ORIGINAL ARTICLE

Evaluation of the Paediatric Index of Mortality in children managed on adult intensive care units

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Objective: To evaluate the performance of the Paediatric Index of Mortality (PIM) in children cared for in adult intensive care units (ICUs) in district general hospitals in the South West Region of England.

Design and setting: An observational survey of all children admitted to adult ICUs in 15 district general hospitals between November 2000 and August 2002. For comparison, data were also collected from the regional paediatric ICUs between November 2000 and March 2002.

Results: Data were collected from 374 children admitted to adult ICUs and 850 children admitted to the regional paediatric ICU. There were significant differences in the patient characteristics between the two groups. In the adult ICU paediatric population, PIM discriminated well between death and survival (Az ROC=0.96 (95% confidence interval, 0.93 to 0.99)) and calibrated well across deciles of risk (goodness of fit $\chi^2=4.55$ (8 df), $p=0.8$).

Conclusions: PIM performs well as a risk adjustment method in children whose entire care remains in the adult ICU of a district general hospital. This is important should the Paediatric Intensive Care Audit Network (PICAnet) decide to extend its data collection beyond paediatric intensive care units to other units caring for critically ill children.

The Paediatric Index of Mortality (PIM) is a risk adjustment tool that uses physiological variables collected at the time of first contact of the patient with the paediatric intensive unit (PICU) to predict the probability of death. The use of PIM, which adjusts for differences in severity of illness and diagnosis, allows standards of care to be compared between units, and within units over time. Mortality prediction models such as PIM have been used to stratify patients appropriately in research trials and to compare different systems of health care delivery.¹ The calibration of PIM has been assessed in United Kingdom paediatric intensive care units (PICUs),² and has recently been updated to take into account changes in treatment and referral practice.³

The Paediatric Intensive Care Audit Network (PICAnet), supported by the Department of Health and based at the Trent Institute for Health Services Research, aims to establish a clinical database of paediatric intensive care activity that identifies best practice and facilitates strategic planning. PICAnet has chosen PIM as its preferred risk adjustment tool, and henceforth PIM/PIM2 variables are collected as part of the minimum core dataset from all PICUs. Recently, it has been proposed to extend this data collection exercise to adult ICUs that care for critically ill children. However, an important limitation of mortality prediction models is that they are only applicable to situations where the characteristics and diagnoses of the patients are similar to the original dataset from which the model was derived. Henceforth, in the case of PIM/PIM2 this translates to children managed in recognised paediatric intensive care units. It follows therefore that if PICAnet is usefully to be extended to include children cared for in adult ICUs, it will be necessary to make a proper evaluation of its performance in this distinct paediatric population. The aim of our study was to evaluate the performance of PIM in children cared for in adult ICUs in district general hospitals in the South West Region of England.

METHODS

In the South West Region of the United Kingdom, data are routinely collected on all children who are admitted to adult

intensive care units (ICUs) as part of the south west critically ill children's audit. This data collection exercise allows the outcome of patients to be monitored, facilitates planning of paediatric services, and provided a dataset for this study. We conducted an observational survey of all children admitted to adult ICUs in 15 district general hospitals between November 2000 and August 2002. This study group encompassed children who remained on the ICU, and did not include those patients transferred to the lead PICU. For comparison, data were also collected from the regional PICU between November 2000 and March 2002. This comparison group included some children who were cared for initially in an adult ICU and were subsequently transferred to the PICU.

The dataset included PIM variables, demographic variables, level of dependency, ICU diagnosis, and outcome. The method for collecting and calculating PIM is published and readily available.⁴ Levels of dependency are defined by the context of the patient's level of care: level 1, high dependency; level 2, intensive care associated with intubation and ventilated; level 3, as for level 2 and associated with additional therapeutic procedures such as inotropic support; level 4, as for level 3 and associated with either renal replacement therapy or ECMO (PICS Standards document 2001). All data collection was undertaken by a single dedicated data collector in each hospital, from patient observation charts and notes, and the data were then collated centrally by a regional coordinator. Patient data were anonymised using unique numerical codes, therefore ensuring personal identification information was not available to the study team. The paediatric admissions records of each unit were reviewed at regular intervals to check for the completeness of recruitment. A 10% random sample of data collection forms was checked by the regional coordinator against the original observation charts to ensure accuracy of data collection. Ethical approval for the collection of these data had previously been sought and obtained from all the local research ethics committees (LRECs) of the participating

Abbreviations: PIM, Paediatric Index of Mortality; ROC, receiver operator characteristic

Table 1 Comparison of admissions to adult and paediatric intensive care units

	Adult ICU	PICU	p Value
Age (years) (mean (range))	9.0 (0.1 to 18)	1.2 (0 to 18)	<0.01
Sex ratio (M:F)	1:0.9	1:0.6	<0.01
Level of dependency			
1	47%	38%	<0.01
2	46%	40%	
3	6%	21%	
Ventilated in first hour	50%	65%	<0.01
Diagnostic breakdown			
Cardiology	2%	11%	
Cardiac surgery	0%	29%	
Respiratory	17%	23%	
Neurology	17%	11%	
Neurosurgery	26%	2%	
Infectious diseases	6%	4%	
Metabolic/endocrine	4%	2.5%	
Surgery	8.5%	7%	
ENT	4%	4%	
Orthopaedic/trauma	10%	2%	
Miscellaneous	4.6%	4.5%	

ENT, ear, nose and throat; F, female; M, male; ICU, intensive care unit; PICU paediatric intensive care unit.

hospitals.⁵ Therefore specific LREC approval for this analysis was not judged to be necessary.

Statistics

The characteristics of patients in both groups were compared using the Mann–Whitney test for continuous variables and the χ^2 test for categorical variables. The goodness of fit of PIM in this population of patients was tested in two ways. Discrimination evaluates how well PIM distinguishes between patients who lived and those who died, and was assessed using the area under receiver operator characteristic (ROC) plot. Calibration evaluates the performance of PIM at different risks of mortality, and was assessed by examining a Hosmer–Lemeshow 2×10 table. This displays how well the model matches observed outcomes in deciles of the population ranked by probability of death. The mean probability of death and the ratio of observed to expected death rates (standardised mortality ratio) was also calculated.

RESULTS

Data were collected on 374 children admitted to adult ICUs and from 850 admitted to the PICU. Table 1 shows the patient characteristics.

Table 2 shows the sample period, standardised mortality ratios, and the discrimination of the model in adult ICUs and in the regional PICU. The area under the ROC curve was 0.96 (95% confidence interval, 0.93 to 0.99) for the district general hospital adult ICUs, and 0.78 (0.71 to 0.85) for the regional PICU.

Table 3 shows calibration of the PIM model in adult ICUs. There was no significant heterogeneity between observed and predicted deaths across the 10 deciles of risk ($\chi^2 = 4.55$ (8 df),

$p = 0.8$). The calibration of PIM in the regional PICU was less good ($\chi^2 = 14.81$ (8df), $p = 0.06$).

DISCUSSION

In the South West Region of the UK, despite the centralisation of paediatric intensive care, many critically ill children continue to be managed in district general hospital adult ICUs. Such units only treat level 2 patients within an agreed protocol with the lead PICU, based upon a 24 hour rule—that is, children are only admitted to these units if at the outset it is not envisaged that they will require intubation for more than 24 hours. It is important for commissioners and health planners to monitor the activity of such units, and to do this some adjustment for the severity of illness at admission is necessary, using a risk adjustment tool such as PIM.

Analyses of the patient characteristics show significant differences between the two groups. Although this study was not designed to compare outcome, the standardised mortality ratio (SMR) of children managed in the PICU was lower than in adult ICUs, and previous studies of critically ill children have shown that those in the highest risk stratum have a significantly greater risk of dying if treated outside a designated PICU.⁵ Interestingly, PIM discriminated better between death and survival in district general hospitals than in the regional PICU. One might speculate that the reason for this closer modelling is because the physiological data necessary for PIM are collected at an earlier time point in the child's hospital course than when the PICU team collects them. Hence it represents primary organ failure, and is less affected by the treatment that may have been incurred before the child was retrieved by a PICU team. Unfortunately, owing to the small number of patients involved in the study it was not possible to evaluate the performance of PIM in different diagnostic groups. Such evaluation is important and in the past it has shown that in PICU patients PIM does not perform well in certain diagnostic groups. If PIM overpredicts or underpredicts death in a specific diagnostic group, then the overall performance of units as assessed by PIM would be influenced by the proportion of patients admitted in this category and bias the estimation of the SMR. Owing to the diagnostic disparity of the treatment groups acting as a potential source of confounding, it would be important to repeat this study with larger numbers of patients in order to assess the calibration of PIM/PIM2 in adult ICUs across diagnostic groups.

In summary, this study shows that PIM performs well as a risk adjustment method in children whose entire care remains in the adult ICU of a district general hospital. PIM discriminated well between death and survival (Az ROC = 0.96 (95% confidence interval, 0.93 to 0.99)) and calibrated well across deciles of risk (goodness of fit $\chi^2 = 4.55$ (8 df), $p = 0.8$). Therefore, on the basis of these findings the performance of PIM can be judged to be satisfactory as a risk adjustment method in this population of patients. However, future attempts by PICAnet to monitor outcome of children cared for on adult ICUs using revised risk adjustment tools such as PIM2 will require further evaluation in this population of patients.

Table 2 Outcome data by place of admission

	Duration of data collection (months)	Number of admissions (No of deaths)	Crude mortality	SMR (95% CI)	Mean probability of death (SD)	Median length of stay by hours (IQR)	Area under ROC plot
Adult ICUs	20	374 (31)	8.3%	0.94 (0.63 to 1.34)	0.087 (0.182)	20 (12.4 to 42)	0.958
Regional PICU	16	850 (43)	5%	0.69 (0.50 to 0.93)	0.073 (0.122)	58 (26.5 to 114)	0.785

CI, confidence interval; ICU, intensive care unit; IQR, interquartile range; PICU, paediatric intensive care unit; ROC, receiver operator characteristic; SMR, standardised mortality ratio.

Table 3 Calibration of the PIM model in district general hospital adult intensive care units

		Deciles of risk										Total
		1	2	3	4	5	6	7	8	9	10	
Died	Observed	0	0	0	0	0	1	0	2	6	22	31
	Expected	0.2	0.4	0.3	0.5	1.0	1.5	1.9	2.5	4.6	20.4	33.2
	O/E ratio	0	0	0	0	0	0.7	0	0.8	1.3	1.1	0.9
Survived	Observed	40	42	30	38	38	36	37	36	31	15	343
	Expected	39.7	41.6	29.7	37.5	37.0	35.5	35.1	35.5	32.4	16.6	340.8
	O/E ratio	1.01	1.01	1.01	1.01	1.03	1.01	1.05	1.01	0.96	0.9	1.01
Total		40	42	30	38	38	37	37	38	37	37	374

Hosmer and Lemeshow goodness of fit test: $\chi^2 = 4.55$ (8 df), $p = 0.8$.

O/E, observed over expected; PIM, Paediatric Index of mortality.

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ARCHIVIST

Serotype 1 pneumococcus and empyema

Empyema has increased in incidence among children in the UK over the last 10 years but the reasons are unknown. In the USA the most common pathogen in childhood empyema is *Streptococcus pneumoniae* serotype 1 and in Sweden the emergence of a new clone of this serotype was associated with a quadruple increase in invasive pneumococcal disease. Experience in Newcastle upon Tyne (KM Eastham and colleagues. *Thorax* 2004;**59**:522–5) has confirmed the importance of serotype 1.

Between February 1997 and August 2001 a total of 47 children were referred from district hospitals to the regional centre with empyema or parapneumonic effusion. There was a steady increase in numbers from four in 1998 to 15 in the first 8 months of 2001. Boys outnumbered girls by two to one and the mean age was 5.6 years (range 0.6–16.9 years). Thirty-one children had had no significant previous or concurrent illnesses; four had a concurrent infection (varicella zoster 3, campylobacter 1), eight had had previous respiratory problems (bronchiolitis 3, recurrent respiratory infection 3, asthma 2), two had haematological malignancy, and two had severe neurological disability. The median length of illness before hospital admission was 5 days and median stay in the district hospital 3 days. Almost all children (45) were treated with antibiotics before transfer. Thirty-seven children were infected with *S pneumoniae*, one also had *Staphylococcus aureus*, one was infected with *Streptococcus pyogenes*, and one with *Streptococcus viridans*. One child had tuberculosis. Bacterial culture of pleural fluid at the regional centre produced no organism in 44 cases, *S pyogenes* in one, *S aureus* in one, and *Staphylococcus epidermidis* (considered contaminant) in one. One child who was receiving chemotherapy for leukaemia had cytomegalovirus in her pleural fluid. PCR assay for pneumococcal DNA in pleural fluid was positive in 32 of 43 cases tested whereas pneumococcal latex antigen testing was positive in only 12 of 47. The 32 DNA-positive samples were submitted to a second PCR test for a conserved sequence of the *pbp2b* gene associated with penicillin susceptibility and all were positive. Seventeen of the 32 were serotype 1, four serotype 14, and three serotype 3. Eight were not serotyped. Thirty-two children underwent decortication and median postoperative inpatient stay was 4 days. At one month 41 were well, two were treated for haematological malignancy, three had a persistent cough, and one was breathless on exercise.

The number of children referred to this regional paediatric respiratory centre with empyema increased between 1998 and 2001 and this high rate has continued (there were 28 cases in the 2 years, August 2001–July 2003). Penicillin-sensitive pneumococci of serotype 1 appear to be the cause in many cases. The 7-valent conjugate vaccine does not contain serotypes 1 or 5 but a new 9-valent conjugate vaccine does. In a recent study in Soweto, South Africa the 9-valent vaccine given to HIV-negative infants had an efficacy of 83% in the prevention of invasive pneumococcal disease.