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A comparison of the RIFLE and AKIN criteria for acute kidney injury in critically ill patients

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Abstract

Background. The Acute Dialysis Quality Initiative Group has published a consensus definition/classification system for acute kidney injury (AKI) termed the RIFLE criteria. The Acute Kidney Injury Network (AKIN) group has recently proposed modifications to this system. It is currently unknown whether there are advantages between these criteria.

Methods. We interrogated the Australian New Zealand Intensive Care Society (ANZICS) Adult Patient Database (APD) for all adult admissions to 57 ICUs from 1 January 2000 to 31 December 2005. We compared the performance of the RIFLE and AKIN criteria for diagnosis and classification of AKI and for robustness of hospital mortality.

Results. We included 120 123 critically ill patients, of which 27.8% had a primary diagnosis of sepsis. We found only small differences (<1%) in the number of patients classified as having some degree of kidney injury using either the AKIN or RIFLE definition or classification systems. AKIN slightly increased the number of patients classified as Stage I injury (category R in RIFLE) (from 16.2 to 18.1%) but decreased the number of patients classified as having Stage II injury (category I in RIFLE) (13.6% versus 10.1%). The area under the ROC curve for hospital mortality was 0.66 for RIFLE and 0.67 for AKIN in all patients and it was 0.65 for both in septic patients.

Conclusion. Compared to the RIFLE criteria, the AKIN criteria do not materially improve the sensitivity, robustness and predictive ability of the definition and classification of AKI in the first 24 h after admission to ICU.

Keywords acute kidney injury; acute renal failure; AKIN; critically ill; RIFLE

Introduction

Acute kidney injury (AKI) is a common clinical problem encountered in critically ill patients and characteristically portends an increase in morbidity and mortality [1].

Previous epidemiologic investigations describing the incidence and outcomes of AKI in critically ill patients have been limited due to the differences used in defining and classifying AKI [2–9]. This has been unfortunate and likely contributed to hindering scientific progress in the field of critical care nephrology [10,11].

The Acute Dialysis Quality Initiative (ADQI) group, comprising experts in the fields of nephrology and critical care medicine, recently published the RIFLE classification, a new consensus and evidence-based definition for AKI [12]. The RIFLE classification defines three grades of severity of AKI (Risk, Injury and Failure) based on changes to serum creatinine and urine output and two clinical outcomes (Loss, End-stage) (Table 1). The RIFLE classification has now been evaluated in a number of clinical studies of critically ill patients with AKI [13–24]. In general, these criteria have been found to have clinical relevance for the diagnosis of AKI, classifying the severity of AKI and for monitoring the progression of AKI, as well as having modest predictive ability for mortality.

More recently, the Acute Kidney Injury Network (AKIN) group, an international collaboration of nephrologists and intensivists, have proposed refinements to the RIFLE criteria [25]. In particular, the AKIN group sought to increase the sensitivity of the RIFLE criteria by recommending that a smaller change in serum creatinine ($\geq$26.2 μmol/L) be used as a threshold to define the presence of AKI and identify patients with Stage 1 AKI (analogous to RIFLE-Risk) (Table 1). Second, a time constraint of 48 h for the diagnosis of AKI was proposed. Finally, any patients receiving renal replacement therapy (RRT) were to now be classified as Stage 3 AKI (RIFLE-Failure).

It is currently unknown whether discernible advantages exist with one approach to definition and classification versus the other.

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Table 1. A comparison of the RIFLE and AKIN definition and classification schemes for AKI

RIFLE category	Serum creatinine criteria	UO criteria
(A) The Acute Dialysis Quality Initiative (ADQI) criteria for the definition and classification of AKI (i.e. RIFLE criteria)		
Risk	Increase in serum creatinine ≥1.5X baseline or decrease in GFR ≥25%	<0.5 mL/kg/h for ≥6 h
Injury	Increase in serum creatinine ≥2.0X baseline or decrease in GFR ≥50%	<0.5 mL/kg/h for ≥12 h
Failure	Increase in serum creatinine ≥3.0X baseline or decrease in GFR ≥75% or an absolute serum creatinine ≥354 μmol/L with an acute rise of at least 44 μmol/L	<0.3 mL/kg/h ≥24 h or anuria ≥12 h
AKIN criteria	Serum creatinine criteria	UO criteria
(B) The proposed Acute Kidney Injury Network (AKIN) criteria for the definition and classification of AKI		
Stage 1	Increase in serum creatinine ≥26.2 μmol/L or increase to ≥150–199% (1.5- to 1.9-fold) from baseline	<0.5 mL/kg/h for ≥6 h
Stage 2	Increase in serum creatinine to 200–299% (>2–2.9 fold) from baseline	<0.5 mL/kg/h for ≥12 h
Stage 3	Increase in serum creatinine to ≥300% (≥3-fold) from baseline or serum creatinine ≥354 μmol/L with an acute rise of at least 44 μmol/L or initiation of RRT	<0.3 mL/kg/h ≥24 h or anuria ≥12 h

Accordingly, we interrogated the Australian and New Zealand Intensive Care Society (ANZICS) Adult Patient Database (APD) to obtain information on AKI as defined by both the RIFLE and AKIN criteria in a large cohort of critically ill patients from 57 Australian hospitals over a 5-year period. The ANZICS APD is a clinical database containing data from >600 000 individual adult admissions to 135 intensive care units (ICUs) from 1987 to the present [26].

Our primary objectives were to evaluate (1) the occurrence of AKI within 24 h of ICU admission using the two different classification systems, (2) the effect on epidemiology of classifying patients according to the AKIN or RIFLE criteria in a large multi-centre heterogenous population of critically ill patients and (3) the robustness of the AKIN and RIFLE criteria and their relationship with hospital mortality in all patients and in those patients with a primary admission diagnosis of sepsis.

Methods

This was a retrospective analysis of prospectively collected data to compare the RIFLE and AKIN definition/classification schemes for AKI [12,25]. We interrogated the ANZICS APD for all adult (age ≥18 years) ICU admissions for a duration ≥24 h from 1 January 2000 to 31 December 2005. Only the index admission to ICU was considered. Patients discharged and re-admitted within 72 h were classified as part of the index admission.

We excluded patients with end-stage kidney disease (ESKD) on chronic dialysis, prior ESKD or patients admitted following kidney transplant.

We included data from only those ICUs that had continuously contributed data to the APD during this 5-year period. This comprised of 57 ICUs (19 tertiary referral, 15 metropolitan, 12 regional/rural and 11 private hospitals).

Identification of cases

AKI was classified according to both the RIFLE and AKIN criteria [12,25] (Table 1). The RIFLE criteria (acronym indicating Risk of renal dysfunction; Injury to the kidney; Failure of kidney function; Loss of kidney function; and End-stage kidney disease) classify AKI into three categories of severity (Risk, Injury and Failure) and two categories of clinical outcome (Loss and End-stage kidney disease). The AKIN criteria classify AKI into three stages of severity (Stages 1, 2 and 3).

Urine output data were available for 92.4% of patients ($n = 111\,091$). However, only a cumulative 24-h output was described. We did not have patient weights. Thus, we used a minor modification of the RIFLE and AKIN urine output criteria, assuming an average patient weight of 70 kg, into <35 mL/h (Risk or Stage 1), <21 mL/h (Injury or Stage 2) or <4 mL/h (Failure or Stage 3). We did not have data available on the proportion of patient receiving acute RRT.

Baseline serum creatinine values were unavailable and were estimated by the Modification of Diet in Renal Disease (MDRD) equation as recommended (assuming a lower limit of normal baseline GFR of 75 mL/min) and previously applied [12,20,23,27]. For analysis, patients were assigned to their worst RIFLE or AKIN category according to either serum creatinine or urine output criteria.

Data collection

Standard demographic, clinical and physiologic data were retrieved. Demographic information included age, sex and duration of ICU and hospital stay. Clinical data included primary diagnosis, a diagnosis of sepsis/septic shock, surgical status, presence of co-morbidities and need for mechanical ventilation. Physiologic data included serum pH, serum potassium, serum creatinine, urea and urine output [28]. Severity of illness was assessed using the Acute Physiology and Chronic Health Evaluation (APACHE) II [29]. The presence of pre-existing comorbidities was defined by use of the chronic health evaluation for APACHE II, APACHE III and SAPS II systems as outlined in the ANZICS APD data dictionary. Sepsis/septic shock included all admissions for primarily sepsis-related diagnoses and included sepsis associated with pneumonia, gastrointestinal disease, urinary tract infections, central nervous system infections, soft tissue infections and the unique ANZICS APD additions of sepsis with shock of undetermined source.

Table 2. Patient demographics and primary diagnosis at ICU admission for the total cohort and septic subgroup

Characteristics	Total ($n = 120\,123$)	Septic ($n = 33\,375$)
Age (years) [mean (SD)]	61.6 (17.5)	61.3 (17.6)
Male sex (%)	59.5	57.3
Comorbidities disease (%)	28.6	30.3
Surgical admission (%)	49.7	28.8
Sepsis/septic shock (%)	27.8	100
APACHE II score [mean (SD)]	16.9 (7.7)	18.3 (8.3)
Mechanical ventilation (%)	52	49.4
pH [mean (SD)]	7.33 (0.11)	7.33 (0.13)
Potassium (mmol/L) [mean (SD)]	4.3 (0.8)	4.2 (0.9)
Creatinine (μmol/L) [median (IQR)]	98 (68–130)	93 (69–154)
Urea (mmol/L) [median (IQR)]	6.6 (4.6–10.8)	7.6 (4.9–13.5)
Urine output (L/24h) [mean (SD)]	2.1 (1.3)	2.1 (1.3)

Abbreviations: APACHE = Acute Physiology and Chronic Health Evaluation; SAPS = Simplified Acute Physiology Score. SI conversion rates: serum creatinine 1 mg/dL = 88.4 μmol/L; serum urea 1 mg/dL = 0.357 mmol/L.

Table 3. Incidence of AKI stratified by the RIFLE and AKI definition/classification schemes

RIFLE category	Total (%) ($n = 120\,123$)	Septic (%) ($n = 33\,375$)	AKIN category	Total (%) ($n = 120\,123$)	Septic (%) ($n = 33\,375$)
None (%)	76 728 (63.9)	19 336 (57.9)	None (%)	75 570 (62.9)	18 889 (56.6)
Risk (%)	19 547 (16.2)	5 406 (16.2)	Stage 1 (%)	21 741 (18.1)	6 140 (18.4)
Injury (%)	16 344 (13.6)	5 444 (16.3)	Stage 2 (%)	12 160 (10.1)	4 010 (12.0)
Failure (%)	7 504 (6.3)	3 189 (9.6)	Stage 3 (%)	10 652 (8.9)	4 336 (13.0)
Any category (%)	43 395 (36.1)	14 039 (42.1)	Any stage (%)	44 553 (37.1)	14 486 (43.4)

Abbreviations: RIFLE = Risk, Injury, Failure, Loss, End-stage kidney disease; AKIN = Acute Kidney Disease Network.

Statistical analysis

Analysis was performed using Stata version 8.2 (Stata Corp., College Station, TX, USA). In the event of missing data values, data were not replaced. Normally or near normally distributed variables are reported as means with standard deviations (SD) and compared by Student's *t*-test, analysis of variance or simple linear regression. Non-normally distributed continuous data are reported as medians with inter-quartile ranges (IQR) and compared by the Mann–Whitney *U*-test or Kruskal–Wallis test. Categorical data were reported as proportions and compared using Fisher's exact test. Logistic regression analysis was used to assess the association of each RIFLE and AKIN category with hospital mortality. Model fit was assessed by the goodness-of-fit test and discrimination was assessed by the area under the receiver operator characteristic (AuROC) curve. Data are presented as odds ratios (OR) with 95% confidence intervals (CI). A P-value of < 0.05 was considered statistically significant for all comparisons.

Results

During the study period, 124 088 critically ill patients were admitted for a minimum 24 h to the 57 ICUs. From these, a total of 120 123 (96.8%) had satisfactory data for analysis (Table 2). Sepsis/septic shock was the primary admission diagnosis for 27.8% of the cohort.

Acute kidney injury stratified by the RIFLE criteria

AKI occurred in 36.1% with a maximum RIFLE category: Risk in 16.2%, Injury in 13.6% and Failure 6.3% (Table 3). An estimated 42.1% of patients with sepsis/septic shock had evidence of AKI defined by the RIFLE criteria within 24 h of ICU admission.

Acute kidney injury stratified by the AKIN criteria

When defined by the AKIN criteria, AKI occurred in 37.1% with 18.1% with Stage 1, 10.1% with Stage 2 and 8.9% with Stage 3 (Table 3). A total of 43.4% of patients with sepsis/septic shock were classified by the AKIN criteria as having AKI within 24 h of ICU admission (Table 3).

Mortality

Crude hospital mortality was significantly higher for AKI defined by any of the RIFLE criteria (24.2% versus 8.9%, OR 3.29, 95% CI 3.19–3.41, $P < 0.0001$) (Table 4). This was similarly shown for AKIN defined by the AKIN criteria (24.5% versus 8.5%, OR 3.13, 95% CI 3.0–3.3, $P < 0.0001$). There were no statistical differences in mortality by the AKI definition/classification criteria ($P = 0.40$) (Table 5) (Figure 1).

Discussion

We conducted a 5-year analysis of 120 123 admissions to 57 ICUs across Australia, using a large clinical database, to compare the RIFLE and AKIN definition/classification systems for AKI.

We have confirmed that the RIFLE criteria identify and classify a significant proportion of all critically ill patients

Table 4. Clinical outcomes stratified by the RIFLE and AKI definition/classification schemes

Clinical outcome	Classification system	
	RIFLE	AKIN
Crude mortality (%)		
Total cohort	None 8.9	None 8.5
	Risk 17.9	Stage 1: 18.5
	Injury 27.7	Stage 2: 28.1
	Failure 33.2	Stage 3: 32.6
	Any 24.2	Any 24.5
Crude mortality (%)		
Septic cohort	None 12.6	None 12.0
	Risk 23.4	Stage 1: 24.1
	Injury 32.2	Stage 2: 32.8
	Failure 35.8	Stage 3: 35.5
	Any 29.7	Any 29.9
ICU length of stay (days)		
Dead [median (IQR)]	3.7 (2.0–8.1)	3.7 (2.0–8.1)
Alive [median (IQR)]	3.0 (1.8–6.0)	3.0 (1.8–5.9)
Hospital length of stay (days)[a]		
Dead [median (IQR)]	9.1 (3.7–20.7)	9.2 (3.8–20.9)
Alive [median (IQR)]	14.5 (8.6–26.9)	14.6 (8.6–27.1)

[a]Any AKI criteria.

with AKI, and show robustness for prediction of hospital outcome in this large heterogenous cohort. This has been similarly shown in numerous smaller studies in a variety of critically ill populations [13–24].

However, the AKIN group has proposed a number of modifications to the RIFLE criteria [25]. The principal aim for these revisions was to improve the sensitivity and reproducibility of the criteria for defining and classifying AKI [25]. These included incorporating an acute change in serum creatinine as little as 26.2 μmol/L to the diagnostic criteria for AKI. In addition, a time constraint of 48 h for the diagnosis of AKI was proposed. Finally, the AKIN group amended the AKI Stage 3 (RIFLE-Failure) to now include any patient receiving RRT. It is currently unknown whether these proposed modifications improve the ability of the definition/classification system to identify patients at risk of dying or whether these modifications materially influence how patients are classified into different severity categories of injury.

Accordingly, we have utilized a large multi-centre clinical database to compare the performance of the RIFLE and AKIN definition/classification systems in a heterogeneous population of critically ill patients [26]. We compared the overall incidence and severity classification of the RIFLE and AKIN criteria in this cohort and found no significant differences. We also compared the clinical outcomes, specifically hospital mortality and duration of stay in ICU and hospital, and found no material differences. Moreover, we also evaluated the subgroup of critically ill patients with a primary admission diagnosis of sepsis/septic shock. Sepsis is the leading contributing factor to AKI in critically ill patients and generally portends a worse prognosis [30]. We found no clinically important differences in outcome by the RIFLE or AKIN criteria in this subgroup analysis.

These findings are relevant as they suggest that the proposed modifications to an already recognized and established definition/classification system (i.e. RIFLE criteria) fail to bring about material advantages. Moreover, our results suggest that future effort should focus more on the successful application and extend use of the RIFLE criteria to the randomization of patients in clinical trials or on its use as a surrogate marker of a clinically important outcome in clinical trials aimed as prevention or attenuation of renal injury.

Our study has both strengths and weaknesses. First, our study focuses on the occurrence of AKI at or within the first 24 h of admission to ICU only. We recognize a number of ICU patients will have delayed onset of AKI occurring >24 h after ICU admission or even considerably later in their course of critical illness. As such, our incidence estimates of early AKI may be an underestimate of the true cumulative burden of AKI in our cohort. We are

Table 5. Predictive ability for crude hospital mortality by separate multivariable logistic regression models for the RIFLE and AKIN definition/classification schemes. (**A**) RIFLE criteria; (**B**) AKIN criteria

Criteria	Odds ratio (95% CI)	*P*	AuROC curve
(A) RIFLE criteria			
RIFLE category[a]			
Risk	2.24 (2.1–2.3)	<0.001	0.66
Injury	3.95 (3.8–4.1)	<0.001	
Failure	5.13 (4.9–5.4)	<0.001	
Septic cohort RIFLE category[a]			
Risk	2.12 (1.9–2.3)	<0.001	0.65
Injury	3.31 (3.1–3.5)	<0.001	
Failure	3.89 (3.6–4.2)	<0.001	
(B) AKIN criteria			
AKI category[a]			
Stage 1	2.45 (2.3–2.6)	<0.001	0.67
Stage 2	4.23 (4.0–4.4)	<0.001	
Stage 3	5.22 (5.0–5.5)	<0.001	
Septic cohort AKIN category[a]			
Stage 1	2.33 (2.2–2.5)	<0.001	0.65
Stage 2	3.59 (3.3–3.9)	<0.001	
Stage 3	4.04 (3.7–4.4)	<0.001	

[a]Reference variable: no acute kidney injury.

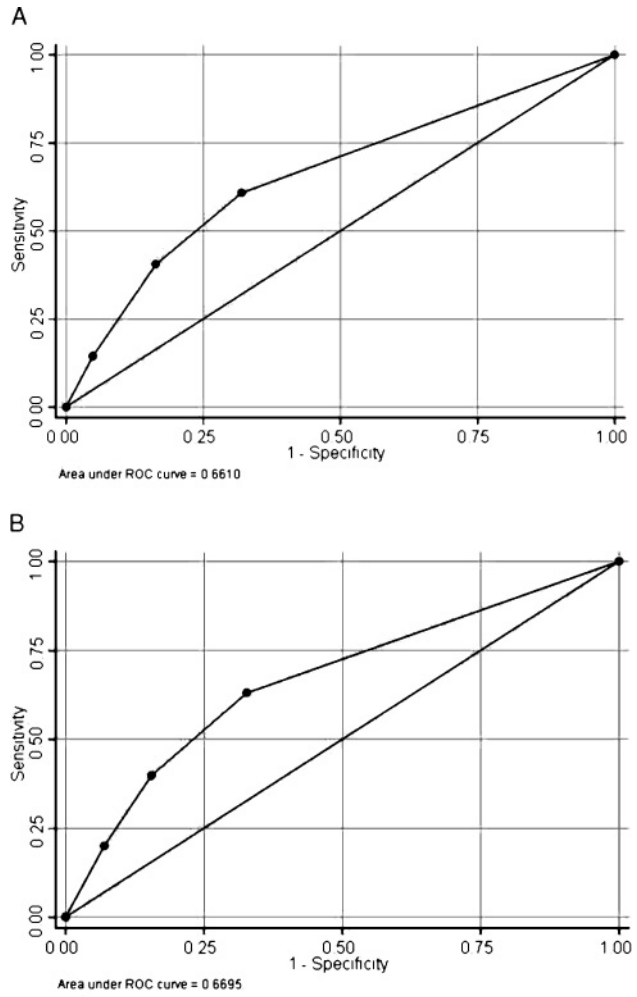

Fig. 1. AuROC curves for the total cohort for the RIFLE and AKIN definition/classification schemes.

also unable to specifically comment on the differences in incidence of AKI or associated clinical outcomes by the variable time constraints originally proposed by the RIFLE criteria (1–7 days) and now by the AKIN criteria (<48 h). At present, there is a paucity of data to show whether small differences in the time over which AKI occurs (i.e. 24 versus 48 versus 72 h) have any meaningful impact on clinical outcome. However, while perhaps the AKIN criteria are more sensitive than the RIFLE criteria, the added constraint for defining AKI proposed by the AKIN criteria of <48 h potentially risks misclassifying a significant proportion of patients. We believe this issue requires prospective investigation. Second, we did not have the baseline serum creatinine or the prevalence of CKD (except for those with end-stage kidney disease). However, we know this problem is common. Instead, we calculated an estimate of baseline function by use of the MDRD equation. Third, we did not have hourly urine output data for all critically ill patients. As a result, our study may provide a biased estimate of the true burden of AKI according to urine output criteria across this large heterogeneous cohort. Overall, we recognize that any biases would influence both the RIFLE and AKIN criteria and thus not significantly influence our conclusions. We were also not able to specifically evaluate the performance of the proposed minimum urine output criteria (<0.5 mL/kg/h for ≥6 h) to qualify as AKI as defined by both the RIFLE and AKIN criteria. While such a change in urine output may be a sensitive marker of AKI, it will likely have poor specificity. Clearly, urine output can be modified by additional factors independent of changes in kidney function (i.e. diuretic therapy). However, these urine output criteria have yet to be prospectively evaluated. Yet, the proposed AKIN criteria also recommend only applying the urine output criteria 'following adequate fluid resuscitation'. Regrettably, this statement is ambiguous and may possibly just add confusion as to when to apply the urine output criteria in the diagnosis of AKI. We contend that the urine output criteria for AKI, as originally proposed by the RIFLE criteria, should be used until prospective evaluations conclude otherwise. Fourth, we do not have data on the proportion of patients with AKI that required acute RRT. This may translate into a discriminating variable, both for classification and outcome, between the RIFLE and AKIN criteria. However, we recognize from prior studies that RRT is generally performed in only 4% of all critically ill patients and that the majority of those requiring acute RRT would fulfil the RIFLE-Failure category. Thus, we believe it unlikely that many patients would have been re-classified had we had such data available. Nonetheless, the relationship between the RIFLE category at the time of ICU admission and the subsequent need for RRT is worthy of further investigation. Finally, our study is greatly strengthen by the inclusion of >120 000 heterogenous critically ill patients from 57 ICUs across Australia. This represents the largest cohort study of AKI performed to date.

Conclusion

In conclusion, compared to the RIFLE criteria, the newly proposed AKIN criteria do not materially improve the sensitivity, robustness or predictive ability of the definition and classification of AKI in the first 24 h after admission to ICU. There would appear to be no justification at present for the introduction of a modified definition and classification system for AKI. Any future refinements to the RIFLE criteria (i.e. time constraint or urine output) should ideally occur only after prospective evaluation in clinical studies. Moreover, instead of seeking minor modifications which do not materially affect the robustness, clinical utility and predictive ability of RIFLE, future investigations should also ideally focus on its utility as a means of identifying patients for randomization into clinical trials of early interventions to protect the kidney from advanced renal injury, as a means of stratification of injury for optimal trial randomization and as a surrogate outcome measure in pilot investigations aimed at identifying new interventions which protect the kidney during critical illness.

Key messages

- The RIFLE criteria identify and classify an estimated 36.1% of all critically ill patients as having AKI.

- The RIFLE criteria are robust in this large heterogenous population of critically ill patients for prediction of hospital mortality.
- The proposed modifications to the RIFLE criteria by the AKIN group increase the sensitivity of the RIFLE-Risk category, however, show no significant differences in incidence or outcome.

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Conflict of interest statement. None declared. S.M.B. developed the study protocol, analysed data, wrote and revised the manuscript. C.G. extracted the data from the ANZICS APD. R.B. conceived the study, assisted in developing the study protocol, wrote and revised the manuscript. All authors read and approved the final manuscript.

(See related article by John A Kellum. Defining and classifying AKI: one set of criteria. *Nephrol Dial Transplant* 2008; 23: 1471–1472.)

References

1. Uchino S, Kellum JA, Bellomo R *et al*. Acute renal failure in critically ill patients: a multinational, multicenter study. *JAMA* 2005; 294: 813–818
2. Bagshaw SM, Laupland KB, Doig CJ *et al*. Prognosis for long-term survival and renal recovery in critically ill patients with severe acute renal failure: a population-based study. *Crit Care* 2005; 9: R700–R709
3. Metnitz PG, Krenn CG, Steltzer H *et al*. Effect of acute renal failure requiring renal replacement therapy on outcome in critically ill patients. *Crit Care Med* 2002; 30: 2051–2058
4. Metcalfe W, Simpson M, Khan IH *et al*. Acute renal failure requiring renal replacement therapy: incidence and outcome. *QJM* 2002; 95: 579–583
5. Silvester W, Bellomo R, Cole L. Epidemiology, management, and outcome of severe acute renal failure of critical illness in Australia. *Crit Care Med* 2001; 29: 1910–1915
6. de Mendonca A, Vincent JL, Suter PM *et al*. Acute renal failure in the ICU: risk factors and outcome evaluated by the SOFA score. *Intensive Care Med* 2000; 26: 915–921
7. Cole L, Bellomo R, Silvester W *et al*. A prospective, multicenter study of the epidemiology, management, and outcome of severe acute renal failure in a 'closed' ICU system. *Am J Respir Crit Care Med* 2000; 162: 191–196
8. Liano F, Junco E, Pascual J *et al.* The Madrid Acute Renal Failure Study Group. The spectrum of acute renal failure in the intensive care unit compared with that seen in other settings. *Kidney Int Suppl* 1998; 66: S16–S24
9. Brivet FG, Kleinknecht DJ, Loirat P *et al*. French Study Group on Acute Renal Failure. Acute renal failure in intensive care units—causes, outcome, and prognostic factors of hospital mortality; a prospective, multicenter study. *Crit Care Med* 1996; 24: 192–198
10. Kellum JA, Levin N, Bouman C *et al*. Developing a consensus classification system for acute renal failure. *Curr Opin Crit Care* 2002; 8: 509–514
11. Bellomo R, Kellum JA, Ronco C. Defining and classifying acute renal failure: from advocacy to consensus and validation of the RIFLE criteria. *Intensive Care Med* 2007; 11: 409–413
12. Bellomo R, Ronco C, Kellum JA *et al*. Acute renal failure—definition, outcome measures, animal models, fluid therapy and information technology needs: the second international consensus conference of the Acute Dialysis Quality Initiative (ADQI) group. *Crit Care* 2004; 8: R204–R212
13. Abosaif NY, Tolba YA, Heap M *et al*. The outcome of acute renal failure in the intensive care unit according to RIFLE: model application, sensitivity, and predictability. *Am J Kidney Dis* 2005; 46: 1038–1048
14. Bell M, Liljestam E, Granath F *et al*. Optimal follow-up time after continuous renal replacement therapy in actual renal failure patients stratified with the RIFLE criteria. *Nephrol Dial Transplant* 2005; 20: 354–360
15. Hoste EA, Clermont G, Kersten A *et al*. RIFLE criteria for acute kidney injury are associated with hospital mortality in critically ill patients: a cohort analysis. *Crit Care* 2006; 10: R73
16. Kuitunen A, Vento A, Suojaranta-Ylinen R *et al*. Acute renal failure after cardiac surgery: evaluation of the RIFLE classification. *Ann Thorac Surg* 2006; 81: 542–546
17. Lin CY, Chen YC, Tsai FC *et al*. RIFLE classification is predictive of short-term prognosis in critically ill patients with acute renal failure supported by extracorporeal membrane oxygenation. *Nephrol Dial Transplant* 2006; 21: 2867–2873
18. Lopes JA, Jorge S, Neves FC *et al*. An assessment of the rifle criteria for acute renal failure in severely burned patients. *Nephrol Dial Transplant* 2007; 22: 285
19. Lopes JA, Jorge S, Silva S *et al*. An assessment of the RIFLE criteria for acute renal failure following myeloablative autologous and allogeneic haematopoietic cell transplantation. *Bone Marrow Transplant* 2006; 38: 395
20. Uchino S, Bellomo R, Goldsmith D *et al*. An assessment of the RIFLE criteria for acute renal failure in hospitalized patients. *Crit Care Med* 2006; 34: 1913–1917
21. Ahlstrom A, Kuitunen A, Peltonen S *et al*. Comparison of 2 acute renal failure severity scores to general scoring systems in the critically ill. *Am J Kidney Dis* 2006; 48: 262–268
22. O'Riordan A, Wong V, McQuillan R *et al*. Acute renal disease, as defined by the RIFLE criteria, post-liver transplantation. *Am J Transplant* 2007; 7: 168–176
23. Guitard J, Cointault O, Kamar N *et al*. Acute renal failure following liver transplantation with induction therapy. *Clin Nephrol* 2006; 65: 103–112
24. Ostermann M, Chang RW. Acute kidney injury in the intensive care unit according to RIFLE. *Crit Care Med* 2007; 35: 1837–1843
25. Mehta RL, Kellum JA, Shah SV *et al*. Acute kidney injury network: report of an initiative to improve outcomes in acute kidney injury. *Crit Care* 2007; 11: R31
26. Stow PJ, Hart GK, Higlett T *et al*. Development and implementation of a high-quality clinical database: the Australian and New Zealand intensive care society adult patient database. *J Crit Care* 2006; 21: 133–141
27. Heringlake M, Knappe M, Vargas Hein O *et al*. Renal dysfunction according to the ADQI-RIFLE system and clinical practice patterns after cardiac surgery in Germany. *Minerva Anestesiol* 2006; 72: 645–654
28. Bagshaw SM, George C, Bellomo R. Changes in the incidence and outcome for early acute kidney injury in a cohort of Australian intensive care units. *Crit Care* 2007; 11: R68
29. Knaus WA, Draper EA, Wagner DP *et al*. APACHE II: a severity of disease classification system. *Crit Care Med* 1985; 13: 818–829
30. Bagshaw SM, Uchino S, Bellomo R *et al*. Septic acute kidney injury in critically ill patients: clinical characteristics and outcomes. *Clin J Am Soc Nephrol* 2007; 2: 431–439

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