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**Background** The relationship between residual urine output and postoperative survival in maintenance hemodialysis patients is unknown.

**Objective** To explore the relationship between amount of urine before surgery and postoperative mortality and differences between postoperative nonanuria and anuria in maintenance hemodialysis patients.

**Methods** A total of 109 maintenance hemodialysis patients underwent major operations. Anuria was defined as urine output <30 mL in the 8 hours before the first session of postoperative dialysis. Propensity scores for postoperative anuria were developed.

**Results** Postoperative residual urine output was 159.2 mL/8 h (SD, 115.1) in 33 patients; 76 patients were anuric. Preoperative residual urine output and adequate perioperative blood transfusion were positively related to postoperative urine output. Propensity-adjusted 30-day mortality was associated with postoperative anuria (odds ratio [OR], 4.56; 95% confidence interval [CI], 1.16-17.96; \( P = .03 \)), prior stroke (OR, 4.46; 95% CI, 1.43-13.89; \( P = .01 \)) and higher disease severity (OR, 1.10; 95% CI, 1.00-1.21; \( P = .049 \)) at the first postoperative dialysis. OR of 30-day mortality was 5.38 for nonanuria to anuria vs nonanuria to nonanuria (\( P = .03 \)) and 5.13 for preoperative anuria vs nonanuria to nonanuria (\( P = .01 \)). By Kaplan-Meier analysis, 30-day mortality differed significantly among patients for nonanuria to nonanuria, anuria, and nonanuria to anuria (log rank, \( P = .045 \)).

**Conclusion** Patients with preoperative nonanuria and postoperative anuria had higher mortality than did patients with no anuria before and after surgery and patients with anuria before surgery. Postoperative residual urine output is an important surrogate marker for disease severity. (American Journal of Critical Care. 2009;18:446-455)
Residual renal function (RRF) declines exponentially after the start of dialysis therapy, and many patients with end-stage renal disease (ESRD) have no RRF. Loss of RRF impairs both the removal of fluids and the clearance of solutes, including phosphate, potassium, sodium, and uric acid, leading to toxic uremic effects and increased morbidity and mortality. Anuric peritoneal dialysis patients have more adverse cardiovascular, inflammatory, nutritional, and metabolic profiles than do patients with RRF. RRF is more often overlooked in maintenance hemodialysis patients than in peritoneal dialysis patients because of its more rapid decline and minor contribution to solute clearance in the first group. Hemodialysis patients with RRF, even a low level, have a lower risk for mortality than do patients with no RRF.

The focus of concerns about acute dialysis-related mortality has often been patients’ disease severity before surgery. However, perioperative hemodynamic status and biochemical factors are also related to such patients’ mortality, especially in patients with ESRD. Although many factors are related to surgical mortality in patients with ESRD, information on the relationship between RRF and mortality in ESRD patients who undergo a major surgical procedure is limited. In addition, whether perioperative RRF independently is predictive of mortality after major surgery is not known. According to Shemin et al., renal function, as measured by timed urine collections, can have either a beneficial or a protective effect in hemodialysis patients. The role of residual urine output (RJO) in hemodialysis patients is often neglected, and it remains unknown whether the results of survival studies in hemodialysis patients with anuria can be extrapolated to hemodialysis patients who still have RJO after major surgery.

Because the amount of urine can be measured accurately in the intensive care unit (ICU), we attempted to gauge RRF by RUO and examined the predictive value of postoperative anuria for ICU mortality among maintenance hemodialysis patients and the difference between postoperative patients with or without anuria. We also constructed a propensity-adjusted logistic regression model to explore the effect of a perioperative change in the amount of urine and other clinical variables on 30-day mortality in postoperative ESRD patients.

Methods
Approval for the study was obtained from the institutional review board of National Taiwan University Hospital, Taipei, Taiwan.

Sample
Information for the study was prospectively obtained from the database of renal failure patients in the surgical ICU of National Taiwan University Hospital and its branch hospitals. From January 2002 to April 2005, a total of 9108 patients were admitted to the ICU after major surgical procedures, including 124 patients who had received hemodialysis for more than 3 months before undergoing surgery. Surgical procedures were considered major if the length of stay for patients in a given diagnosis-related group exceeded 2 days. Patients who underwent obstetrical procedures were excluded (n = 2). All the patients with an ICU stay of more than 48 hours were regularly followed up until death or discharge from the hospital. A total of 7 patients were excluded from the study because they were admitted to the ICU for septic shock (n = 5) or after cardiopulmonary resuscitation (n = 2). Patients who had liver (n = 4) or kidney (n = 2) transplantation were excluded.
Renal Replacement Therapy

The patients received hemodialysis according to an alternate-day protocol; the first postoperative dialysis session was started within 2 days of surgery. The type of dialysis was based on the hemodynamic status of the patient. Continuous venovenous hemofiltration was used if a dose of inotropic equivalent greater than 15 points was required to maintain systolic blood pressure up to 120 mm Hg. High-flux filters (PAN-10 hemofilter, Asahi Kasei Medical Company, Tokyo, Japan), an HF-400 dialysis machine (Infomed, Geneva, Switzerland), and a hemofiltration flow of 35 mL/kg per hour with a blood flow of 200 mL/min were used. Replacement fluid was buffered with bicarbonate and was administered predilutionally at a dynamically adjusted volume to achieve the desired fluid therapy goals. Default composition was sodium 142 mEq/L, bicarbonate 33 mEq/L, magnesium 1.4 mEq/L (to convert to millimoles per liter, multiply by 0.25), and calcium 2.6 mEq/L (to convert to millimoles per liter, multiply by 0.50). All renal replacement therapy fluids were anticoagulant-free. Vascular access was obtained via arteriovenous grafts or fistulas.

The adequacy of hemodialysis was measured by using the $Kt/V$, a dimensionless ratio representing volume of plasma cleared ($Kt$) divided by the distribution volume of urea ($V$), where $K$ stands for the dialyzer blood water urea clearance, expressed in milliliters per minute, $t$ stands for the duration of the dialysis session in minutes, and $V$ is urea distribution volume in milliliters. For our study, we used the following equation: prescribed $Kt/V = ((in vitro urea clearance) \times (prescribed time))/predialysis total body water$. The urea distribution volume is roughly equal to the total body water calculated via the Watson formula from the patient’s sex, height, and weight to calculate the volume:

For men: $2.447 - (0.09156 \times age) + (0.1074 \times height) + (0.3362 \times predialysis weight)$

For women: $-2.097 + (0.1069 \times height) + (0.2466 \times predialysis weight)$.

Postoperative anuria was a urine output of less than 30 mL/8 hours. Patients who died were more likely than patients who lived to have postoperative anuria.

Clinical Assessment

Clinical assessment included medical history, physical examination, baseline biochemistry data, and determination of comorbid diseases at the time of hospital admission. Comorbid diseases, age, vital signs, RUO, and biochemical data were recorded after hospital admission, after ICU admission, and at the first postoperative dialysis session. Mechanical ventilation, types of surgery, score on the Acute Physiology and Chronic Health Evaluation (APACHE) II, and the use of vasopressors were recorded at the first postoperative dialysis session. Postoperative anuria was defined as urine output less than 30 mL during an 8-hour collection before the first postoperative dialysis without diuretics; preoperative anuria was also assessed at the time of hospital admission. Because urine output was not normally distributed, square root transformation of the raw data was used for statistical analyses. Adequate blood transfusion was defined as transfusions designed to keep hematocrit greater than 33% during the operation.

Severity of Disease

The 30-day mortality, defined as death within 30 days after a patient’s ICU stay, was the outcome variable. Organ failure was classified according to the following: respiratory failure, ratio of $P_{aO_2}$ to fraction of inspired oxygen less than 200 mm Hg; coagulopathy, platelet count $50 \times 10^9/\mu$L or greater; central nervous system failure, score on Glasgow Coma Scale, 9 or less; cardiac failure, indications of low cardiac output with a central venous pressure greater than 12 mm Hg and administration of an inotropic equivalent greater than 5 points; and liver dysfunction, total bilirubin, 6.0 mg/dL or greater (to convert to micromoles per liter, multiply by 17.104). Sepsis was defined as the persistence or progression of signs and symptoms of systemic inflammatory response syndrome with a documented or presumed persistence of infection.

Statistical Analysis

Data are expressed as means and standard deviations unless otherwise specified. In the main analysis, 30-day survivors were compared with non-survivors. An unpaired $t$ test was used to analyze continuous data; the Fisher exact test was used to analyze categorical data.

Variables with significant association on univariate screening were considered candidates for multivariable analysis. Multivariable logistic regression was performed by using forward stepwise selection, with variable exit criteria set at $P<.05$. The area under the receiver-operating-characteristic curve was used to assess discrimination of the model. Calibration was estimated by using the Hosmer-Lemeshow goodness-of-fit test. In addition to adjustments for significant covariates in multivariable regression, residual confounding and selection effects were addressed by using propensity scores. In order to develop the propensity score, a separate multivariable
logistic regression analysis was used that included all factors that differed among the groups with and without postoperative anuria and a more liberal significance criterion of \(P < .20\). Initially, we build the propensity score for postoperative anuria by propensity-adjusted logistic regression model; with anuria as the dependent variable, a model was fit to construct the propensity of postoperative anuria. Then, the new propensity-adjusted mortality model with 30-day survival as the independent variable was built, with all eligible univariate predictors of mortality along with the new propensity score for postoperative anuria. Inclusion of the propensity score as a covariate in a multivariable regression theoretically normalizes the likelihood of postoperative anuria and may effectively adjust for unobserved confounding and selection bias, thereby refining regression estimates.

Finally, the Kaplan-Meier (product-limit) method was used to estimate survival of patients with and without postoperative RUO. Statistical analyses were performed with SPSS for Windows, version 12.0 (SPSS Inc, Chicago, Illinois). Significance was set at \(P < .05\).

**Results**

Demographic and Biochemical Data

Data for 109 maintenance hemodialysis patients, 67 men and 42 women, were analyzed (Tables 1 and 2).
categories, and rate of sepsis. At ICU admission, the blood lactate level (mean, 3.15 mmol/L, SD, 3.35 vs mean 2.64 mmol/L, SD, 1.60; $P = .29$); urea nitrogen (mean, 59.7 mg/dL, SD, 27.8 vs mean, 50.2 mg/dL, SD, 21.3; $P = .09$; to convert to millimoles per liter, multiply by 0.357), and arterial pressure (mean, 94.0 mm Hg, SD, 21.8 vs mean, 88.8, SD, 22.1; $P = .26$) did not differ between the 2 groups (Figure 1). However, at the first postoperative dialysis session, patients with anuria had higher blood lactate levels (mean, 2.98 mmol/L, SD, 3.40 vs mean, 1.81 mmol/L, SD, 1.36; $P = .01$) than did patients without anuria. After surgery, patients with anuria had significantly lower levels of urea nitrogen (Table 1), required more ventilator use on the first postoperative dialysis session, and had a higher 30-day mortality rate than did patients without anuria (Table 2). A total of 56 patients (74%) who had postoperative anuria had anuria before the surgery (Table 1).

### Propensity Score for Postoperative Anuria

The mean APACHE II score of all patients at the time of ICU admission was 19.11 (SD, 4.79). Log odds of postoperative anuria ($X = (\text{adequate blood transfusion} \times -2.088) + (\log [\text{urea output (mL/8 h)}])$ at hospital admission $\times -3.008) + (\text{APACHE II score at the time of ICU admission} \times 0.147) + 4.203$. Then, the propensity score for postoperative anuria on the day of the first dialysis session equals $e^X/[1 + (e^X)]$ (Table 3).

This model had a good calibration, as indicated by the Hosmer-Lemeshow goodness of fit (Cg = 2.637; $P = .96$), and good discriminating power (mean area under the receiver-operating-characteristic curve, 0.938; SD, 0.022; $P < .001$). The mean propensity score was 0.303 (SD, 0.351). The propensity score itself can be interpreted as the likelihood of having postoperative anuria on the basis of the observed array of covariates included in the model.

### Thirty-Day Hospital Mortality

Disease severity, as indicated by the mean APACHE II score, was 19.59 (SD, 4.74) at the first postoperative dialysis session. A total of 29 patients (27%) died in the surgical ICU at a mean of 13.0 days (SD, 13.2) after surgery; the mean ICU stay for surviving patients was 9.2 days (SD, 15.3). The patients who died were more likely to have had a prior stroke (34% vs 9%; $P = .02$; Table 4) and a lower rate of coronary artery disease (24% vs 52%; $P = .009$) than were the patients who survived. The patients who died had a longer duration of dialysis (mean, 5.1 years, SD, 4.3 vs mean, 3.1 years, SD, 3.6; $P = .02$), were more likely to have postoperative

### Risk factors for the 30-day mortality were postoperative anuria, prior stroke, and greater disease severity.

Mean age was 63.6 years (SD, 10.5). Diabetes mellitus was the most common cause of ESRD (45.9%).
anuria (90% vs 62%; \( P = .009 \)), lower blood pressure (mean, 61.4 mm Hg, SD, 28.1 vs mean, 95.3 mm Hg, SD, 15.8; \( P = .02 \)), and a higher APACHE II score (mean, 21.4, SD, 5.0 vs mean, 18.5, SD, 4.8; \( P = .007 \)) at the first postoperative dialysis session, and less use of intermittent hemodialysis (69% vs 88%; \( P = .03 \)) than did the survivors (Table 4). The perioperative change in the amount of urine differed between patients who died and patients who survived (\( P = .02 \)); the percentage of patients with no preoperative anuria who had anuria after surgery was higher among the patients who died (24% vs 16%). The independent risk factors for the 30-day mortality indicated by propensity-adjusted logistic regression analysis (Table 5a) were propensity score for postoperative anuria (odds ratio [OR] = 4.56; 95% confidence interval [CI], 1.16-17.96; \( P = .03 \)), a prior stroke (OR = 4.46; 95% CI, 1.43-13.89; \( P = .01 \)), and a higher disease severity as indicated by the APACHE II score at the first postoperative dialysis session (OR = 1.10; 95% CI, 1.00-1.21; \( P = .049 \)). This model had a good calibration, as indicated by the Hosmer-Lemeshow goodness of fit (\( C^2 = 4.098 \), \( P = .77 \)), and good discriminating power (mean area under the receiver-operating-characteristic curve, 0.720; SD, 0.049; \( P < .001 \)).

Thirty-day hospital mortality based on the difference in the amount of urine before and after surgery was also constructed (Table 5b). The OR was 5.38 for a change from no anuria to anuria vs no anuria to no anuria (\( P = .03 \)) and 5.13 for previous anuria vs no anuria to no anuria (\( P = .01 \)). Kaplan-Meier analysis showed a significant difference in the 30-day mortality among patient groups of no anuria to no anuria, anuria, and no anuria to anuria (log rank, \( P = .045 \); Figure 2).

Discussion

Only a few studies\textsuperscript{25,26} have been done on the survival of maintenance hemodialysis patients who have undergone major surgical procedures. Because of comorbid diseases, these patients are assumed to have a higher mortality rate after major surgery than are patients who have normal or mild impairment of renal function. This notion is supported by our finding of a higher mortality rate in maintenance hemodialysis patients than in general ICU patients (27% vs 11%\textsuperscript{27}), even though the APACHE II scores were similar (19.11 vs 15-19, respectively\textsuperscript{27}). Disease severity scores, especially APACHE II scores, are predictive of the overall mortality of patients with ESRD and have good discrimination.\textsuperscript{28} In our study of maintenance hemodialysis patients, survivors had lower APACHE II scores than did the patients.
who died. Our findings also highlight the poor postoperative prognosis after stroke in patients with ESRD. Compatible with our results, patients with prior stroke are a high-risk cohort for major surgery and have higher rates of adverse events than do patients without prior stroke. In addition, although hemodialysis ameliorates many of the metabolic disturbances of uremia, patients with ESRD have a substantially higher risk for death due to cerebrovascular disease than does the general population.

In addition to the APACHE II score and history of stroke, we found that postoperative RUO, even at low levels, was an independent predictor of lower 30-day mortality rate in maintenance hemodialysis patients. The OR of 30-day mortality was 4.56 for patients with postoperative anuria. RRF contributes significantly to the total solute clearance, nutritional status, and quality of life in maintenance peritoneal dialysis patients and is well recognized as an important factor influencing mortality. However, few studies have addressed the effect of RRF or RUO on mortality in hemodialysis patients. In addition to better fluid balance and solute clearance, patients with RRF have higher levels of endogenous erythropoietin than do patients without RRF.

RRF also contributes to overall nutritional status in maintenance hemodialysis patients. Hemodialysis patients with stable urine output have a greater lean body mass, an indicator of nutritional status in maintenance hemodialysis patients, than do those without RRF, a finding that is consistent with our findings. Loss of RRF has been associated with an increased inflammatory response and may enhance an inflammatory response via increased oxidative stress, a situation that may lead to activation of monocytes and production of cytokines. Because of the effect of RUO on solute removal, fluid balance, nutrition, and cytokine handling, it is not surprising that postoperative survival in maintenance hemodialysis patients was higher in those with RUO than in those with anuria. Despite a greater prescribed Kt/V, the patients with anuria had a higher mortality rate. We speculate that the loss of RRF could not be overcome by simply prescribing a greater hemodialysis dose for the anuric patients.

A particularly interesting finding was that patients with anuria had a higher blood lactate level at the first postoperative dialysis session, in spite of similar APACHE II scores, than did patients without anuria. This finding implies that anuric patients have compromised tissue perfusion following surgery. Elevated blood lactate level is often considered evidence of tissue hypoxia, with values proportional to the defect in oxidative metabolism. Patients who made urine before the operation and became anuric after surgery had significantly higher lactate levels than did those who did not become anuric, most likely reflecting unstable hemodynamic status and poor overall perfusion or shock.

Although use of iothalamate, iohexol, or inulin has been suggested for estimating RRF in hemodialysis patients, it is not practical for routine clinical use, especially in these critically ill patients. Unstable creatinine kinetics due to variable urine output and creatinine production in critically ill patients makes accurate estimation of glomerular filtration rate impossible. The use of prediction equations is as inaccurate as measured clearance in ICU patients in unstable condition; the only practical measurement is urine volume. Currently, measurement of the amount of urine is more acceptable than other methods used to estimate RRF, especially in ICU patients in unstable condition.

Many investigators have attempted to determine mortality risk factors after surgery. Previous studies often focused on preoperative variables, but some perioperative variables may have greater effects than others on patient mortality. As our analysis in

### Table 3

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Parameter estimate</th>
<th>SE</th>
<th>P</th>
<th>Odds ratio</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perioperative adequate blood transfusion (Yes vs No)</td>
<td>-2.088</td>
<td>0.733</td>
<td>.004</td>
<td>0.12</td>
<td>0.03-0.52</td>
</tr>
<tr>
<td>APACHE II score on admission to intensive care unit</td>
<td>0.147</td>
<td>0.078</td>
<td>.06</td>
<td>1.16</td>
<td>1.00-1.35</td>
</tr>
<tr>
<td>Log (urine output, mL/8 h)</td>
<td>-3.008</td>
<td>0.719</td>
<td>&lt;.001</td>
<td>0.05</td>
<td>0.01-0.20</td>
</tr>
</tbody>
</table>

Abbreviation: APACHE, Acute Physiology and Chronic Health Evaluation.

* Propensity score of postoperative anuria: $e^X/(1 + (e^X))$, where $X = (\text{adequate blood transfusion} - 2.088) + (\log \ [\text{urine output (ml/8 h)}] \times \text{APACHE II score on admission to intensive care unit}) + 4.203$.

Patients who made urine and then became anuric after surgery had higher lactate levels.

Maintenance hemodialysis patients with residual urine output had better postoperative survival than anuric patients did.
Table 3 indicates, the predictive power of generic APACHE II score can be improved markedly by adding perioperative parameters. Thus, after adjustments for the effects of the other risk factors in the regression models used in earlier studies, preoperative RUO and adequate blood transfusion had positive direct effects on the postoperative residual urine, and then a positive indirect effect on the ICU mortality rate via amount of postoperative urine, an intermediate variable.

Preoperative levels of urine and of serum creatinine provided valuable information about the development of acute renal failure in patients undergoing coronary artery bypass grafting. In our propensity model, the hemodialysis patients who had preoperative anuria were at greater risk than were hemodialysis patients who had RUO before surgery. Furthermore, the mortality rate of patients progressing from no anuria before surgery to anuria after surgery was the highest in the patients who ultimately died (Table 5b and Figure 2). Taken together, careful monitoring and maintaining of perioperative RUO are crucial for achieving an optimal outcome. In ESRD patients with RUO, contrast media, nonsteroidal anti-inflammatory drugs, and some nephrotoxic agents should be avoided.

Our study has limitations. First, we could not truly evaluate the impact of perioperative RUO with an observational study design, even though the propensity score adjustment addressed problems related to multicollinearity and selection bias. Although a randomized prospective study is required to provide a conclusive answer of whether or not anuria in dialysis patients is predictive of postoperative mortality, the high goodness of fit and a good discriminative power in our model suggest that perioperative RUO affected postoperative urine output. Our results clearly indicate that procedures that push an at-risk ESRD patient from no anuria to anuria increase mortality. Besides, our results may not be applicable to other regions or practice settings where the surgical methods or dialysis techniques differ. Finally, the current database provided information on short-term risks to patients but did not include information on the patients’ long-term survival.

**Conclusion**

This study is the first in which the role of RRF in predicting survival in maintenance hemodialysis patients after major surgery was evaluated. Postoperative RUO is a good surrogate marker for severity of illness and should be included in the clinical risk assessment of maintenance hemodialysis patients.

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**Table 4** Comparison of characteristics of patients who survived 30 days and patients who died

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Survival (n = 80)</th>
<th>Death (n = 29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>46 (58)</td>
<td>21 (72)</td>
<td>.19</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>63.2 (10.7)</td>
<td>64.6 (10.1)</td>
<td>.54</td>
</tr>
<tr>
<td>Body mass index, mean (SD)</td>
<td>23.1 (3.8)</td>
<td>22.0 (3.8)</td>
<td>.22</td>
</tr>
<tr>
<td>Dialysis duration, y</td>
<td>3.1 (3.6)</td>
<td>5.1 (4.3)</td>
<td>.02</td>
</tr>
<tr>
<td>Preoperative anuria</td>
<td>37 (46)</td>
<td>19 (66)</td>
<td>.09</td>
</tr>
<tr>
<td>Operation time, mean (SD), min</td>
<td>238.8 (122.1)</td>
<td>204.4 (145.0)</td>
<td>.23</td>
</tr>
<tr>
<td>Intraoperative hemodynamics changed</td>
<td>68 (85)</td>
<td>21 (72)</td>
<td>.16</td>
</tr>
</tbody>
</table>

**Comorbid diseases**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Survival (n = 80)</th>
<th>Death (n = 29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes mellitus</td>
<td>36 (45)</td>
<td>14 (48)</td>
<td>.83</td>
</tr>
<tr>
<td>Hypertension</td>
<td>50 (62)</td>
<td>15 (52)</td>
<td>.38</td>
</tr>
<tr>
<td>Stroke</td>
<td>7 (9)</td>
<td>10 (34)</td>
<td>.002</td>
</tr>
<tr>
<td>Myelodysplasia syndrome</td>
<td>11 (14)</td>
<td>4 (14)</td>
<td>.99</td>
</tr>
<tr>
<td>Immunodeficiency</td>
<td>10 (12)</td>
<td>2 (7)</td>
<td>.51</td>
</tr>
<tr>
<td>Carotid artery disease</td>
<td>42 (52)</td>
<td>7 (24)</td>
<td>.009</td>
</tr>
<tr>
<td>Peripheral arterial occlusive diseases</td>
<td>11 (14)</td>
<td>5 (17)</td>
<td>.77</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>14 (18)</td>
<td>6 (21)</td>
<td>.78</td>
</tr>
</tbody>
</table>

**Operation categories**

<table>
<thead>
<tr>
<th>Category</th>
<th>Survival (n = 80)</th>
<th>Death (n = 29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal</td>
<td>29 (36)</td>
<td>16 (55)</td>
<td>.06</td>
</tr>
<tr>
<td>Chest</td>
<td>6 (8)</td>
<td>3 (10)</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>41 (51)</td>
<td>7 (24)</td>
<td></td>
</tr>
<tr>
<td>Neurological</td>
<td>3 (4)</td>
<td>3 (10)</td>
<td></td>
</tr>
<tr>
<td>Abdominal</td>
<td>29 (36)</td>
<td>16 (55)</td>
<td></td>
</tr>
</tbody>
</table>

**At the first postoperative dialysis session**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Survival (n = 80)</th>
<th>Death (n = 29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum creatinine, mean (SD), mg/dl</td>
<td>6.8 (2.6)</td>
<td>6.5 (2.6)</td>
<td>.61</td>
</tr>
<tr>
<td>Serum urea nitrogen, mean (SD), mg/dL</td>
<td>55.9 (22.5)</td>
<td>58.5 (22.7)</td>
<td>.60</td>
</tr>
<tr>
<td>Postoperative anuria</td>
<td>50 (62)</td>
<td>26 (90)</td>
<td>.009</td>
</tr>
<tr>
<td>APACHE II score, mean (SD)</td>
<td>18.5 (4.8)</td>
<td>21.4 (5.0)</td>
<td>.007</td>
</tr>
<tr>
<td>Mean arterial pressure, mean (SD), mm Hg</td>
<td>95.3 (15.8)</td>
<td>61.4 (28.1)</td>
<td>.02</td>
</tr>
<tr>
<td>Pao2/Fio2, mean (SD)</td>
<td>324.1 (132.6)</td>
<td>329.9 (153.9)</td>
<td>.48</td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>46 (58)</td>
<td>22 (76)</td>
<td>.12</td>
</tr>
<tr>
<td>IHD vs CVVH</td>
<td>70 (88)</td>
<td>20 (69)</td>
<td>.03</td>
</tr>
<tr>
<td>Hemoglobin, mean (SD), g/dL</td>
<td>9.7 (2.2)</td>
<td>9.2 (1.8)</td>
<td>.31</td>
</tr>
<tr>
<td>Lactate, mean (SD), mmol/L</td>
<td>2.4 (2.5)</td>
<td>3.2 (4.0)</td>
<td>.19</td>
</tr>
<tr>
<td>Vasopressor</td>
<td>37 (46)</td>
<td>12 (41)</td>
<td>.66</td>
</tr>
<tr>
<td>Inotropic equivalent, mean (SD)</td>
<td>3.1 (5.3)</td>
<td>5.3 (7.4)</td>
<td>.16</td>
</tr>
<tr>
<td>Emergency operation</td>
<td>14 (18)</td>
<td>7 (24)</td>
<td>.58</td>
</tr>
</tbody>
</table>

**Organ failure**

<table>
<thead>
<tr>
<th>Failure</th>
<th>Survival (n = 80)</th>
<th>Death (n = 29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central nervous system</td>
<td>28 (35)</td>
<td>10 (34)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Lung</td>
<td>16 (20)</td>
<td>6 (21)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Heart</td>
<td>4 (5)</td>
<td>5 (17)</td>
<td>.05</td>
</tr>
<tr>
<td>Liver</td>
<td>5 (6)</td>
<td>6 (21)</td>
<td>.04</td>
</tr>
<tr>
<td>Coagulation</td>
<td>3 (4)</td>
<td>2 (7)</td>
<td>.61</td>
</tr>
<tr>
<td>Sepsis</td>
<td>14 (18)</td>
<td>3 (10)</td>
<td>.55</td>
</tr>
</tbody>
</table>

**Change of urine amount from before to after surgery**

<table>
<thead>
<tr>
<th>Change</th>
<th>Survival (n = 80)</th>
<th>Death (n = 29)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>No anuria to no anuria</td>
<td>30 (38)</td>
<td>3 (10)</td>
<td>.02</td>
</tr>
<tr>
<td>No anuria to anuria</td>
<td>13 (16)</td>
<td>7 (24)</td>
<td></td>
</tr>
<tr>
<td>Anuria</td>
<td>37 (46)</td>
<td>19 (66)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; CVVH, continuous venovenous hemofiltration; FIO2, fraction of inspired oxygen; IHD, intermittent hemodialysis.

SI conversion factors: To convert serum creatinine to mmol/L, multiply by 88.4; serum urea nitrogen to mmol/L, multiply by 0.357.

a Values are expressed as number (%) of patients unless otherwise indicated.
b Calculated as the weight in kilograms divided by height in meters squared.
c Univarate with variable exit criteria set at P < .05 was put into multivariable logistic regression model.
d Defined as a change in systolic blood pressure >30% during operation.
e Inotropic equivalent is the combined dose of dopamine and dobutamine in micrograms per kilogram per minute.

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undergoing major surgical procedures. The development of postoperative anuria in those who had RIJO before surgery was associated with a higher rate of postoperative mortality. Careful monitoring and management of perioperative RIJO are crucial for achieving an optimal outcome. Further prospective studies should be done to reconcile the beneficial effect of maintaining perioperative RIJO to improve ICU survival.

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REFERENCES


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