Brazilian Journal of Medical and Biological Research (2006) 39: 1339-1347
ISSN 0100-879X

Incidence, risk factors and prognostic factors of acute renal failure in patients admitted to an intensive care unit

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Abstract

The objective of the present study was to assess the incidence, risk factors and outcome of patients who develop acute renal failure (ARF) in intensive care units. In this prospective observational study, 221 patients with a 48-h minimum stay, 18-year-old minimum age and absence of overt acute or chronic renal failure were included. Exclusion criteria were organ donors and renal transplantation patients. ARF was defined as a creatinine level above 1.5 mg/dL. Statistics were performed using Pearsons' χ^2 test, Student *t*-test, and Wilcoxon test. Multivariate analysis was run using all variables with $P < 0.1$ in the univariate analysis. ARF developed in 19.0% of the patients, with 76.19% resulting in death. Main risk factors (univariate analysis) were: higher intra-operative hydration and bleeding, higher death risk by APACHE II score, logist organ dysfunction system on the first day, mechanical ventilation, shock due to systemic inflammatory response syndrome (SIRS)/sepsis, noradrenaline use, and plasma creatinine and urea levels on admission. Heart rate on admission (OR = 1.023 (1.002-1.044)), male gender (OR = 4.275 (1.340-13642)), shock due to SIRS/sepsis (OR = 8.590 (2.710-27.229)), higher intra-operative hydration (OR = 1.002 (1.000-1004)), and plasma urea on admission (OR = 1.012 (0.980-1044)) remained significant (multivariate analysis). The mortality risk factors (univariate analysis) were shock due to SIRS/sepsis, mechanical ventilation, blood stream infection, potassium and bicarbonate levels. Only potassium levels remained significant (P = 0.037). In conclusion, ARF has a high incidence, morbidity and mortality when it occurs in intensive care unit. There is a very close association with hemodynamic status and multiple organ dysfunction.

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Received June 15, 2005
Accepted June 5, 2006

Key words
- Acute renal failure
- Risk factors
- Prognostic factors
- Intensive care unit
- Mortality

Introduction

Despite the recent technological advances, there is still a high incidence of acute renal failure (ARF) in intensive care unit (ICU) leading to high mortality (1-6). ARF can be defined as a sudden and continuous decrease of glomerular function associated with azotemia, followed or not by decreased urinary output (7). It occurs mostly as part of a multiple organ dysfunction syndrome associated with the systemic inflammatory response syndrome (SIRS) and sepsis, but it can also occur as a separate event. Its incidence varies from 3 to 30% (4,8-11) with mortality ranging from 36 to 90% (1-4,11, 12), depending on the type of ICU or type of patient assessed and the period during which the study is conducted. One of the factors that contribute to this high incidence and mortality is the greater morbidity of the patients currently admitted to ICU. Due to the better diagnostic and therapeutic resources available today, elderly patients and others with important co-morbidities, such as immunosuppression and chronic organ dysfunctions, undergo more aggressive treatments.

Several risk factors involved in the genesis of ARF have been analyzed in the medical literature. Obstetric bleeding and digestive hemorrhage, proposed by several investigators in earlier studies (5-8), have given way to consideration of other factors such as sepsis, shock, infections, use of contrast, and drug toxicity (4,5,8,13,14). Other associated factors are congestive heart failure and acute myocardial infarction (4,15,16), cirrhosis (4), chemotherapy (4), large burns (4), polytrauma, mostly associated with rhabdomyolysis, and surgery (17,18), mainly, complex heart and vascular surgeries (6). Mechanical ventilation is a frequently reported factor (19), probably as a marker of multiple organ dysfunction syndrome.

Similarly, the risk factors for mortality are also multiple in patients with ARF. Studies have demonstrated the importance of age and male gender, the latter possibly due to preexistent vascular diseases (1,3,4,6,10,13, 20-23). The delay before ARF onset, Acute Physiology, Age and Chronic Health Evaluation II (APACHE II) score and length of stay in the ICU seem to be important, probably because they are markers of the severity of the patient's condition (24).

The objective of the present study was to evaluate the incidence of ARF among ICU patients with normal renal function on admission, as assessed by creatinine levels, and to analyze the risk and prognostic factors of ARF and its impact on the clinical course as well as the mortality of these patients.

Patients and Methods

This was a prospective observational study conducted in a general ICU of a tertiary care university hospital. From October 1, 1999 to September 30, 2000, 828 patients were admitted to the ICU and only 221 satisfied both the inclusion and exclusion criteria. They were assessed prospectively once they met all the inclusion criteria, such as 48-h minimum stay, plasma creatinine levels of 1.5 mg/dL or lower, and minimum age of 18 years. Organ donors and renal transplant recipients were excluded.

The study was approved by the Ethics Committee of Hospital São Paulo.

On admission, demographic data were collected (gender and age), as well as category of admission (clinical, emergency surgical or elective surgical patients), cause of admission (infected or non-infected clinical patients and type of surgery), physiologic variables (heart rate, mean arterial pressure and central venous pressure), first 24-h stay water balance and APACHE II score with their respective death risk (25) and prior admission data (chronic diseases and previous length of hospital stay). Intraoperative data, such as surgery duration, surgical complications (bleeding, hypotension, hypoxemia, and acidemia), urinary output and hydration volume, as the total volume administered during surgery, were also recorded.

To quantify organ dysfunction, the logistic organ dysfunction system (LODS) score (26) was used on the first and seventh days. Laboratory evaluation was performed daily and included acid-base balance, sodium, potassium, urea, creatinine, hemogram, and coagulogram. Risk factors included use of radiocontrast media, nephrotoxic and vasoactive drugs before ARF onset, mechanical ventilation and occurrence of SIRS/sepsis, shock due to SIRS/sepsis, acute lung injury, and acute respiratory distress syndrome. Patients were followed until ICU discharge or death.

ARF was defined as a creatinine level above 1.5 mg/dL. Patients who developed ARF were monitored for total water balance, duration of ARF episode, plasma bicarbonate levels, need for dialysis, and use of a diuretic in order to complete the evaluation of prognostic factors. Standard treatment of ARF and criteria to start renal replacement therapy were not protocolled or recorded. All clinical decisions were made by the attending physician.

Statistical analysis was performed using an SAS 6.12 database. Quantitative variables are reported as means ± SD and qualitative variables as percentage. In the univariate analysis of risk factors we used the Student *t*-test or Wilcoxon test for the quantitative variables and the Pearsons' χ^2 test for the qualitative ones. All variables with a P value <0.1 in the univariate analysis were selected for multivariate analysis. The logistic regression forward method was used for multivariate analysis of the risk factor, and its results are reported as odds ratio (OR) and confidence interval. The logistic regression method could not be used to analyze the prognostic factors due to the instability of the model. Therefore, discriminating analysis was performed, with the level of significance set at P < 0.05.

Results

Global data of the study population

The demographic and overall features of the study population are shown in Table 1. ARF occurred in 42 patients (19%) of the study population.

Risk factors for acute renal failure development

There was no significant difference in mean age between patients with and without ARF (55.3 ± 18.4 (20-85) years and 54.7 ± 19.4 (18-94) years, respectively), with P = 0.873. We observed a trend towards an increasing number of ARF cases among male patients compared to female patients (59.5 and 40.5%, respectively, with P = 0.053). Although this difference was not statistically significant in univariate analysis, it was one of the significant variables in multi-

Table 1. General characteristics of the 221 patients studied.

Age (years)	54.8 ± 19.2
Gender	
Female	119 (53.8%)
Male	102 (46.2%)
Chronic diseases	
All	141 (63.8%)
Hypertension	79 (35.7%)
Diabetes mellitus	31 (14.0%)
Coronary heart disease	18 (8.1%)
Category of admission	
Clinical	61 (27.6%)
Emergency surgery	62 (28.1%)
Elective surgery	98 (44.3%)
Type of surgery	
Neurosurgery	45 (20.4%)
Gastrosurgery	36 (16.3%)
Vascular surgery	22 (9.9%)
Surgical complications[a]	
All	50 (22.6%)
Hypotension	38 (17.2%)
Bleeding	29 (13.1%)
APACHE II score	15.2 ± 7.7
Death risk	14.8 ± 17.4
1st day LODS score	5.3 ± 3.0
7th day LODS score	6.9 ± 4.7
Acute renal failure	19.0%
Mortality	36.2%

Data are reported as means ± SD or as number of patients, with percent given in parentheses. All percentages refer to the total number of patients (N = 221). Only main categories are presented, and therefore the sum is not 100%. [a]A patient could have had more than one complication. APACHE II = Acute Physiology, Age and Chronic Health Evaluation II; LODS = logistic organ dysfunction system.

variate analysis. Other significant differences between males and females could explain this finding. There was a higher number of surgical complications in males (28.4 and 17.6%, respectively, with P = 0.002), including hypotension (23.5 *vs* 11.8%, with P = 0.033) and bleeding (17.6 and 9.2%, with P = 0.065). Previous coronary heart disease and acute myocardial infarction were also more frequent in males than in females (11.8 *vs* 5.0%, with P = 0.068 and 6.9 *vs* 0.8%, with P = 0.019, respectively).

The mean hospital stay before ICU admission of ARF patients was longer than that of non-ARF patients (8.6 ± 8.2 (0-31) days *vs* 6.9 ± 10.1 (0-55) days, with P = 0.044). Surgical complications, namely bleeding and hypotension, were both more frequent among ARF patients (34.4 and 37.5% in ARF patients *vs* 14.2 and 20.5% in non-ARF patients, P = 0.008 and 0.04, respectively). Intraoperative hydration was also related to ARF development (P = 0.01; Table 2).

Organ dysfunction severity assessed by the LODS score on the first day of stay correlated with ARF development (6.5 ± 3.5 - ARF patients *vs* 5.0 ± 2.9 - non-ARF patients, P = 0.006). However, when we used the APACHE II score this correlation was not very clear (17.5 ± 9.4 - ARF patients *vs* 14.6 ± 7.1 - non-ARF patients, P = 0.073), although the death risk was significantly higher in the ARF population (20.9 ± 23.1 - ARF patients *vs* 13.2 ± 15.2 - non-ARF patients, P = 0.006). Plasma creatinine and urea levels on admission were higher in the ARF population (1.0 ± 0.3 (0.3-1.5) and 41.4 ± 19.0 (15.0-84.0) mg/dL) compared to non-ARF patients (0.9 ± 0.3 (0.2-1.5) and 34.9 ± 19.5 (10.0-128.0) mg/dL), with P = 0.0007 and 0.048, respectively. SIRS/sepsis, shock due to SIRS/sepsis and respiratory failure requiring mechanical ventilation were associated with ARF development (Table 2).

Only the previous use of noradrenaline correlated with the development of ARF (39.5 and 17.9%, ARF and non-ARF patients, respectively, with P = 0.003). Regarding nephrotoxic drugs, only the use of radiocontrast media was significantly more frequent among ARF patients (9.5%) compared to the non-ARF ones (1.7%), with P = 0.026. The univariate analysis of risk factors is presented in Table 2.

In multivariate analysis the variables that

Table 2. Univariate analysis of risk factors for the development of acute renal failure (ARF).

Characteristics	ARF patients	Non-ARF patients	P
Male gender	25 (59.5%)	77 (43.0%)	0.053
Surgical complications	15 (46.5%)	35 (27.6%)	0.035
Bleeding	11 (34.4%)	18 (14.2%)	0.008
Hypotension	12 (37.5%)	26 (20.5%)	0.04
SIRS/sepsis	30 (78.9%)	75 (41.9%)	0.0001
Shock due to SIRS/sepsis	21 (50.0%)	30 (16.8%)	0.0001
Use of noradrenaline	15 (39.5%)	32 (17.9%)	0.003
Use of radiologic contrast	4 (9.5%)	3 (1.7%)	0.026
Respiratory failure	33 (86.8%)	99 (55.3%)	0.001
Previous length of stay (days)	8.6 ± 8.2	6.9 ± 10.1	0.044
LODS score	6.5 ± 3.5	5.02 ± 2.9	0.006
APACHE II score	17.49 ± 9.37	14.59 ± 7.14	0.073
Death risk (%)	20.95 ± 23.14	13.19 ± 15.24	0.049
Urea on admission (mg/dL)	41.36 ± 18.98	34.93 ± 19.46	0.048
Creatinine on admission (mg/dL)	1.04 ± 0.29	0.88 ± 0.26	0.0007
Intraoperative hydration (mL/kg)	124.23 ± 117.83	95.31 ± 173.26	0.0170
Chronic diseases			
Hypertension	15 (35.7%)	64 (35.7%)	NS
Diabetes mellitus	7 (16.7%)	24 (13.4%)	NS
Coronary heart disease	6 (14.3%)	12 (6.7%)	NS
COPD	2 (4.8%)	11 (6.1%)	NS
Admission category			
Clinical	10 (23.8%)	51 (28.5%)	NS
Elective surgery	21 (50.0%)	77 (43.0%)	NS
Emergency surgery	11 (26.2%)	51 (28.5%)	NS
Nephrotoxic drugs			
Aminoglycosides	17 (40.5%)	58 (32.4%)	NS
Vancomycin	14 (33.3%)	54 (30.2%)	NS
Vasoactive drugs			
Dobutamine	6 (15.8%)	12 (6.7%)	NS
Dopamine	15 (39.5%)	14 (25.1%)	NS
Surgery characteristics			
Length (min)	325.5 ± 183.3	276.1 ± 160.2	NS
Urinary output (mL kg^{-1} h^{-1})	4.5 ± 6.2	5.2 ± 7.6	NS
Age (years)	55.3 ± 18.4	54.7 ± 19.4	NS

Data were analyzed statistically by the Pearsons' χ^2 test and the Student *t*-test. Data are reported as means ± SD or as number of patients, with percent given in parentheses. SIRS = systemic inflammatory response syndrome; LODS = logistic organ dysfunction system; APACHE II = Acute Physiology, Age and Chronic Health Physiology Evaluation II; COPD = chronic obstructive pulmonary disease. All variables with P < 0.1 were selected for multivariate analysis. NS = not significant.

remained independently associated with ARF development are listed in Table 3. In the surgical subgroup analysis the same variables have been found (Table 3).

Clinical outcome

During the ICU stay the mortality of ARF patients (76.2%) was significantly higher than that of non-ARF patients (27.0%), with P = 0.018. There was also a significant increase of ICU length of stay in the first group (16.1 ± 13.3 *vs* 12.7 ± 14.9 days, P = 0.018).

Patients developed ARF after a mean of 5.8 ± 7.7 (2-41) days of ICU stay. Creatinine levels remained high for a mean period of 7.8 ± 8.4 (2-33) days and mean peak levels were 3.3 ± 1.8 (1.6-9.1) mg/dL. Among 42 patients with ARF, 41 (97.6%) had at least one complication while in the group without ARF the rate reached 73.2% (P = 0.001). The most frequent complications can be seen in Table 4.

Organ dysfunction, when assessed by LODS score on the seventh day, was more severe in patients with ARF (10.8 ± 4.8 (4-22) *vs* 6.1 ± 4.3 (0-17), P = 0.0001). The accumulated water balance was higher in patients with ARF (78.6%) than in those without it (54.2%), with P = 0.004. Only 10 patients (23.8%) needed renal replacement therapy and all of these received hemodialysis.

Analysis of risk factors for mortality in acute renal failure patients

Univariate analysis showed that the presence of shock due to SIRS/sepsis, respiratory failure requiring mechanical ventilation, plasma bicarbonate levels, and potassium levels correlated with mortality (Table 5). The variables that did not correlate with mortality are also shown in Table 5. In the discriminating analysis, only potassium levels remained as a risk factor for mortality, with P = 0.037.

Discussion

The definition of ARF is not uniform in the medical literature. Most studies, even the latest ones, have used biochemical criteria based on plasma creatinine levels, whereas others were based on the need for dialysis (1-4,6,7). Kidney tomography or biopsy has also been used (1). This heterogeneity of criteria makes the comparison among studies extremely difficult (27). The criterion

Table 3. Risk factors associated with the development of acute renal failure (ARF) identified by multivariate analysis.

Characteristics	OR	CI (95%)
Total population (N = 221)		
Heart rate on admission	1.023	1.002-1.044
Male gender	4.275	1.340-13.642
Shock due to SIRS/sepsis	8.590	2.710-27.229
Intraoperative hydration	1.002	1.000-1.004[NS]
Urea on admission	1.012	0.980-1.044
Surgical patients (N = 160)		
Heart rate on admission	1.025	1.004-1.047
Male gender	3.943	1.235-12.590
Shock due to SIRS/sepsis	9.421	2.912-30.480
Intra-operative hydration	1.002	1.000-1.004[NS]
Urea on admission	1.011	0.979-1.044[NS]

Multiple regression, OR = odds ratio; CI = confidence interval (95%); SIRS = systemic inflammatory response syndrome.
[NS]Not significant.

Table 4. Incidence of complications during the stay in the intensive care unit.

Complications	ARF patients	Non-ARF patients	P
Respiratory failure	38 (85.7%)	104 (51.1%)	0.0001
ALI	14 (33.3%)	43 (24.0%)	NS
ARDS	9 (21.4%)	12 (6.7%)	0.007
Pulmonary embolism	2 (4.8%)	0 (0.0%)	0.035
SIRS/sepsis	35 (83.3%)	79 (44.1%)	0.0001
Shock due to SIRS/sepsis	28 (68.3%)	30 (16.8%)	0.0001
Infectious complications	18 (42.9%)	50 (27.9%)	NS
Blood stream infection	10 (23.8%)	20 (11.2%)	0.031
Pneumonia	16 (38.1%)	49 (27.4%)	NS
Urinary tract infection	3 (7.1%)	5 (2.8%)	NS

Data are reported as number of patients, with percent given in parentheses. Total number of patients = 221. Pearsons' χ^2 test. ARF = acute renal failure; ALI = acute lung injury; ARDS = acute respiratory distress syndrome; SIRS = systemic inflammatory response syndrome; NS = not significant.

adopted here was based on a rather wide definition, with high sensitivity, in order to detect as large a number of patients as possible. Based on this definition, we found an incidence of 19.0%, which agrees with studies in similar populations (3,8,13,15,17). Within the inclusion criteria, patients with previous renal dysfunction were not evaluated in order to obtain the real incidence of ARF inside the ICU. Thus, we tried to disregard all patients who presented worsening of chronic renal failure. Therefore, the real magnitude of the problem may have been underestimated.

Table 5. Univariate analysis of risk factors for mortality of patients with acute renal failure.

Characteristic	Survivors (N = 10)	Non-survivors (N = 32)	P
Shock due to SIRS/sepsis	1 (11.1%)	27 (84.4%)	0.0001
Respiratory failure	6 (60.0%)	30 (93.7%)	0.021
Blood stream infection	0 (0.0%)	10 (31.3%)	0.084
Use of noradrenaline	1 (10.0%)	14 (43.7%)	0.068
Plasma bicarbonate levels (mEq/L)	18.4 ± 3.8	15.3 ± 4.1	0.037
Plasma potassium levels (mEq/L)	5.0 ± 1.0	6.0 ± 0.8	0.013
Male gender	5 (50.0%)	20 (62.5%)	NS
Chronic diseases	7 (70.0%)	21 (65.6%)	NS
Surgical complications	4 (44.4%)	11 (47.8%)	NS
Clinical complications	9 (90.0%)	32 (100.0%)	NS
Infectious complications	2 (11.1%)	16 (88.9%)	NS
SIRS/sepsis	7 (20.0%)	28 (80.0%)	NS
ARDS	1 (10.0%)	8 (25.0%)	NS
Use of dobutamine	2 (20.0%)	5 (15.6%)	NS
Use of dopamine	3 (30.0%)	17 (53.1%)	NS
Need for hemodyalisis	0 (0.0%)	9 (28.1%)	NS
Age (years)	58.80 ± 19.57	54.16 ± 18.17	NS
Urea levels at admission (mg/dL)	42.23 ± 19.43	38.14 ± 18.22	NS
Lower PaO_2/FiO_2 rate	351.63 ± 264.41	310.50 ± 127.95	NS
Creatinine levels at admission (mg/dL)	1.04 ± 0.25	1.04 ± 0.43	NS
ICU stay (days)	19.50 ± 18.42	15.09 ± 11.51	NS
Hospital stay before ICU (days)	10.88 ± 10.47	8.03 ± 7.70	NS
APACHE II score	17.94 ± 9.23	15.75 ± 10.33	NS
1st day LODS score	6.60 ± 3.95	6.44 ± 3.37	NS
7th day LODS score	8.16 ± 2.40	11.80 ± 5.13	NS
Duration of abnormal creatinine (days)	7.80 ± 9.86	7.78 ± 8.07	NS
Levels of creatinine (mg/dL)	3.03 ± 2.10	3.39 ± 1.72	NS
Urine output post-ARF (mL/kg)	235.77 ± 302.63	215.98 ± 255.18	NS
Diuretic use (number of vials)	4.00 ± 4.24	13.71 ± 22.84	NS

Data are reported as means ± SD or as number of patients, with percent given in parentheses. SIRS = systemic inflammatory response syndrome; ARDS = acute respiratory distress syndrome; PaO_2/FiO_2 = arterial O_2 partial pressure/inspired pressure of O_2; ICU = intensive care unit; APACHE II = Acute Physiology, Age and Chronic Health Physiology Evaluation II; LODS = logistic organ dysfunction system; ARF = acute renal failure. All variables with P < 0.1 were selected for multivariate analysis. NS = not significant.

The unit where the study was conducted is predominantly surgical, with a consequent basically very complicated postoperative population, since the inclusion only of patients with more than 48 h of ICU admission excluded the majority of uncomplicated elective surgical patients. The mean hospital stay prior to admission was long, with a high frequency of associated co-morbidities. These overlapping factors characterized a high-risk population, explaining the high mortality of the ARF patients studied. There is a wide range of reported mortality rates and this could be secondary to a wide variation in patient characteristics and practice patterns across institutions.

However, the mean APACHE II score and its respective death risk were relatively low compared to other studies. There was a difference between predicted and real mortality suggesting that this index is not appropriate for ARF assessment. This finding has been reported previously (28,29). On the other hand, LODS score on the first ICU admission day has proved to be very suitable for mortality assessment. It is possible that the first 24 h of admission do not define so clearly the prognosis in the population with ARF as the severity of organ dysfunction of these patients would do.

Our results show that men were more affected than women, presenting a 4-fold higher risk (OR = 4.275). This was an interesting finding since male gender and shock were the variables with strongest association with ARF in multivariate analysis. This finding has also been reported by others (13). The greater number of surgical complications, such as hypotension and bleeding as well as the presence of previous coronary heart disease and acute myocardial infarction may have contributed to this finding. Differences related to gender are common in the population of critically ill patients. For instance, it has been shown that sepsis is more frequent among men (30) and renal failure is part of the organ dysfunction context in sepsis. It is also possible that still unknown genetic aspects may have influenced the incidence of ARF in the male population.

Few studies have assessed the impact of surgical complications on ARF development, in spite of their potential as risk factors (31-33). The mean volume replacement during the intraoperative period among the patients that developed ARF was higher than in the patients that did not, and this factor remained as an independent risk factor in multivariate analysis, although with a low OR. Higher intraoperative hydration can be a marker of disease severity, since more severely ill patients need more fluid during surgery. On the other hand, giving fluids to the surgical patient can by itself increase morbidity. Interstitial edema is a concern in this population as it predisposes to suture dehiscence, with wounds being less prone to healing. Our study was not designed to address this question, and therefore only an association can be considered with no causality assessment.

Although it did not remain in the multivariate analysis, the small difference in creatinine levels on admission in these two populations was highly significant ($P = 0.0007$). Hypotension or hypovolemia could have contributed. This fact may have clinical implications since a surgical patient admitted to the ICU with slightly elevated creatinine levels must be considered and treated as a patient at risk to develop ARF.

Like other investigators (5,6,8), we found shock due to SIRS/sepsis as a risk factor associated with ARF development both in the group as a whole and in the subgroup of surgical patients. Although resulting hypotension is the most quoted factor, not all pathophysiologic mechanisms of sepsis are clear, and therefore the relationship with ARF development is still a matter of discussion (34,35). The absence of correlation with the use of nephrotoxic drugs may suggest that pre-renal causes are the leading pathophysiological phenomena. These results strengthen the fundamental role of hemodynamic instability in the onset of ARF within the organ dysfunction context of a patient with sepsis or with an inflammatory response secondary to other aggression agents.

Among the prognostic factors, four were associated with a worse outcome of patients with ARF: shock due to SIRS/sepsis, respiratory failure with mechanical ventilation, plasma bicarbonate levels, and maximum plasma potassium levels. The only variable that remained significant in the multivariate analysis was the maximum plasma potassium level. This suggests that ARF seriousness assessed by this variable is a determinant of the prognosis of these patients. However, this analysis may have been confounded by the small number of patients in each subgroup, which prevented logistic regression analysis.

The present study had some limitations. Many patients with normal creatinine levels during ICU stay could have been considered to have ARF, if other criteria such as creatinine clearance had been used. Thus, the real incidence of ARF may have been underreported here. There is also the same problem regarding our inclusion criteria since patients already with ARF but with normal creatinine levels on admission could have been included. It is well known that ARF can be present in patients with normal creatinine levels, mostly middle-aged or elderly patients. Thus, strictly speaking, our incidence of ARF cannot be considered as the true incidence in patients with previous normal renal function, since several patients in our sample could have, in fact, mild or moderate chronic renal failure if estimated by creatinine clearance. Nonetheless, there is no consensus in the literature regarding ARF definition and all other criteria, even calculated or measured creatinine clearance, have their own limitations.

Another limitation of our study is the low

OR observed during multivariate analysis. Despite a significant P value, the clinical significance of these results is questionable. Moreover, the confidence intervals frequently involved the unit (1.0), such as intraoperative hydration, urea levels on admission and even heart rate on admission (1.002-1.044), which could compromise the strength of our results. It is possible that our small sample size (221) is responsible for these low intervals. For this reason, our results should be interpreted with caution.

There is a high incidence of ARF in ICU patients who do not present it on admission, with a high mortality rate. Risk and prognostic factors are primarily related to hemodynamic status. The global knowledge of the factors involved in the onset and prognosis of ARF is of fundamental importance regarding the management of critically ill patients. The high mortality associated with this organ dysfunction causes it to be somewhat more feared than other dysfunctions, such as acute respiratory distress syndrome, disseminated intravascular coagulation or even septic shock itself.

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