The results of three major studies in the field of critical care nephrology have been published over the past 5 years. Their findings are important and likely to influence the practice of renal replacement therapy (RRT) worldwide. Therefore, beyond the main results, a thorough understanding of the data is of paramount importance for clinical research in acute kidney injury (AKI). However, comparison of outcomes between these three studies is made difficult by the use of three different scoring systems to report on illness severity — Simplified Acute Physiology Score (SAPS II), Acute Physiology and Chronic Health Evaluation (APACHE) II and APACHE III. To date, no method has been reported to help translate the results of one score into another. Hence, differences in outcomes between the studies cannot be compared as such.

Simple translational equations between illness severity scores would help develop comparisons between studies in the field of critical care nephrology. Accordingly, we sought to study the correlations between three of the most commonly reported illness severity scores (APACHE II, APACHE III and SAPS II) in critically ill patients with AKI. We used a large database where data for all three scores were simultaneously obtained and used for calculation. Our aim was to develop simple translational equations.

Methods
For the purpose of our study, we used data collected as part of the Australian and New Zealand Intensive Care Society (ANZICS) Adult Patient Database (APD). This database contains data for all the admissions to most adult intensive care units in Australia and New Zealand (>190 centres). Each hospital gives ethics approval and allows the data to be used for appropriate research, which is governed by the ANZICS Centre for Outcomes and Resource Evaluation (CORE) terms of reference and waives the need for informed consent. The database records contain APACHE II, APACHE III and SAPS II scores.

ABSTRACT

Background: In the field of critical care nephrology, recent publications have used different illness severity scoring systems, making outcome comparisons difficult.

Objective: To establish a methodology to translate one illness severity scoring system into another for critically ill patients with acute kidney injury (AKI).

Design: Statistical analysis of prospectively obtained data.

Methods: Using data from the Australian and New Zealand Intensive Care Society Adult Patient Database, we obtained Acute Physiology and Chronic Health Evaluation (APACHE) II, APACHE III and Simplified Acute Physiology Score (SAPS II) scores for all patients admitted with AKI. We applied correlation and linear regression analyses as well as cross-validation with holdout samples.

Results: Between 2001 and 2010, the three illness severity scores were obtained in 636,431 admissions. Of these, 37,203 fulfilled the APACHE score criteria for AKI. The coefficient of determination (R²) between APACHE II and APACHE III scores was 0.66. The overall model was APACHE III = 3.13 × APACHE II + 7.99 (P < 0.001). Similarly, the R² between APACHE III and the SAPS II scores was 0.78. The overall model was APACHE III = 1.49 × SAPS II + 15.5 (P < 0.001). The R² between APACHE II and SAPS II scores was 0.62. The overall model was APACHE II = 0.35 × SAPS II + 9.26 (P < 0.001).

Conclusions: Simple, robust translational formulae can be developed to allow clinicians to compare illness severity of patients with AKI when illness severity is expressed with different scoring systems.

Table 1. Correlations between illness severity scores from 37,203 records of patients with acute kidney disease, 2001–2010

<table>
<thead>
<tr>
<th></th>
<th>No. of observations</th>
<th>R²</th>
<th>P*</th>
<th>Coefficient (SE)</th>
<th>Intercept (SE)</th>
<th>P†</th>
</tr>
</thead>
<tbody>
<tr>
<td>APACHE II v APACHE III</td>
<td>37,203</td>
<td>0.66</td>
<td>&lt; 0.001</td>
<td>3.13 (0.010)</td>
<td>7.99 (0.33)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>APACHE III v SAPS II</td>
<td>37,203</td>
<td>0.78</td>
<td>&lt; 0.001</td>
<td>1.49 (0.004)</td>
<td>15.5 (0.23)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>APACHE II v SAPS II</td>
<td>37,203</td>
<td>0.62</td>
<td>&lt; 0.001</td>
<td>0.35 (0.001)</td>
<td>9.26 (0.08)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

APACHE = Acute Physiology and Chronic Health Evaluation. SAPS II = Simplified Acute Physiology Score.
* P for correlation test. † P for logistic regression.
Acute kidney injury definition and data extraction

As per the ANZICS CORE definition, AKI was defined as present if the 24-hour urine output was less than 410mL, the serum plasma creatinine concentration was acutely above 133 μmol/L, and the patient was not receiving chronic dialysis. We identified all admissions in the database for which these criteria were met between January 2001 and December 2010. We then recorded the corresponding APACHE II, APACHE III and SAPS II scores and analysed all patients stays with at least two simultaneous scores.

Statistical analyses

The distributions of APACHE II, APACHE III and SAPS II were found to be approximately normal. Linear relationships between severity markers were determined using linear regression with results reported as an intercept and slope estimate with a coefficient of determination ($R^2$). To establish the predictive capacity without bias associated from overfitting, the data were randomly divided into two samples of equal size, with parameter estimates derived from the first sample (derivation) and tested on the second (validation). To assess the relationship with mortality, logistic regression was performed using the validation sample with results reported as area under the receiver operating characteristic curve (AUROC). All analysis was performed using SAS, version 9.2 (SAS Institute Inc, Cary, NC, USA).

Results

In the study period, APACHE II, APACHE III and SAPS II scores were obtained from 636,431 admissions entered in the ANZICS APD. Of these, 37,203 met the criteria for AKI and were included in the analysis. Mean patient age was 66.7 years (SD, 15.9), 49.4% required mechanical ventilation, and 41.4% did not survive to hospital discharge.

Correlations between the different injury severity scores are shown in Table 1 and detailed below.

Correlation between APACHE II and APACHE III

There was a good correlation between APACHE II and APACHE III scores ($R^2 = 0.66$). The overall model was:

$$\text{APACHE III} = 3.13 \times \text{APACHE II} + 7.99$$

The standard error (SE) was 0.01 for the coefficient and 0.33 for the intercept ($P < 0.001$). On cross-validation, the training $R^2$ was 0.655 versus 0.664 in the validation sample, suggesting an absence of overfitting of the data.

Correlation between APACHE III and SAPS II

There was a very good correlation between SAPS II and APACHE III scores ($R^2 = 0.78$). The overall model was:

$$\text{APACHE III} = 1.49 \times \text{SAPS II} + 15.5$$

The SE was 0.004 for the coefficient and 0.23 for the intercept ($P < 0.001$). On cross-validation, the training $R^2$ was 0.774 versus 0.779 in the validation sample, suggesting an absence of overfitting of the data.
Correlation between APACHE II and SAPS II
The correlation between APACHE II and SAPS II scores was good ($R^2 = 0.62$). The overall model was:
APACHE II = 0.35 × SAPS II + 9.3 (Figure 1C).

The SE was 0.001 for the coefficient and 0.08 for the intercept ($P < 0.001$). On cross-validation, the training $R^2$ was 0.615 versus 0.621 in the validation sample, suggesting an absence of overfitting of the data.

Mortality prediction
The AUROC for mortality prediction for the APACHE III score was 0.80 (95% CI, 0.79–0.81). It was 0.75 (95% CI, 0.74–0.76) for the equivalent APACHE III calculated based on our APACHE II model, and 0.80 (95% CI, 0.80–0.81) for the equivalent APACHE III calculated based on our SAPS II model.

Discussion
To the best of our knowledge, this report is the first to study the relationship between APACHE II, APACHE III and SAPS II scores among critically ill patients with AKI. We found good correlations between the scores, and developed translational equations to enable conversion of numerical scores obtained with one into another. The proposed models achieve high statistical significance and the associations are robust. These models appear likely to improve the quality of comparisons of illness severity among AKI patients from different studies.

Of note, physiological data were only collected in the first 24 hours of admission; thus, patients who developed AKI later during their ICU stay were not included. Similarly, we cannot report data on RRT during the ICU stay or correct for AKI severity. However, such biases are unlikely to be of any significant relevance, as the importance of the creatinine concentration in the scoring system is only minor, and this limitation is common to all scoring systems, which are based only on the first 24 hours of the ICU admission.

To illustrate the importance of such translational equations, we can now compare illness severity between three recent RRT trials using the proposed models. Accordingly, the mean APACHE II scores reported in the ATN (Acute Renal Failure Trial Network) study2 (26.6 in the “intensive strategy” group and 26.1 in the “less-intensive strategy” group) would translate into equivalent APACHE III scores of 87.7 and 86.1, respectively. Similarly, the mean SAPS II score of 48 for the patients included in the BEST Kidney (Beginning and Ending Supportive Therapy for the Kidney) study1 would translate into an equivalent APACHE III score of 87. These results would suggest that under any conceivable assumptions, the patients enrolled in both these studies could not have been more severely ill than those enrolled in the RENAL (Randomized Evaluation of Normal versus Augmented Level) Replacement Therapy Study,3 in which APACHE III scores were 102.5 and 102.3 in the “higher intensity” and “lower intensity” groups, respectively.

Before they can be universally recognised, the reproducibility of these translational formulae need to be confirmed by other large databases. Further studies should include databases where simultaneous and prospective calculation of at least two of these scores was performed.

Conclusions
There are good correlations between the APACHE II, APACHE III and SAPS II scores of patients with AKI. Simple, robust translational formulae can be developed to allow clinicians to compare illness severity in intensive care studies of similar patients when such illness severity is expressed with different scoring systems.

Competing interests
None declared.

Author details
Antoine G Schneider, Research Fellow1,2
Miklós Lipcsey, Specialist Physician in Anaesthesia and Intensive Care3
Michael Bailey, Chief Biostatistician2
David V Pilcher, Intensivist,4 and Director5
Rinaldo Bellomo, Director of Research,1 and Co-director2
1 Department of Intensive Care, Austin Health, Melbourne, VIC, Australia.
2 Australian and New Zealand Research Centre, Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, VIC, Australia.
3 Section of Anaesthesiology and Intensive Care, Department of Surgical Sciences, Uppsala University, Uppsala, Sweden.
4 Department of Intensive Care Medicine, Alfred Hospital, Melbourne, VIC, Australia.
5 Adult Patient Database, Australian and New Zealand Intensive Care Society Centre for Outcomes and Resource Evaluation, Melbourne, VIC, Australia.

Correspondence: Rinaldo.Bellomo@austin.org.au

References