been lower than what we found. It might be the other reason for the high SMR in our study.

Strength and Limitation of the study

To our knowledge, this study is the first study in Ethiopia to validate the pediatric index of the mortality-2 scoring system which could assist pediatricians and child health experts. Also, PIM-2 could be more helpful for early identification and referral of a child to critical centers for better treatment and management. However, this study has limitations. We used a modified PIM-2 score where base excess and FiO2 were not considered; PaO2 was taken by imputation from Sao2 measured by pulse Oximeter as there was no Arterial blood gas analyzer in our PICU during the study period. The other limitation of this study is that it is a single-center study with a small sample size when compared to the original study done to develop the model.

Conclusion

Our study showed that the discrimination and calibration of the Pediatric Index of Mortality 2 were fair and good respectively. We can use the PIM-2 scoring system in our setting to improve the quality of service and for effective and efficient resource utilization. We recommend a multi-center study at the national level incorporating all the 11 parameters of the PIM-2 score to improve the quality of care through risk-adjusted assessment of mortalities. We also recommend developing and validating another parsimonious risk prediction score with a better discriminatory function.

What is known about the subject?

The pediatric index of mortality-2 (PIM-2) is a suitable prognostic tool for pediatric critical care units in low-income countries. There are no studies that show the validation of the PIM-2 score in Ethiopia.

What this study adds

The Pediatric Index of Mortality-2 score has a fair discriminatory function between death and survival and is well-calibrated.

Abbreviations

AUROC: Area Under Receiver Operating Characteristics Curve, ICD: International Classification of Disease, ICU: Intensive Care Unit, IQR: Interquartile Range, MV: Mechanical Ventilation, PIM: Pediatric Index of Mortality, PICU: Pediatric Intensive Care Unit, ROC: Receiver Operating Curve, SD: Standard Deviation, WHO: World Health Organization

Declaration

Ethics approval and consent to participate

Ethical clearance was obtained from the Institutional Ethical Review Board of the College of Medicine and Health Scienc-

es, University of Gondar (ref.no 20/1/2017). Informed verbal consent was obtained from the patient's parents who gave their parental consent for this study. Names or any other identifying information were not recorded on the questionnaire, and all information taken from the chart was kept strictly confidential and in a safe place. We use the retrieved information only for the study purpose.

Consent for publication

Not applicable

Availability of data and material

Data is available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

NWT, ATA, KST, KAA, and **GBG** participated in the design of the study, performed data analysis, visualization, and validation of the whole work, and prepared the manuscript. **NWT** took part in funding acquisition, data collection, supervision and software, and other resources. All authors read and approved the final manuscript.

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