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

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.
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.

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
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, 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. 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%). The stratification of risk categories in this study differs from that of other studies 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.

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.
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
Models for prediction of paediatric mortality

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 and Australia and New Zealand. Other reports from Asian PICUs could not be compared with this study because they used an earlier version of PRISM.

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.

The study population had similar diseases and age-group distribution to other series. A similar percentage of patients to those of PICUs in England and Turkey 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%). The mortality of sepsis in a Turkish PICU was reported as higher than 50%. 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. 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) but similar to figures reported from 10 PICUs in Australia and New Zealand (0.77; 95% CI, 0.72-0.82).

The characteristics of prediction power of the two

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Probability of death (%)</th>
<th>Survivors</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected</td>
<td>Observed</td>
<td></td>
<td>Expected</td>
<td>Observed</td>
<td>SMR (95% CI)</td>
<td>P value</td>
</tr>
<tr>
<td>PRISM III</td>
<td>0.0 to &lt;25.0</td>
<td>288.81</td>
<td>288</td>
<td>2.19</td>
<td>3</td>
<td>1.37 (0.82-4.10)</td>
<td>0.395</td>
</tr>
<tr>
<td></td>
<td>25.0 to &lt;50.0</td>
<td>2.45</td>
<td>4</td>
<td>1.55</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50.0 to &lt;75.0</td>
<td>0.89</td>
<td>2</td>
<td>1.11</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75.0 to 100.0</td>
<td>0.66</td>
<td>1</td>
<td>5.94</td>
<td>5</td>
<td>0.94 (0.82-1.01)</td>
<td>0.380</td>
</tr>
<tr>
<td>PIM</td>
<td>0.0 to &lt;25.0</td>
<td>284.98</td>
<td>288</td>
<td>6.03</td>
<td>3</td>
<td>0.50 (0.36-0.82)</td>
<td>0.380</td>
</tr>
<tr>
<td></td>
<td>25.0 to &lt;50.0</td>
<td>2.97</td>
<td>4</td>
<td>2.03</td>
<td>1</td>
<td>0.49 (0.32-1.06)</td>
<td>0.380</td>
</tr>
<tr>
<td></td>
<td>50.0 to &lt;75.0</td>
<td>0.75</td>
<td>3</td>
<td>2.25</td>
<td>1</td>
<td>0.44 (0.31-0.79)</td>
<td>0.380</td>
</tr>
<tr>
<td></td>
<td>75.0 to 100.0</td>
<td>0.09</td>
<td>0</td>
<td>2.91</td>
<td>3</td>
<td>1.03 (0.94-1.15)</td>
<td>0.380</td>
</tr>
</tbody>
</table>

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