Risk-Adjusted Outcome Evaluation in a Multidisciplinary Intensive Care Unit

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ABSTRACT

Objective: *To evaluate the outcome of a multidisciplinary Intensive Care Unit (ICU) by applying the Acute Physiology and Chronic Health Evaluation (APACHE II) and Paediatric Index of Mortality (PIM) – version-2 scoring systems.*

Subjects and Methods: *Two-hundred and seventeen patients admitted consecutively to the ICU during a period of one year were included for prospective data collection. Data recorded were demographics, diagnoses at admission, APACHE II score for adults and PIM -2 score for children, the duration of ICU stay and hospital outcome. Predicted mortality and standardized mortality ratios were calculated. Calibration and discriminant function of the systems were done by Hosmer-Lemeshow analysis and Receiver Operating Characteristic (ROC) curves.*

Results: *In adults, the mean APACHE II score was 14.3 ± 8.3; in survivors, it was 8.7 ± 5.9 (SD) when compared to 21.2 ± 5.9 (SD) in non-survivors (p < 0.0001). The predicted mortality in adults by APACHE II was 16.5%, the observed mortality being 19.8%. The predicted mortality by the PIM-2 in children was 34.8% with the observed mortality rate being 30%. The overall mean duration of stay was 5.2 ± 7.5 days. The goodness-of-fit for APACHE II and PIM-2 systems were fair (HL chi-square,* p = *0.71, 0.69, respectively). The area under the ROC curve was 0.88 for APACHE II and 0.62 for PIM-2.*

Conclusion: *Evaluation of risk-adjusted outcome in multidisciplinary ICUs is challenging because of the need to apply more than one prognostic scoring system.*

Evaluación del Resultado Clínico Ajustado por Riesgo en una Unidad Multidisciplinaria de Cuidados Intensivos

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RESUMEN

Objetivo*: Evaluar el resultado clínico de una Unidad de Cuidados Intensivos (UCI) multidisciplinaria, aplicando la versión 2 de los sistemas de puntuación de la Evaluación de la fisiología aguda y la enfermedad crónica, versión II (conocida por su sigla en inglés como APACHE II) y del Índice Pediátrico de Mortalidad (IPM).*

Sujetos y Métodos: *Doscientos diecisiete pacientes ingresados consecutivamente en la UCI durante un período de un año fueron incluidos en la recopilación de datos prospectivos. Los datos registrados fueron la demografía, los diagnósticos de ingreso, la puntuación APACHE II para adultos y la puntuación IPM-2 para niños, la duración de la estadía en la UCI, y el resultado de la hospitalización. Se calcularon las proporciones (ratios) de mortalidad predicha y mortalidad estandarizada. La calibración y la función discriminante de los sistemas se realizaron mediante el análisis Hosmer-Lemeshow y las curvas de características operativas del receptor (ROC).*

Resultados: *En los adultos, la puntuación APACHE II media fue 14.3 ± 8.3; en los sobrevivientes fue 8.7 ± 5.9 (SD) en comparación con 21.2 ± 5.9 (SD) en los no sobrevivientes, (p < 0.0001). La mor-talidad predicha en los adultos por APACHE II fue 16.5%, siendo la mortalidad observada 19.8%. La mortalidad predicha para los niños según IPM-2 fue 34.8% con una tasa de mortalidad observada de 30%. La duración general promedio de estadía fue 5.2 ± 7.5 días. La bondad de ajuste para los sistemas APACHE II y IPM-2 fue aceptable (HL chi-square, p = 0.71, 0.69, respectivamente). El área bajo la curva de ROC fue 0.88 para APACHE II y 0.62 para IPM-2.*

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Conclusión: *La evaluación del resultado clínico ajustado por riesgo en las UCIs multidisciplinarias representa un desafío debido a la necesidad de aplicar más de un sistema de puntuación de pronóstco.*

INTRODUCTION

Many illness severity scoring systems are being used for predicting the outcome of patients admitted to intensive care units (ICU) (1). Although it is difficult to predict individual outcome of ICU patients accurately, there have been attempts to codify and validate models which may prognosticate groups of patients having similar presentations of the illness (2). Scoring systems are primarily being used to predict the general prognosis of patients but are also used as performance indicators of ICUs (3). This is usually accomplished by calculating the risk-adjusted mortality for a particular unit and comparing it with that of another (4).

The Acute Physiology and Chronic Health Evaluation (APACHE) scoring system is one of the most commonly used scoring systems for this purpose. Designed initially in 1981 by Knaus *et al*, the system has gone through three versions of which the most popular has been the APACHE II version (5). Paediatric Index of Mortality (PIM) was introduced by Shann *et a*l in 1997 to predict outcome in children admitted to ICUs (6). This system was also updated recently (PIM-2) and is supposedly better than the earlier version in outcome-predictability (7).

International comparisons of intensive care outcomes are important because critical care delivery patterns and resource consumption may vary considerably in various regions (8). This is especially true in many developing nations. There has been a multitude of studies in the literature comparing ICUs of different regions (9–13) but there is still a need for more work comparing different regions of the world (14). With this background, we conducted this prospective study in a multidisciplinary ICU to determine the value of scoring systems in predicting the outcome of our case-mix and also assessing the efficiency of the unit when compared to international standards.

Although there have been studies comparing different scoring systems in adult ICUs and paediatric ICUs separately, to our knowledge there have been few reports combining different systems pertaining to adult and paediatric patients in the same ICU.

Hospital and ICU setting

Trinidad and Tobago is a twin-island nation of the English-speaking Caribbean with a population of 1.3 million. The Eric Williams Medical Sciences Complex (EWMSC) is a 500-bed tertiary care centre, affiliated to The University of the West Indies and is a member of the American Hospitals Association.

The Multidisciplinary Intensive Care Unit in the EWMSC is a 6-bed open unit admitting both adult and paediatric patients belonging to all medical and surgical specialties. Patients are admitted from a Priority Care Facility (Emergency Department) directly, from the operating rooms and also from the general wards.

Two Senior House Officers take care of the unit around the clock under the supervision of an anaesthesiology registrar and a consultant while medical staff from the concerned specialty visit the patients daily. The nurse-patient ratio is 1:1.

The Radiology department and the Pathology and Microbiology laboratories of the hospital have state-of-the-art equipment facilitating a wide range of investigations. The majority of the patients admitted to the unit have invasive lines. The unit has facilities for blood gas analyses, portable radiograph and ultrasound.

METHODS

Approval of the Ethics Committee of the Faculty of Medical Sciences, The University of the West Indies, was obtained prior to conducting the study. All patients consecutively admitted to the multidisciplinary ICU over a period of one year from January 2004 to December 2004 were enrolled for prospective collection of data.

The demographic data recorded were the age and gender of the patients. The diagnoses on admission were noted. The APACHE II scoring system was applied to all adult patients. The worst Acute Physiology Score and the Glasgow Coma Score in the first 24 hours of admission were recorded in addition to the scores for age and chronic health status to calculate the APACHE II score. PIM-2 scoring system was applied on the day of admission to patients who were 12 years old and less. Patients were followed-up throughout their stay in ICU and during the hospital stay to record their final outcome. The length of stay in ICU was recorded. The hospital outcome was classified into – either "Discharged" or "Died".

The APACHE II score, the diagnostic category weight and the regression equation were used to calculate the predicted mortality for each adult patient:

{ln [R/1-R] = -3.517 + (APACHE II score × 0.146) + 0.603 (if post emergency surgery only) + diagnostic category weight}. Similarly, the regression equation published with PIM-2 scoring system was used to calculate the predicted mortality in paediatric patients:

PIM2 = [0.01395(PaO_2-120))] + [3.0791*pupil sign] + [0.2888*(FiO_2* 100/PaO_2)] + [0.104* base] + [1.3352*mechanical ventilation] – [0.9282*elective admission] – [1.0244*recovery] + [0.7507*cardiac bypass] – [1.6829*high risk diagnosis] – [1.5770*low risk diagnosis] – [4.8841]*

Probability of mortality = exponential (PIM2)/1 + exponential (PIM2)

Students "t" test was used to compare APACHE scores and length of stay between survivors and non-survivors.

Hosmer-Lemeshow goodness-of-fit analysis was done to calibrate both scoring systems. Receiver Operating Characteristic curve (ROC) analyses were done to analyze the discriminant function of the systems. Standardized mortality ratios (SMR) (ratio of the observed to the predicted mortality rate) were obtained for the adult and paediatric case mix separately. Statistical analyses were done using the Statistical Package for Social Sciences (SPSS®) version –12 software.

RESULTS

During the period of study, 217 patients were admitted to the ICU of which 117 (53.9%) were adult patients and 100 (46.1%) were paediatric patients. The median age of the adult patients was 52 years [42, 63 interquartile range (IQR)] [mean age 50.9 ± 17.3 (Standard Deviation) (SD)]. The median age of paediatric patients was 3 years (1, 7 IQR) [mean age 2.4 ± 3.2 (SD)].

Tables 1a and 1b show the demographic data, length of stay (LOS) and the outcome in adult and paediatric patients

Table 1a: Demographic data, length of stay and outcome in adults

Variable	**Overall (n = 117)**	**Survivors (n = 94)**	**Non-survivors (n = 23)**	***p*-value**
Age (Mean ± SD)	50.9 ± 17.3	50.1 ±16.3	53.8 ± 20.5	$p = 0.68$
Gender (n)				
Male	59	52	7	
Female	58	42	16	
APACHE II (Mean ± SD)	14.3 ± 8.3	8.7 ± 5.9	21.2± 5.9	$p < 0.001$
Length of stay (days) (Mean ± SD)	5.2 ± 7.5	4.2 ± 6.0	8.9 ± 10.7	$p < 0.001$
Observed mortality rate **(%)**	19.7	–	–	
Predicted mortality (%) (Mean ±SD)	16.5 ± 21.9	9.6 ± 12.2	45.0 ± 29.0	$p < 0.001$

Table 1b: Demographic data, length of stay and outcome in children

Variable	**Overall (n = 100)**	**Survivors (n = 70)**	**Non-survivors (n = 30)**	***p*-value**
Age (Mean ± SD)	2.4 ± 3.2	2.7 ± 3.3	1.8 ± 2.9	$p = 0.41$
Gender (n)				
Male	67	45	19	
Female	33	25	11	
Length of stay (days) (Mean ± SD)	9.15 ± 12.3	4.1 ± 4.3	4.5 ± 4.1	$p = 0.32$
Observed mortality rate **(%)**	30	–	–	
Predicted mortality (%) (Mean ± SD)	34.8 ± 15.1	18.4 ± 21.2	96.3 ± 25.3	$p < 0.001$

* As determined by independent 't'-test

respectively. The most common diagnostic categories are shown in Tables 2a and 2b.

Table 2a: Diagnostic categories of adult patients (n = 117)

Diagnosis	**Number**	**Percentage**
Multiple trauma	30	26
Cardiac surgery	27	23
Sepsis/ARDS	25	22
Myocardial infarction	23	19
General surgery	7	6
Others*	5	4

Table 2b: Diagnostic categories of paediatric patients (n = 100)

Diagnosis	**Number**	**Percentage**
Acute bronchopneumonia	43	43
Cardiac surgery	26	26
Paediatric surgery	10	10
Acute asthma	9	9
Congenital heart disease	8	8
Others*	4	4

Others* = renal failure, infective polyneuritis

One-hundred and eighty-six patients (86%) had mechanical ventilatory support during their stay in ICU.

In adult patients, the APACHE II scores ranged between 2 and 42 and the median APACHE score was 13 (8, 17 IQR); [mean APACHE II score 14.3 ± 8.3 (SD)]. The mean APACHE II score of the non-survivors was significantly higher [21.2 ± 5.9 (SD)] when compared to that of survivors [8.7 ± 5.9 (SD); $p < 0.0001$].

Overall, the patients' stay in the ICU ranged from 1 to 45 days and the median duration of stay for all patients in the ICU was 3 [2, 5 (IQR)] days. The mean length of stay of adult non-survivors was significantly higher than that of adult survivors while there was no significant difference in paediatric group. Paediatric patients had an LOS ranging from one to 22 days with a median of 4 [2, 5 (IQR)] days. The adult patients had an LOS ranging from two to 42 days with a median of 3 [2, 5 (IQR)] days. The length of stay of adult patients belonging to the category having an APACHE II score in the range of 16 to 30 was higher than the rest of the patients [mean LOS 16.5 ± 21.9 (SD)].

Among all patients, 7 (6%) of the adult patients and 9 (9%) of the paediatric patients had clinically confirmed brain-stem death due to trauma, cerebrovascular accidents and post cardiopulmonary resuscitation. All of them continued to receive mechanical ventilatory support until cessation of their heart-beat.

The observed mortality in adults was 19.7%; the mean predicted mortality for the adults according to APACHE II was 16.5%. The standardized mortality ratio (SMR) was 1.2.

The mortality rate increased with increase in APACHE II scores.

The observed mortality was 30% in paediatric patients; the mean predicted mortality according to PIM-2 was 34.8%. The standardized mortality ratio was 0.86.

Tables 3 and 4 depict the Hosmer –Lemeshow chi-square analyses for APACHE II and PIM-2 scoring systems

Table 3: Hosmer-Lemeshow goodness-of-fit analysis in adult patients for APACHE II

Groups (Predicted mortality)	Survivors Observed (n = 94)	Survivors Expected	Non-survivors Observed (n = 23)	Non-survivors Expected	Total (n = 117)
1	11	10.42	0	0.58	11
2	13	12.26	0	0.74	13
3	11	10.34	0	0.66	11
4	13	12.14	0	0.87	13
5	10	11.12	2	0.89	12
6	10	11.04	2	0.97	12
7	11	10.75	1	1.25	12
8	9	9.40	3	2.60	12
9	5	4.67	7	7.33	12
10	1	0.88	8	8.12	9

Goodness-of-fit test Chi-square value: 5.4223 df: 8 $p = 0.7116$

Table 4: Hosmer-Lemeshow goodness-of-fit analysis in paediatric patients for PIM 2

Groups (Predicted mortality	Survivors Observed (n = 70)	Survivors Expected	Non-survivors Observed (n = 30)	Non-survivors Expected	Total (n = 110)
1	7	7.52	3	2.48	10
2	8	8.24	3	2.76	11
3	10	8.19	1	2.81	11
4	7	7.40	3	2.60	10
5	8	7.25	2	2.75	10
6	8	7.21	2	2.80	10
7	8	7.17	2	2.83	10
8	6	7.85	5	3.15	11
9	5	6.64	5	3.36	10
10	3	2.54	4	4.46	7

Goodness-of-fit test Chi-square value: 5.6132 df: 8 $p = 0.6905$

respectively. The goodness-of-fit for APACHE II system was 5.42 (df: 8) and $p = 0.71$ while that for PIM-2 system was 5.61 (df: 8), $p = 0.69$.

Figures 1 and 2 show the Receiver Operating Characteristic (ROC) curves for APACHE II and PIM-2 scoring systems. The area under the curve (AUC) for the ROC curve for APACHE II system is 0.88 [95% Confidence Intervals (CI) 0.80, 0.96]. For PIM-2 scoring system the AUC is 0.62 (95% CI 0.49, 0.75).

DISCUSSION

The ICU had a wide range of admissions both with respect to age as well as diagnoses. Neonates were admitted to the unit because of the policy of the neonatal units in the country not to admit neonates who had been delivered elsewhere and/or transferred from other neonatal units. Many of the adult admissions were due to multiple trauma following motor vehicle accidents. In adult patients, the mortality rates increased with the increasing APACHE II scores and age which is the usual finding of other studies (15, 16). There was a considerable number of both adult and paediatric post-cardiac surgery patients because this institution has the unique opportunity of a variety of visiting cardiac surgeons from the United Kingdom and Latin American countries.

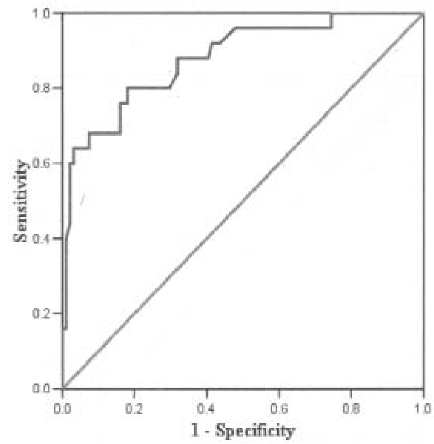

Fig. 1: Receiver operating characteristic curve for APACHE II in adult patients

Area under the curve (AUC) = 0.88
95% CI = 0.80, 0.96

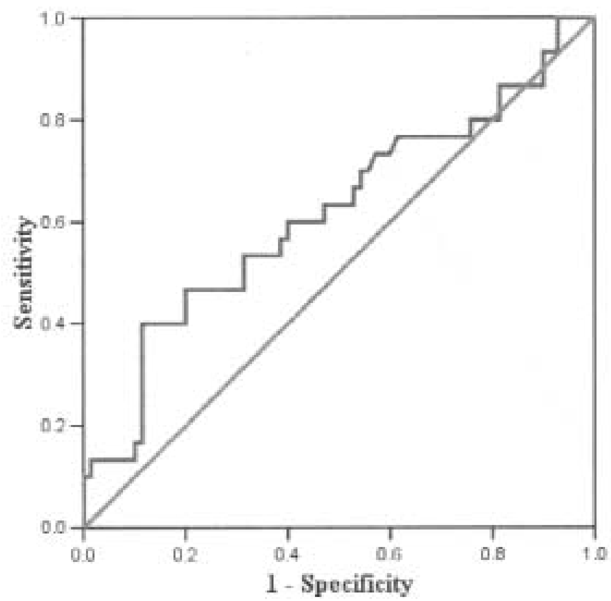

Fig. 2: Receiver operating characteristic curve for PIM-2 in paediatric patients

Area under the curve (AUC) = 0.62
95% CI = 0.49, 0.75

The length of stay of the patients also varied widely and was significantly higher in adult non-survivors than that in the survivors. This has also been reported by other studies (17). Similar to a report from Barbados, Trinidad and Tobago also does not have statutory regulations for withdrawing life-support in moribund and brain-dead patients (18). Hence, there was a number of patients (7%) with confirmed brain-death by clinical criteria but life support could not be withdrawn. This contributed to some of the increased length of stay in some non-survivors and inappropriate utilization of the resources.

Goodness-of-fit analyses of both scoring systems with respect to groups stratified according to predicted mortality showed that the models did fairly well (Tables 3 and 4). The area under the ROC curve for the APACHE II scoring system was 0.88. Although this may show that the system did reasonably well to discriminate the case mix, it was not perfect. This may be due to the fact that the APACHE II system does not have good predictive ability in certain groups of patients most notably trauma, sepsis and post cardiac surgery patients (19, 20), who formed the major groups of patients in the adult case-mix. Many studies have recommended that the differences in the case-mix have to be adjusted and also the data standardized to compare performances between ICUs. Under-prediction and over-prediction might be observed because of the lack of uniformity of the APACHE II equation when patients are grouped by certain characteristics (21, 22). The PIM-2 scoring system when introduced, calibrated well for risk deciles but poorly for diagnostic groups. The present study also showed a good calibration with respect to the groups of predicted mortality. By ROC analysis, the area under the curve for PIM-2 scoring system was 0.62 which may again point to the fact that this system did not discriminate well to predict the mortality of the paediatric case-mix. The authors who designed the PIM-2 scoring system themselves have acknowledged the fact that the system may not perform well in different environments. There may be a need to change the coefficients used for the regression equation to suit individual needs. However, firstly this may need a larger database and secondly the authors have opined against this alteration since they feel it may defeat the purpose of the model.

There have been many published reports comparing several paediatric prognostic scoring systems such as PIM, PRISM and its different versions and most of the these studies were done exclusively in paediatric ICUs (23–25). It was suggested that PIM may perform well in ICUs having relatively high mortality. Hence, we applied the latest version of PIM. It has been recognized that outcome evaluation in critically ill paediatric patients is a challenging task (26).

The standardized mortality ratio in adult patients in the present study is 1.20 which is comparable to reports from ICUs in the developed world and better than those reported from other developing countries such as India and Brazil (27, 28). The standardized mortality ratio in paediatric patients in the present study is 0.86. Although this may suggest that the unit is performing well, the fact is that because of the over-prediction of mortality, it may be interpreted that the unit has qualified with "honors" due to "grade inflation" as described by Popovich (29), in the commentary regarding the findings of the study of the Project Impact which showed very good performance of most of the ICUs when evaluated by the prognostic models (30).

The present study has limitations. The overall sample size was small. Preference of admission is usually given to paediatric patients due to the fact that the ICU services are free for this age group while it is fee-for-service pattern for adult patients. Although there were many adult patients in the present study, some patients would have been transferred from other ICUs and vice versa. Hence, there could have been lead-time effect in these admissions.

In conclusion, although illness severity scoring systems are commonly used for evaluating the outcome of an ICU and comparing it with international standards, the present study reinforces the view that this method of benchmarking ICUs inherently has pitfalls, especially in the case of a multidisciplinary ICU and there is a need to find new methods to assess performance of ICUs in a much broader sense.

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