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Original Article

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Costs and outcomes of acute kidney injury (AKI) following cardiac surgery

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Abstract

Background. Acute kidney injury (AKI) is a recognized complication of cardiac surgery; however, the variability in costs and outcomes reported are due, in part, to different criteria for diagnosing and classifying AKI. We determined costs, resource use and mortality rate of patients. We used the serum creatinine component of the RIFLE system to classify AKI.

Methods. A retrospective cohort study was conducted from the electronic data repository at the University of Pittsburgh Medical Center of patients who underwent cardiac surgery and had an elevation ($\geq$0.5 mg/dl) of serum creatinine postoperatively. Data were compared to age- and APACHE III-matched controls. Cost, mortality and resource use of AKI patients were determined postoperatively for each of the three RIFLE classes on the basis of changes in serum creatinine.

Results. Of the 3741 admissions, 258 (6.9%) had AKI and were classified as RIFLE-R 138 (3.7%), RIFLE-I 70 (1.9%) and RIFLE-F 50 (1.3%). Total and departmental level costs, length of stay (LOS) and requirement for renal replacement therapy (RRT) were higher in AKI patients compared to controls. Statistically significant differences in all costs, mortality rate and requirement for RRT were seen in the patients stratified into RIFLE-R, RIFLE-I and RIFLE-F. Even patients with the smallest change in serum creatinine, namely RIFLE-R, had a 2.2-fold greater mortality, a 1.6-fold increase in ICU LOS and 1.6-fold increase in total postoperative costs compared to controls.

Discussion. Costs, LOS and mortality are higher in postoperative cardiac surgery patients who develop AKI using RIFLE criteria, and these values increase as AKI severity worsens.

Keywords: acute renal failure; CABG; costs; RIFLE

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Introduction

Acute kidney injury (AKI) is a recognized complication of cardiac surgery [1] and even small decreases in renal function are associated with increased mortality [2,3]. Furthermore, despite considerable advances in diagnosis and management of severe AKI, including renal replacement therapy (RRT), mortality for this subgroup is 40–83% [4–6]. These wide ranges can be explained by the lack of comparability of case mix, use of different criteria for diagnosis and classification of AKI and need for RRT [7,8].

Recently, the Acute Dialysis Quality Initiative (ADQI), an international, interdisciplinary workgroup, proposed consensus-based classification criteria for AKI. They assigned degrees of kidney dysfunction into Risk (RIFLE-R), Injury (RIFLE-I) and Failure (RIFLE-F) on the basis of incremental changes in maximum serum creatinine (SCr) concentration from baseline or hourly urine output [8]. These criteria have subsequently been validated with regard to mortality in several studies involving different patients' populations [3,7,9–11].

There are over 400 000 coronary artery bypass graft (CABG) procedures annually and the hospital cost for these patients is substantial, averaging $20 673 [12,13]. Studies have reported 5–30% of these patients develop some degree of acute renal impairment, most fulfilling criteria for AKI [9,14]. When AKI is severe enough to require RRT mortality rates soar to 50–90% compared to <3% for patients without AKI [9,14].

The RIFLE criteria have been recently used to classify AKI following CABG surgery and shown to predict mortality and prolonged length of stay (LOS) [9]. However, costs and average lengths of stay were not evaluated. This information would be useful to quantify the resource use in CABG-associated AKI and to further validate the RIFLE system in this population. Thus, we sought to determine the costs, resource use and mortality rate of patients developing AKI following CABG surgery and classified them using RIFLE criteria.

Table 1. Demographics and co-morbid conditions of patients with and without AKI after coronary artery bypass graft surgery

	AKI ($n = 258$)	Matched controls ($n = 258$)	*P*-value
Age [mean (SD)], years	69.91 (10.1)	69.98 (9.9)	0.94
Race [*N* (%)]			0.19
White	240 (93.0)	229 (88.7)	
Black	8 (3.1)	13 (5.0)	
Other	10 (3.8)	16 (6.2)	
Gender [*N* (%)]			0.41
Male	162 (62.8)	152 (58.9)	
Female	96 (37.2)	106 (41.1)	
Apache III	54.5 (16.6)	55.8 (17.2)	0.38
Age >70 years	152 (58.9)	153 (60.0)	0.85
Redo CABG	24 (9.3)	19 (7.4)	0.52
Number of vessels	2.9 (1.6)	3.2 (1.2)	.001
Off-pump procedure	33 (12.8)	28 (10.9)	0.58
Diabetes	109 (42.2)	97 (37.6)	0.32
Congestive heart failure	55 (21.3)	34 (13.2)	0.02
Myocardial infarction	104 (40.3)	101 (39.1)	0.85
Chronic kidney disease	21 (8.1)	0	<0.01

AKI, acute kidney injury; CABG, coronary artery bypass graft.

Subjects

All patients admitted to the 24-bed cardio-thoracic ICU at University of Pittsburgh Medical Center Presbyterian Hospital (UPMC-P) with the following primary ICD-9-CM codes: (36.11—CABG 1 vessel, 36.12—CABG 2 vessels, 36.13—CABG 3 vessels, 36.14—CABG 4 vessels, 36.15, 36.16, 36.17, 36.19 and 36.10—coronary graft) were identified. Patients had AKI if they had a $\geq$0.5 mg/dl increase in SCr postoperatively on at least two consecutive occasions [15]. The following patients were excluded with SCr at baseline $\geq$ 4 mg/dl and no recorded baseline SCr (SCr up to 90 days before surgery).

Methods

Following approval from the institutional review board, we obtained data from June 1998 through May 2002 from the Medical Archival Retrieval System (MARS) UPMC-P. MARS is an electronic data repository of clinical and financial information. All data were obtained from MARS except APACHE III, which was acquired from the hospital's ICU-specific EMTEK® database. All records obtained on a patient were de-identified to maintain anonymity. We used the serum creatinine criteria of the RIFLE system to classify AKI [8]. We did not use the urine output criteria of RIFLE since data on hourly urine output were not available to us. Since baseline characteristics influence the likelihood of developing post-operative ARF, we chose to match on these characteristics. Therefore, when patients were identified, they underwent a one-to-one case match to control patients using Day 1 APACHE III scores (±2.0) and age (±5 years).

The following data were abstracted from the medical records: patient demographics, all SCr, disposition codes, APACHE III scores, type of CABG, patient outcomes, discharge summaries and charges. Patients' demographics included age, gender and race. Co-morbid conditions identified for each patient were diabetes, renal disease, myocardial infarction and congestive heart failure using International Classification of Diseases, version 9 (ICD-9-CM) codes. Information concerning the CABG procedure, such as redoing the CABG, number of vessels grafted and use of off-pump procedure, was obtained from the electronic chart review of the hospital discharge summaries. Patient outcomes obtained were ICU LOS, total post-operative LOS, use of RRT and hospital mortality. Cost-center charges included ICU room and supplies, laboratory, pharmacy, dialysis, and mechanical ventilation from the day of surgery to day of discharge (total postoperative costs). Total and departmental level charges were converted to costs using cost-to-charge ratios for each cost center [16]. This method of obtaining costs and cost center breakdowns has been used previously [17]. Cost data were not censored for mortality but were adjusted for inflation and reflected 2002 costs.

Data analysis was performed using SAS for Windows, version 8.01 (SAS Institute, Cary, NC, USA) and Statistical Package for the Social Sciences (SPSS), version 13.0 (Chicago, IL, USA). The chi-square and Fisher's exact test were used to analyze the nominal data. Continuous data were analyzed with Student's *t*-test, ANOVA, Wilcoxon's rank sum and Kruskal–Wallis test when appropriate. The alpha level was set at <0.05.

Results

Of the 3741 admissions, 258 (6.9%) met inclusion criteria and were classified as RIFLE-R 138 (3.7%), RIFLE-I 70 (1.9%), and RIFLE-F 50 (1.3%). The average age was 70.1 years (SD 10.1), and APACHE III score was 54 (17.3). There were 63.4% males: 86.3% were white and 8.2% were black. Table 1 summarizes the demographics and co-morbidities of the patients and controls. There were no differences in co-morbidities except patients' with AKI had fewer vessels grafted, but had a higher incidence of congestive heart failure and chronic kidney disease.

Table 2. Costs and outcomes of patients with and without AKI after coronary artery bypass graft surgery*

	Total postoperative costs	ICU costs	Total postoperative LOS (days)	ICU LOS (days)	RRT (%)	Mortality (%)
AKI patients ($n = 258$)	37 674 (23 654–68 433)	25 949 (15 547–59 175)	11.0 (7–18)	3.2 (1.5–6.5)	3.5	11.2
Controls ($n = 258$)	18 463 (14 704–23 822)	13 836 (11 165–19 923)	5.0 (4–7)	1.4 (1.1–2.0)	0.4	2.3

*All are statistically different ($P < 0.001$), medians (interquartile ranges)
AKI, acute kidney injury; ICU, intensive care unit; LOS, length of stay; RRT, renal replacement therapy.

Table 3. Comparison of AKI patient costs for major subcategories of care*

	ICU room	ICU supply	Laboratory	Pharmacy	Ventilatory
AKI patients	4473 (2120–12 478)	721 (172–2023)	3350 (1846–6171)	2550 (1381–5651)	396 (247–1306)
Controls	1331 (1113–2394)	129 (62–338)	1083 (773–2095)	796 (521–1296)	234 (145–304)

*All are statistically different ($P < 0.001$), Medians (interquartile ranges).
AKI, acute kidney injury; ICU, intensive care unit.

Table 4. Resource usage and outcomes of three RIFLE categories in patients with AKI after coronary artery bypass graft surgery[a]

	RIFLE-R	RIFLE-I	RIFLE-F	*P* value
Incidence (%)	53.5	27.1	19.4	
Mortality (%)	5.1	12.9	26.0	<0.003
RRT (%)	0	2.9	14.0	<0.001
Total postoperative costs	29 697 (20 041–52 351)	38 924 (25 092–70 424)	52 618 (35 250–91 954)	<0.001
ICU costs	21 775 (13 444–41 427)	28 872 (17 961–63 322)	49 328 (21 454–83 687)	<0.001
ICU costs (% of total costs)	73.3	74.2	93.7	
Total postoperative LOS (days)	9 (6–17)	11 (7–19)	16 (12–25)	<0.001
ICU LOS days	2.29 (1.34–5.2)	3.45 (1.9–7.7)	5.42 (2.8–12.3)	<0.001
ICU LOS (% of total LOS)	25.4	31.3	33.8	
ICU room	3400 (1197–7901)	5312(2633–13 360)	9054(4392–25 607)	<0.001
ICU supplies	439 (97–1411)	1041 (207–2023)	1930 (578–4465)	<0.001
Laboratory	2865 (1651–5516)	3483 (1788–6478)	4512 (2994–10 817)	<0.001
Pharmacy	2198 (1180–3932)	2426 (1515–6106)	5054 (2878–9995)	<0.001
Ventilatory	304 (152–679)	370 (257–1451)	903 (457–2717)	<0.001
Dialysis	N/A	901 (587–1367)	2413 (841–4534)	0.06

[a]Median (interquartile ranges).
ICU, Intensive care unit; LOS, length of stay; RRT, renal replacement therapy; NA, not applicable.

Comparison of costs and outcomes between patients and controls is shown in Table 2. The 258 patients with AKI generated a cumulative cost of $18.3 million. Costs, LOS, requirement for RRT and mortality were statistically higher in patients with AKI compared to the matched controls. All costs and LOS were approximately double, while there was a five-fold increase in mortality reported in patients with AKI compared to controls. In Table 3, average costs associated with the various departmental cost-centers were all higher in patients with AKI. As shown in Table 4, statistically significant differences in all costs were seen in patients stratified into RIFLE-R, RIFLE-I and RIFLE-F groups. There was a progressive increase in mortality, rate of RRT requirement, LOS and costs with increases of AKI severity as classified by RIFLE. The RIFLE-F group represents patients with the highest cost, longest LOS and highest rates of RRT and mortality. Of note, ICU costs of RIFLE-F accounted for nearly 94% of the total postoperative costs yet ICU LOS was only 34% of postoperative LOS. The mortality rate in these patients was 10 times higher than that for controls and five times higher than that for patients with RIFLE-R criteria. Compared with controls, even patients with the smallest change in SCr, namely RIFLE-R, had a 2.2-fold greater mortality and a 1.6-fold increase in ICU LOS and a 1.6-fold increase in total postoperative costs. In patients receiving RRT there was a doubling of postoperative costs and LOS, tripling of ICU costs and ICU LOS and four-fold increase in mortality compared with AKI patients not requiring RRT, as shown in Table 5.

Discussion

The consequences of AKI following CABG procedures on resource use and mortality have been difficult to quantify and compare without a standard classification system; even less is known about its impact on cost. Furthermore, the wide range reported in the incidence of AKI following CABG procedures of 5–30%, including our incidence of 6.9%, is likely explained by different definitions of renal compromise and the use of fluids, inotropes and vasopressors postoperatively [18].

In this cost analysis using the RIFLE criteria, total postoperative costs and departmental cost-center costs

Table 5. Effects of RRT on costs and outcomes in patients with AKI after coronary artery bypass graft surgery[a]

	Total post operative costs	ICU costs	Total postoperative LOS (days)	ICU LOS (days)	Mortality (%)
Cases with RRT ($n = 27$)	74 040 (38 155–124 425)	71 511 (26 508–122 980)	21.0 (13–35)	6.7 (3.2–20.8)	37.0%
Cases without RRT ($n = 231$)	34 953 (22 275–61 495)	23880 (14 509–49 489)	10.0 (7–17)	2.7 (1.4–6.1)	8.2%
Controls ($N = 258$)	18 463 (14 704–23 822)	13 836 (11,165–19 923)	5.0 (4–7)	1.4 (1.1–2.0)	2.3

Cases with RRT and cases without RRT are significantly different in all categories from each other ($P < 0.001$) Both case cohorts are significantly different from controls in all categories ($P < 0.001$).
[a]Median (interquartile ranges)
ICU, Intensive care unit; LOS, length of stay; RRT, renal replacement therapy.

(ICU room, ICU supplies, laboratory, pharmacy and ventilatory) were higher in patients with AKI compared to the matched controls and they increased progressively with the severity of AKI as determined by RIFLE stages. In fact, the average difference in total postoperative costs between the three RIFLE categories is ∼$9000 to $14 000. Since our study focused on costs and outcomes following surgery, it should better reflect the impact of cardiac surgery on renal dysfunction, as preoperative costs were excluded. Most of the postoperative costs were generated during the ICU stay. For example, the percent of total postoperative costs emanating from the time in the ICU was 73% in RIFLE-R and 94% in RIFLE-F. This occurred despite the ICU LOS ranging from only 25–34% of the total postoperative LOS in those patients. This is consistent with other studies documenting considerable resource use during an ICU stay, with one study of a medical, surgical and trauma patients, reporting the average daily cost in the ICU of $3500 [19]. However, it is difficult to compare our cost data with national averages since those data encompass the patient's entire hospital stay, while we concentrated only on costs following surgery [12,13].

A recent study in CABG patients evaluated the RIFLE classification and showed a strong association between the three stages of AKI and 90-day mortality [9]. However, they did not assess costs and only reported prolonged stay (ICU >5 days). This study quantifies the total postoperative costs associated with RIFLE-classified AKI following CABG surgery and therefore extends the validation of the RIFLE criteria beyond mortality. Also, we offer insight into clinical outcomes of AKI including hospital and ICU LOS, hospital mortality and need for RRT. Highest costs and worse outcomes were seen in the most severe AKI group (RIFLE-F) compared to patients with less severe AKI (RIFLE-R and RIFLE-I). Also, as predicted, the clinical and economic outcomes in patients requiring RRT revealed much higher costs, LOS and mortality rates than AKI patients not requiring RRT.

Our findings reveal that patients with even the smallest increases in SCr, namely 1.5 times baseline, had significantly worse outcomes and higher costs than controls. For example, RIFLE-R patients had a 2.2-fold increase in mortality, 1.8-fold increase in postoperative LOS and 1.6-fold increase in total postoperative costs. Chertow *et al.* have recently shown that small increases in SCr (> 0.3 mg/dl) resulted in a mean increase of $8900 in unadjusted total costs and an increase in mortality and LOS in hospitalized patients compared to controls [20]. Similarly Lassnigg showed in cardiothoracic surgery that patients with a small (0 to 0.5 mg/dl) increase in SCr have a three-fold increase in 30-day mortality rate [2]. Similar findings were seen in trauma patients [21]. Together, these studies suggest that there can be significant improvements in outcomes and reduced costs if therapies were in place to prevent even mild forms of AKI in this population.

Nearly a decade ago, the estimated annual cost of renal failure following CABG exceeds hundreds of millions of dollars [22]. However the first study to quantitate costs in these patients was not published until 2003 [14]. That study examined a random sample of 969 patients from 3493 patients undergoing CABG surgery from 1998–2000. Although these authors used different criteria for classifying AKI as well as different methods of cost accounting than ours, their results were similar in several ways. Compared to controls, patients with renal impairment incurred higher ICU costs (1.7-fold), pharmacy costs (2.3-fold) and laboratory costs (1.6-fold).

Our data are in general agreement with other cost analyses in acute renal disease. Although there have only been a few studies documenting the costs associated with AKI, none have used the RIFLE consensus criteria for classification. The median hospital costs from the SUPPORT study from the start of RRT to discharge or death was $42 000 in 2001 [23]. These authors also estimated the cost per quality-adjusted life-year of $168 711. Their findings are limited to patients requiring RRT. Another study reported the total hospital cost of patients with ARF requiring RRT was $51 429 [24]. While our cost data were adjusted for 2002 and may not represent actual costs in 2008, the percent differences in costs between AKI patients and controls are perhaps a more relevant value relating to the impact of AKI.

There are several limitations to this study. First, these data were generated from a single academic medical center and represents patients with coronary artery disease and subsequent surgical intervention; hence our data cannot be extrapolated to other institutions and other types of ICU patients who develop AKI. However, our AKI incidence and mortality results are consistent with the published literature. Second, although we matched our cases and controls on the basis of APACHE III scores (±2.0) and age (±5 years), our groups had some differences in co-morbid conditions. Thus, we are unable to determine, with certainty, what the specific clinical and economic impact of AKI itself was, independent of co-variables such as congestive heart failure, chronic kidney disease and number of vessels grafted. We furthermore did not record multi-organ failure postoperatively and hence did not analyze how the three

RIFLE categories were related to the failure of other organs. We also limited our RIFLE definition to changes in SCr; hence our data may not apply when urine output is used to characterize AKI using RIFLE. However, SCr has been used in the majority of studies evaluating RIFLE [7]. Finally, we relied on the accuracy of billing codes for patient selection, which is common in claims database analysis but has inherent limitations. However, given auditing procedures already in place, it is unlikely that a case identified as CABG would have been incorrectly coded. Nevertheless, we have demonstrated that total post-operative costs, in addition to mortality, increase in relation to RIFLE class of post-cardiac surgery patients developing AKI.

Conclusion

We report both clinical and economic outcomes of CABG patients with AKI classified by RIFLE criteria. The ICU and postoperative costs and LOS for patients with AKI are higher than matched controls and these values increase as AKI severity worsens. Preventing the development or subsequent progression of AKI would have significant potential to decrease costs. Improved detection, risk-profiling and novel therapies are urgently needed.

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Conflict of interest statement. Dr. Dasta was a consultant to Abbott Laboratories at the time of the study. Dr. Durtschi is an employee of Abbott Laboratories. Dr. Kane-Gill has received other research funds from Abbott Laboratories.

References

1. Wijeysundera DN, Karkouti K, Beattie WS *et al*. Improving the identification of patients at risk of postoperative renal failure after cardiac surgery. *Anesthesiology* 2006; 104: 65–72
2. Lassnigg AL, Schmidlin D, Mouhieddine M *et al*. Minimal changes of serum creatinine predict prognosis in patients after cardiothoracic surgery: a prospective cohort study. *J Am Soc Nephrol* 2004; 15: 1597–1605
3. Hoste EAJ, 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–R82
4. Pruchnicki M, Dasta JF. Acute renal failure in hospitalized patients: part I. *Ann Pharmacother* 2002; 36: 1261–1267
5. Uchino S, Kellum JA, Bellomo R *et al*. Beginning and ending supportive therapy for the kidney (BEST Kidney) investigators: acute renal failure in critically ill patients: a multinational, multicenter study. *JAMA* 2005; 294: 813–818
6. Poole BD, Schrier RW. Acute renal failure. In: Fink M, Abraham E, Vincent J-L, Kochanek PM (eds). *Textbook of Critical Care*, . Philadelphia: Elsevier Saunders, 2005, 1139–1150
7. 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* 2006; 33: 409–413
8. Bellomo R, Ronco C, Kellum JA *et al*. The ADQI Working Group. 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
9. 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
10. 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: 1–5
11. Lopes JA, Fernandes J, Jorge S *et al*. An assessment of the RIFLE criteria for acute renal failure in critically ill HIV-infected patients. *Crit Care* 2007; 11: 1–2
12. Eisenberg MJ, Filion KB, Azoulay A *et al*. Outcomes and cost of coronary artery bypass graft surgery in the United States and Canada. *Arch Intern Med* 2005; 165: 1506–1513
13. Heart Disease and Stroke Statistics—2007. Update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation* 2007; 115: e69–e171
14. Callahan M, Battleman DS, Christos P *et al*. Economic consequences of renal dysfunction among cardiopulmonary bypass surgery patients: a hospital-based perspective. *Value Health* 2003; 6: 137–143
15. Clermont G, Acker CG, Angus DC *et al*. Renal failure in the ICU: comparison of the impact of acute renal failure and end-stage renal disease on ICU outcomes. *Kidney Int* 2002; 62: 986–996
16. Shwartz M, Young DW, Siegrist R. The ratio of costs to charges: How good a basis for estimating costs? *Inquiry* 1995; 32: 476–481
17. Kane-Gill SL, Seybert AL, Lazar J *et al*. Resource use in decompensated heart failure by disease progression. *Cong Heart Fail* 2007; 13: 22–28
18. 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
19. Dasta J, Kim SR, McLaughlin TP *et al*. Incremental daily cost of mechanical ventilation in patients receiving treatment in an intensive care unit. *Crit Care Med* 2005; 33: 1266–1271
20. Chertow GM, Burdick E, Honour M *et al*. Acute kidney injury, mortality, length of stay and costs in hospitalized patients. *J Am Soc Nephrol* 2005; 16: 3365–3370
21. Brandt, MM, Falvo AJ, Rubinfield I *et al*. Renal dysfunction in trauma: even a little costs a lot. *J Trauma* 2007; 62: 1362–1364
22. Mangano CM, Diamondstone LS, Ramsay JG *et al*. For the Multicenter Study of Perioperative Ischemia Research Group. Renal dysfunction after myocardial revascularization: risk factors, adverse outcomes, and hospital resource utilization. *Ann Intern Med* 1998; 128: 194–203
23. Hamel MB, Phillips RS, Davis RB *et al*. for the SUPPORT investigators. Outcomes and cost-effectiveness of initiating daily dialysis and continuing aggressive care in seriously ill hospitalized adults. *Ann Intern Med* 1997; 127: 195–202
24. Korkeila M, Ruokonen E, Takala J. Costs of care, long-term prognosis and quality of life in patients requiring renal replacement therapy during intensive care. *Intensive Care Med* 2000; 26: 1824–1831

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