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Assessment of the Pediatric Index of Mortality (PIM) and the Pediatric Risk of Mortality (PRISM) III score for prediction of mortality in a paediatric intensive care unit in Hong Kong

評估香港一所醫院的兒科深切治療部用於預測小兒死亡的兩種模型：小兒死亡率指數和第三代小兒死亡風險評分法

Objective. To compare two models (The Pediatric Risk of Mortality III score and Pediatric Index of Mortality) for prediction of mortality in a paediatric intensive care unit in Hong Kong.

Design. Prospective case series.

Setting. A five-bed paediatric intensive care unit in a general hospital in Hong Kong.

Patients. All patients consecutively admitted to the unit between April 2001 and March 2003.

Main outcome measures. Scores for both models compared with observed mortality.

Results. A total of 303 patients were admitted to the paediatric intensive care unit during the study period. The median age was 2 years, with an interquartile range of 7 months to 7 years. The male to female ratio was 169:134 (55.8%:44.2%). The median length of hospital stay was 3 days. The overall predicted number of deaths using The Pediatric Risk of Mortality III score was 10.2 patients whereas that by Pediatric Index of Mortality was 13.2 patients. The observed mortality was eight patients. The area under the receiver operating characteristics curve for the two models was 0.910 and 0.912, respectively.

Conclusion. The predicted mortality using both prediction models correlated well with the observed mortality.

目的：比較香港一所醫院兒科深切治療部所採用的兩種預測小兒死亡的模型：小兒死亡率指數 (PIM) 和第三代小兒死亡風險評分法 (PRISM III score)。

設計：前瞻性病例系列研究。

安排：香港一所綜合醫院，設有 5 張病床的兒科深切治療部。

病者：2001 年 4 月至 2003 年 3 月，該部門連續接收的所有病人。

主要結果測量：對兩個模型所得評分，與實際死亡數字作比較。

結果：研究進行期間，該部門共接收 303 位病人。年齡中位數為 2 歲，四份位數間距為 7 個月至 7 年。男女比例為 169：134（55.8%：44.2%）。留院期中位數為 3 天。以第三代小兒死亡風險評分法和小兒死亡率指數計算的預測死亡人數分別為 10.2 和 13.2 ，實際死亡人數則為 8 。兩個模型的 ROC 曲線面積分別為 0.910 和 0.912 。

結論：以小兒死亡率指數和小兒死亡風險評分法計算預測死亡率，結果與實際數據相當吻合。

Key words:
Child;
Intensive care units, pediatric;
Mortality;
Predictive value of tests;
Severity of illness index

關鍵詞：
兒童；
深切治療部，兒科；
死亡率；
檢測的預測值；
病情危重指數

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Introduction

Since the early 1980s, various scoring systems have been used in paediatric intensive care units (PICUs) to evaluate severity of illness. These scoring systems assist in prediction of patient mortality and allow comparison of standards of care of different PICUs.[1-7]

The Pediatric Risk of Mortality (PRISM) III score was first developed in 1996. It is a commonly used mortality prediction model, initially derived from the physiological stability index.[8,9] It is a third-generation physiology-based prediction model for mortality and has been validated by numerous studies worldwide.[7,10-15] The PRISM III score measures the patient's most abnormal variables during the first 12 or 24 hours (PRISM III-24 score) in an intensive care unit, and also predicts possible mortality during that admission.

The Pediatric Index of Mortality (PIM) was developed in 1996 and is a simple model that consists of eight variables measured at the time of admission to an intensive care unit.[16,17] Both PRISM III score and PIM were developed to predict mortality in a PICU. The experience of applying these two prediction models in the Asia-Pacific region is limited.

The PRISM III-24 score was first applied in the PICU of Kwong Wah Hospital, Hong Kong in 1996. The PIM score was additionally used in 2001. A prospective study was conducted to establish the validity of the PRISM III-24 and the PIM scores in predicting the outcome of patients in the PICU. The standardised mortality ratio (SMR) in Kwong Wah Hospital PICU was also determined. This compared cumulative predicted mortality risk with the total actual mortality rate in the study population.[18] No such studies in Hong Kong have been previously published.

Formula of the mortality prediction models:
The Pediatric Risk of Mortality (PRISM) III-24 and Pediatric Index of Mortality (PIM)

PRISM III-24: Proprietary

PIM: Logit = (Pupil x 2.357)+(Underlying x 1.826) +(Elective x −1.552)+[0.021 x | (SBP-120) |]+(0.071 x | base excess |)+[0.415 x (FiO_2/PaO_2)]

Predicted death rate = Logit/(1+Logit)

Pupil = Response of pupils to bright light (>3 mm and both fixed – 1, Other – 0)

Underlying = Presence of any of the following condition(s) [Yes – 1, No – 0, Doubt – 0]
(1) Cardiac arrest out of hospital
(2) Severe combined immune deficiency
(3) Leukaemia/lymphoma after first induction
(4) Spontaneous cerebral haemorrhage from aneurysm or atrioventricular malformation
(5) Cardiomyopathy or myocarditis
(6) Hypoplastic left heart syndrome
(7) HIV infection
(8) IQ <35, worse than Down's
(9) Neurodegenerative disorder (progressive ongoing loss of milestones)

Elective = Booked admission to ICU after elective surgery; or elective admission for a procedure (eg insertion of a central line), or monitoring, or review of home ventilation (Yes – 1, No – 0)

SBP = Systolic blood pressure, mm Hg (unknown = 120)

Base excess = Base excess in arterial or capillary blood, mmol/L (unknown = 0)

FiO_2 = Fractional inspired oxygen (FiO_2) at the time PaO_2 if oxygen via endotracheal tube or headbox, mm Hg (unknown = 0)

PaO_2 = Arterial oxygen tension (PaO_2), mm Hg (unknown = 0)

Web-based version of PIM calculator:
http://www.sfar.org/scores2/pim2.html

Methods

Kwong Wah Hospital is a regional general hospital in Hong Kong with 150 paediatric beds. The PICU consists of five beds and accepts patients aged from 0 to 18 years from general paediatric wards, the Accident and Emergency Department, surgical wards, and operating theatres. It is staffed by one medical officer, one senior medical officer, one consultant, and three registered nurses per shift.

All patients consecutively admitted to the PICU between April 2001 and March 2003 were included in the study. Those patients transferred to other units were not included in mortality figures. All patient demographic data, physiological data, and clinical diagnoses were recorded. Informed consent was not required because no additional procedures were performed.

All patients were classified on admission according to their diagnostic group: central nervous system, respiratory, cardiovascular, gastro-intestinal or liver, sepsis, multi-organ failure, haematological, drug overdose, metabolic, renal, postoperative, scald, accident or trauma, and others. Data were collected by the medical officer in charge at the time of admission and entered by a nurse specialist. Length of stay in the PICU, total hospital stay, and actual mortality were also recorded.

The PRISM III-24 score was calculated using 17 physiological parameters and eight additional risk factors. We used the most abnormal value of each

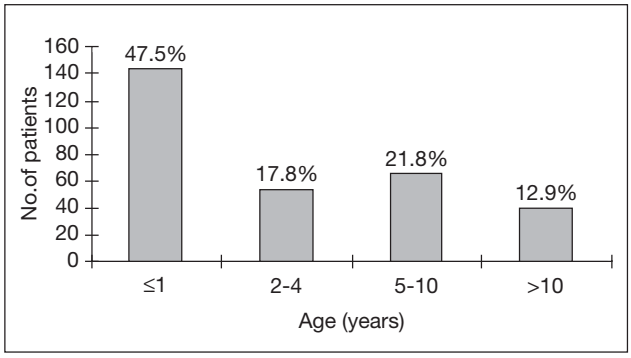

Fig 1. Distribution of age

parameter within the first 24 hours of intensive care unit stay to obtain the PRISM III-24 score. The individual risk of mortality was predicted using the proprietary logistic regression equation, and the overall predicted risk of intensive care unit mortality was subsequently calculated (Box).

The PIM score was calculated using eight physiological variables collected within the first hour of admission to PICU. The individual risk of mortality was predicted by a logistic regression equation,[16] and the overall predicted risk of intensive care unit mortality was subsequently calculated (Box).

Statistical analysis

The Statistical Package for the Social Sciences (Windows version 10.0; SPSS Inc, Chicago [IL], United States) and STATA version 7.0 (Stata Corporation, College Station [TX], United States) were used. Demographic and physiological data were described using median and interquartile ranges (IQRs) because they were not normally distributed. The predicted risk of mortality of two prediction models was compared with the actual mortality. A receiver operating characteristics (ROC) curve was constructed. The area under the ROC curve provides a parameter for the discriminatory performance of the model. An area under the ROC curve of 0.75 or more is considered clinically useful.[19] The area under the curve (AUC) for both models were compared.

The SMR and its 95% confidence interval (CI) were calculated by dividing the total actual mortality rate by the cumulative predicted mortality rate of the study population. To assess the calibration of both scoring systems in patients with different levels of risk, and to compare observed with expected mortality, patients were grouped according to four risk categories (0% to <25.0%, 25.0% to <50.0%, 50.0% to <75.0%, and 75.0% to 100.0%).[18,20] The stratification of risk categories in this study differs from that of other studies[18,20] because of insufficient mortality in certain risk groups. The SMR was significantly less than 1 if the 95% CI around SMR did not cross 1. An SMR significantly less than 1 could be interpreted as an overestimation of mortality in the PICU and/or better performance by the PICU compared with that of the PICUs that developed the scoring systems.[20,21]

Results

A total of 303 patients were admitted to the PICU between April 2001 and March 2003. Median age was 2 years (IQR, 7 months-7 years). Approximately 48% of patients were infants (Fig 1). There were 169 (55.8%) male and 134 (44.2%) female patients. A total of 284 (93.7%) patients were ethnic Chinese, and 19 (6.4%) were of other Asian descent. Median length of stay in the PICU was 3 days (range, 0-186 days; IQR, 1-6 days). The three most common disease categories were respiratory disease (39.6%), postoperative disease (19.8%), and neurological disorders (18.8%) [Fig 2].

During the study period, eight (2.6%) patients died: two died of respiratory diseases, four of neurological problems, one of cardio-respiratory failure, and one of fulminant sepsis with multi-organ failure. The length of stay in the PICU of these eight patients ranged from 2.5 hours to 8 days (Table 1). The predicted mortality using PRISM III-24 score was 10.2 patients, whereas that for PIM was 13.2 patients. The overall SMR was 0.79 (95% CI, 0.65-0.98) and 0.61 (95% CI, 0.50-0.77) for PRISM III and PIM scores, respectively (Table 2). For PRISM III-24, the 95% CI of SMR could not be calculated for two risk categories because there were no deaths. The predicted mortality was significantly overestimated in the risk categories 0% to <25.0% and 50.0% to <75.0% of PIM. Nonetheless, Chi squared goodness-of-fit test showed no significant misfit between the number of expected deaths and observed deaths in four risk categories by the two mortality prediction models (PRISM III-24, P=0.395; PIM, P=0.380).

The ROC curves for both PRISM III-24 and PIM are shown in Fig 3. The AUC for PRISM III-24 was 0.910 (95% CI, 0.805-1.000), whereas that for PIM was 0.912 (95% CI, 0.799-1.00). The AUC of both scoring systems were similar (Chi squared test for equality of ROC areas, P=0.987). Both systems showed the lower limit of 95% CI of AUC greater than 0.75, indicating clinical usefulness.

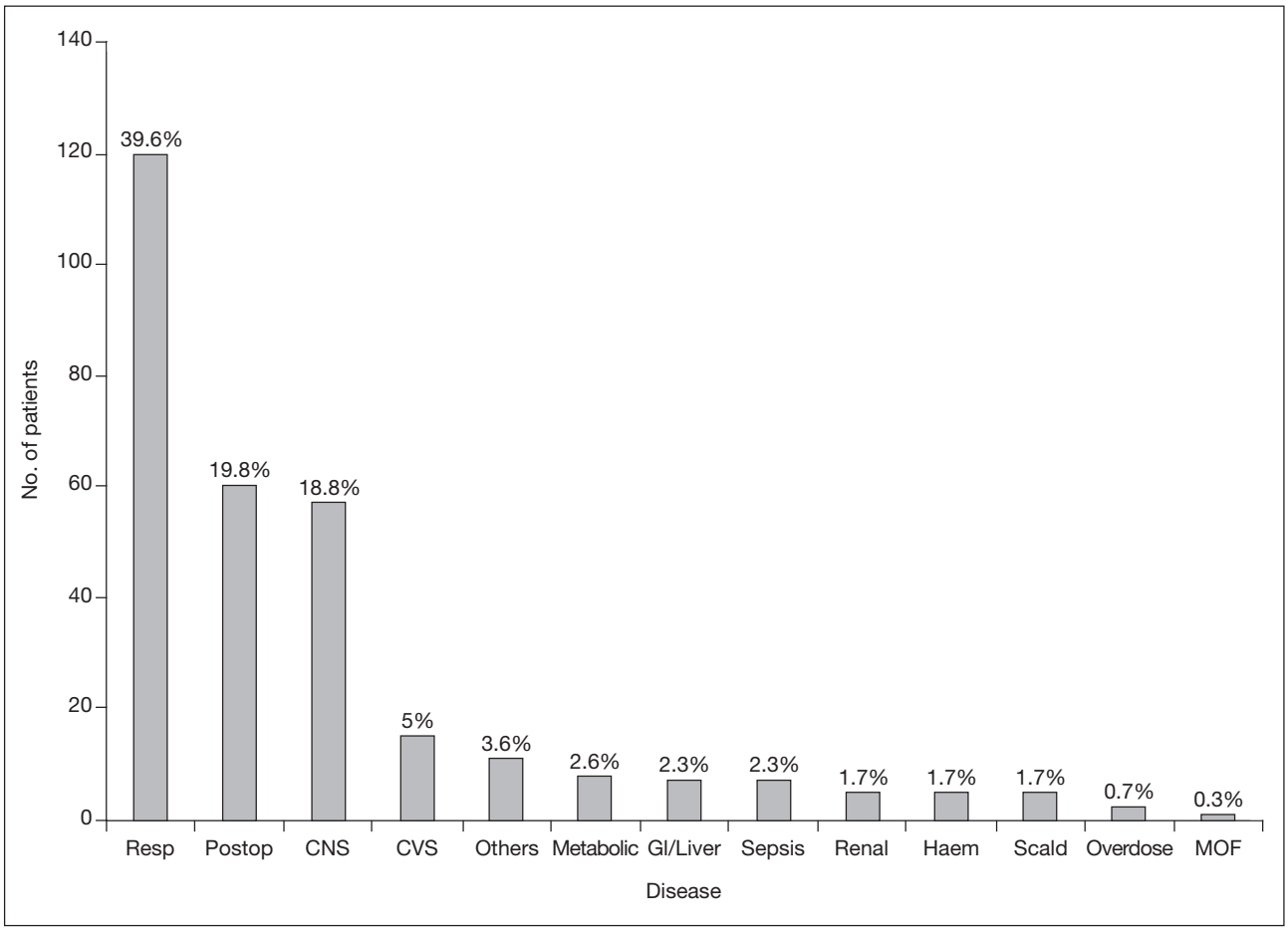

Fig 2. Distribution of diseases*
* Resp denotes respiratory, Postop postoperative, CNS central nervous system, CVS cardiovascular system, GI/Liver gastro-intestinal and liver, Haem haematological, Overdose drug overdose, and MOF multi-organ failure

Table 1. Characteristics of patients who died

Case No.	Age	Diagnosis	Cause of death	Hospital stay	PRISM* III-24 (Predicted mortality rate)	PIM† (Predicted mortality rate)
1	2 years	Endocardial fibroelastosis	Cardio-respiratory failure	2.5 hours	-2.663 (6.52%)	-2.123 (10.69%)
2	8 days	Aspiration/*Escherichia coli* septicaemia	Multi-organ failure	22 hours	4.248 (98.59%)	4.683 (99.08%)
3	6 years	Glioblastoma multiforme	Sepsis/pneumonia	2 days	1.420 (80.53%)	-0.3977 (40.19%)
4	8 months	Spinal muscular atrophy	Respiratory failure	5 days	-5.165 (0.57%)	-3.047 (4.53%)
5	15 years	Germ cell brain tumour	Brainstem death	3 days	2.335 (91.17%)	2.8635 (94.60%)
6	5 months	Shaken baby syndrome	Subdural haematoma	19 hours	1.891 (86.89%)	0.1610 (54.02%)
7	11 years	Brain tumour	Brainstem death	6 days	-5.752 (0.32%)	-4.4398 (1.17%)
8	8 years	Head injury/cerebral haemorrhage	Brainstem death	8 days	3.583 (97.29%)	3.6467 (97.46%)

* PRISM Pediatric Risk of Mortality
† PIM Pediatric Index of Mortality

Discussion

Mortality prediction models need to be validated before they can be applied in an environment that is substantially different to the environment in which they were developed. Mortality prediction models of PICU have not been validated in Hong Kong or Mainland China. This was an important study that

Table 2. Goodness-of-fit test for The Pediatric Risk of Mortality (PRISM) III and Pediatric Index of Mortality (PIM) across a range of risks

Model	Probability of death (%)	Survivors		Death		SMR* (95% CI†)	P value‡
		Expected	Observed	Expected	Observed		
PRISM III	0.0 to <25.0	288.81	288	2.19	3	1.37 (0.82-4.10)	0.395
	25.0 to <50.0	2.45	4	1.55	0	0	
	50.0 to <75.0	0.89	2	1.11	0	0	
	75.0 to 100.0	0.66	1	5.34	5	0.94 (0.82-1.01)	
PIM	0.0 to <25.0	284.98	288	6.03	3	0.50 (0.36-0.82)	0.380
	25.0 to <50.0	2.97	4	2.03	1	0.49 (0.32-1.06)	
	50.0 to <75.0	0.75	3	2.25	1	0.44 (0.31-0.79)	
	75.0 to 100.0	0.09	0	2.91	3	1.03 (0.94-1.15)	

* SMR standardised mortality ratio
† CI confidence interval
‡ Chi squared goodness-of-fit test

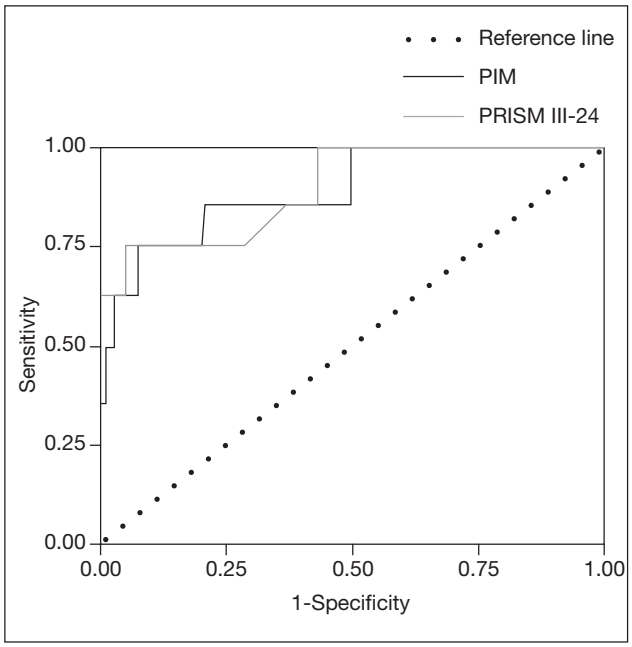

Fig 3. Receiver operating characteristics curves for The Pediatric Risk of Mortality (PRISM) III-24 and Pediatric Index of Mortality (PIM) scoring

assessed the performance and validity of these models in Hong Kong. The prediction of mortality by both PRISM III-24 and PIM systems were comparable when applied in a PICU in Hong Kong. The AUC for both models was greater than 0.75. This reflected the validity of both PRISM III-24 and PIM in predicting mortality. The AUC of the two scoring systems were also similar: this is in agreement with experience in the Netherlands[20] and Australia and New Zealand.[15] Other reports from Asian PICUs could not be compared with this study because they used an earlier version of PRISM.[22-25]

The use of mortality prediction models is important for audit purposes. They allow comparisons to be made between different PICUs in terms of disease severity and clinical outcomes.[15]

The study population had similar diseases and age-group distribution to other series.[7-9,13,16,17] A similar percentage of patients to those of PICUs in England[21] and Turkey[22] were admitted for respiratory, cardiovascular, and neurological diseases. Sepsis was, however, significantly under-represented in our study population (2.3%) compared with other reports (30%-41%).[21,22] The mortality of sepsis in a Turkish PICU was reported as higher than 50%.[22] This may be related to age difference, because patients in other reports were significantly younger. It may partly explain the low mortality of our PICU, although it was similar to that of other western centres.[15] The present study demonstrated the applicability of PRISM III and PIM score-based mortality prediction models in a PICU in Hong Kong. In this study population, the 95% CI for SMR was less than 1.0 for PRISM III-24 (0.79; 95% CI, 0.65-0.98) and PIM (0.61; 95% CI, 0.50-0.77), indicating that the overall performance of the PICU was comparable to those where the scores were developed, and/or the mortality prediction models overestimated the mortality rate in our PICU. The SMR reported in this study based on the PRISM III-24 score was lower than the figure reported from Taiwan (1.08)[14] but similar to figures reported from 10 PICUs in Australia and New Zealand (0.77; 95% CI, 0.72-0.82).[15]

Staff who managed the PICU in this study received similar training to that received by staff of other overseas centres. This may explain the similar validity of the PRISM III and PIM scoring systems.

The characteristics of prediction power of the two

prediction models in patients with different levels of risk-adjusted probability of death are demonstrated in Table 2. Even though significant misfit was not found by the goodness-of-fit test, this test has been proved ineffective in a limited sample size. For PIM, mortality was significantly overestimated in two categories, ie 0% to <25.0% and 50.0% to <75.0%, as indicated by SMR significantly lower than 1. For the remainder, no conclusions can be drawn because of wide 95% CIs with insufficient sample size. Further study with sufficient mortality should be carried out to confirm these findings.

Two of the eight deaths in this study occurred within 24 hours of admission. It has been suggested that the prolonged period of time required to collect the variables for PRISM mortality prediction model obscures poor quality of care.[16] This issue is resolved by application of the PIM model and consequent score that can be obtained within the first hour of admission to a PICU. The PIM model is also more user-friendly with less data required and is thus the model of choice for the authors' department.

Our PICU admitted patients aged from 0 to 18 years. The PIM model was designed for patients aged from 0 to 16 years whereas PRISM III was for those aged from 0 to 18 years. However, the application of PIM was extrapolated to one 18-year-old (survivor with PRISM III score= –5.829, PIM= –4.8730) in this study. Such extrapolation of PIM scoring to patients aged over 16 years has also occurred in another study.[20] Re-analysis of the data in this study with the 18-year-old excluded produced no different findings.

The current study consisted of a small number of patients from one local hospital. The actual mortality was low. This may partly explain why the 95% CI of AUC in the ROC curve in both systems is wider than that reported in other series. The wide 95% CI of SMR can also be explained by the low mortality in our PICU. Validation of mortality prediction models using ROC analysis requires a minimal sample size, mortality and survival. At least 10 cases of death (compared with eight in this study) are required for an ROC analysis of this kind.[26] A study carried out in collaboration with other PICUs in Hong Kong is warranted.

Conclusion

Both PRISM III and PIM scoring systems accurately predicted mortality in the study of PICU. A multicentre study is required to validate the models in Hong Kong.

References

1. Pollack MM, Yeh TS, Ruttimann UE, Holbrook PR, Fields AI. Evaluation of pediatric intensive care. Crit Care Med 1984;12:376-83.
2. Yeh TS, Pollack MM, Ruttimann UE, Holbrook PR, Fields AI. Validation of a physiologic stability index for use in critically ill infants and children. Pediatr Res 1984;18:445-51.
3. Zobel G, Kuttnig M, Grubbauer HM, Rodl S. Evaluation of clinical scoring systems in critically ill infants and children. Clin Intensive Care 1990;1:202-6.
4. Heard CM, Fletcher JE, Papo MC. A report of the use of the Dynamic Objective Risk Assessment (DORA) score in the changing pediatric intensive care environment. Crit Care Med 1998;26:1593-5.
5. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. Crit Care Med 1985;13:818-29.
6. Pollack MM, Getson PR, Ruttimann UE, et al. Efficiency of intensive care. A comparative analysis of eight Pediatric intensive care units. JAMA 1987;258:1481-6.
7. Gemke RJ, Bonsel GJ, van Vught AJ. Effectiveness and efficiency of a Dutch pediatric intensive care unit: validity and application of the Pediatric Risk of Mortality score. Crit Care Med 1994;22:1477-83.
8. Pollack MM, Ruttimann UE, Getson PR. Pediatric risk of mortality (PRISM) score. Crit Care Med 1988;16:1110-6.
9. Pollack MM, Patel KM, Ruttimann UE. PRISM III: An update Pediatric Risk of Mortality score. Crit Care Med 1996;24:743-52.
10. Festa MS, Tibby SM, Taylor D, Durward A, Habibi P, Murdoch IA. Early application of generic mortality risk scores in presumed meningococcal disease. Pediatr Crit Care Med 2005;6:9-13.
11. Leteurtre S, Leclerc, F, Martinot A, et al. Can generic scores (Pediatric Risk of Mortality and Pediatric Index of Mortality) replace specific scores in predicting the outcome of presumed meningococcal septic shock in children? Crit Care Med 2001;29:1239-46.
12. Pollack MM, Patel KM, Ruttimann U, Cuerdon T. Frequency of variable measurement in 16 pediatric intensive care units: influence on accuracy and potential for bias in severity of illness assessment. Crit Care Med 1996;24:74-7.
13. Balakrishnan G, Aitchison T, Hallworth D, Morton NS. Prospective evaluation of the Pediatric Risk of Mortality (PRISM) score. Arch Dis Child 1992;67:196-200.
14. Wang JN, Wu JM, Chen YJ. Validity of the updated pediatric risk of mortality score (PRISM III) in predicting the probability of mortality in a pediatric intensive care unit. Acta Paediatr Taiwan 2001;42:333-7.
15. Slater A, Shann F; ANZICS Paediatric Study Group. The suitability of the Pediatric Index of Mortality (PIM), PIM2, the Pediatric Risk of Mortality (PRISM), and PRISM III for monitoring the quality of pediatric intensive care in Australia and New Zealand. Pediatr Crit Care Med 2004; 5:447-54.
16. Shann F, Pearson G, Slater A, Wilkinson K. Paediatric index of mortality (PIM): a mortality prediction model for children in intensive care. Intensive Care Med 1997;23:201-7.
17. Pearson GA, Stickley J, Shann F. Calibration of the paediatric index of mortality in UK paediatric intensive care units. Arch Dis Child 2001;84:125-8.
18. Rapoport J, Teres D, Lemeshow S, Gehlbach S. A method for assessing the clinical performance and cost-effectiveness

of intensive care units: a multicenter inception cohort study. Crit Care Med 1994;22:1385-91.
19. Zweig MH, Campbell G. Receiver-operating characteristic (ROC) plots: a fundamental evaluation tool in clinical medicine. Clin Chem 1993;39:561-77.
20. Gemke RJ, van Vught J. Scoring systems in pediatric intensive care: PRISM III versus PIM. Intensive Care Med 2002;28:204-7.
21. Tibby SM, Taylor D, Festa M, et al. A comparison of three scoring systems for mortality risk among retrieved intensive care patients. Arch Dis Child 2002;87:421-5.
22. Ozer EA, Kizilgunesler A, Sarioglu B, Halicioglu O, Sutcuoglu S, Yaprak I. The Comparison of PRISM and PIM Scoring Systems for Mortality Risk in Infantile Intensive Care. J Trop Pediatr 2004;50:334-8.
23. Deerojanawong J, Prapphal N, Udomittipong K. PRISM score and factors predicting mortality of patients with respiratory failure in the pediatric intensive care unit. J Med Assoc Thai 2001;84(Suppl 1):68S-75S.
24. Singhal D, Kumar N, Puliyel JM, Singh SK, Srinivas V. Prediction of mortality by application of PRISM score in intensive care unit. Indian Pediatr 2001;38:714-9.
25. Goh AY, Abdel-Latif Mel-A, Lum LC, Abu-Baker MN. Outcome of children with different accessibility to tertiary pediatric intensive care in a developing country—a prospective cohort study. Intensive Care Med 2003;29: 97-102.
26. Obuchowski NA, Lieber ML, Wians FH Jr. ROC curves in clinical chemistry: uses, misuses, and possible solutions. Clin Chem 2004;50:1118-25.