Acute renal failure in the ICU: risk factors and outcome evaluated by the SOFA score

A. de Mendonça  
J.L. Vincent  
P.M. Suter  
R. Moreno  
N.M. Dearden  
M. Antonelli  
J. Takala  
C. Sprung  
F. Cantraine

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Abstract  
Objectives: To describe risk factors for the development of acute renal failure (ARF) in a population of intensive care unit (ICU) patients, and the association of ARF with multiple organ failure (MOF) and outcome using the sequential organ failure assessment (SOFA) score.  
Design: Prospective, multicenter, observational cohort analysis.  
Setting: Forty ICUs in 16 countries.  
Patients: All patients admitted to one of the participating ICUs in May 1995, except those who stayed in the ICU for less than 48 h after uncomplicated surgery, were included. After the exclusion of 38 patients with a history of chronic renal failure requiring renal replacement therapy, a total of 1411 patients were studied.  
Measurements and results: Of the patients, 348 (24.7%) developed ARF, as diagnosed by a serum creatinine of 300 μmol/l (3.5 mg/dl) or more and/or a urine output of less than 500 ml/day. The most important risk factors for the development of ARF present on admission were acute circulatory or respiratory failure; age more than 65 years, presence of infection, past history of chronic heart failure (CHF), lymphoma or leukemia, or cirrhosis. ARF patients developed MOF earlier than non-ARF patients (median 24 vs 48 h after ICU admission, p < 0.05). ARF patients older than 65 years with a history of CHF or with any organ failure on admission were most likely to develop MOF. ICU mortality was 3 times higher in ARF than in other patients (42.8% vs 14.0%, p < 0.01). Oliguric ARF was an independent risk factor for overall mortality as determined by a multivariate regression analysis (OR = 1.59 [CI 95%: 1.23–2.06], p < 0.01). Infection increased the risk of death associated with all factors. Factors that increased the ICU mortality of ARF patients were a past history of hematologic malignancy, age more than 65 years, the number of failing organs on admission and the presence of acute cardiovascular failure.  
Conclusion: In ICU patients, the most important risk factors for ARF or mortality from ARF are often present on admission. During the ICU stay, other organ failures (especially cardiovascular) are important risk factors. Oliguric ARF was an independent risk factor for ICU mortality, and infection increased the contribution to mortality by other factors. The severity of circulatory shock was the most important factor influencing outcome in ARF patients.

Key words  
Mortality · Oliguria · Multiple organ failure · Severity-of-illness · Prognosis · Scoring systems

F. Cantraine  
Faculty of Medicine,  
Free University of Brussels,  
Route de Lennik 808,  
1070 Brussels, Belgium

A.de Mendonça · J.-L. Vincent (✉)  
Department of Intensive Care,  
Erasme University Hospital,  
Route de Lennik 808, 1070 Brussels, Belgium  
e-mail: jlvincen@ulb.ac.be  
Tel.: +32-2-5553380  
Fax: +32-2-5554555

P.M. Suter  
Dept of Surgery Int. Care,  
Hopital Cantonal Universitaire, 24 rue Micheli-du-Crest, 1211 Geneva 14, Switzerland

R. Moreno  
Dept of Intensive Care,  
S. Antonio Capuchos Hospital,  
Al. St. Antonio Capuchos, 1150 Lisbon, Portugal

N.M. Dearden  
Dept of Anaesthesiology,  
Leeds General Infirmary,  
Great George Street, Leeds LS1 3EX, UK

M. Antonelli  
Dept of Anesthesiology and Intensive care,  
Universita “La Sapienza”,  
Policlinico Umberto I, 00161 Roma, Italy

J. Takala  
Dept of Intensive care,  
University Hospital of Bern, 3010 Bern, Switzerland

C. Sprung  
Dept of Anaesthesiology,  
Hadassah Univ. Med. Center, 91120 Jerusalem, Israel
**Table 1** The SOFA score (MAP mean arterial pressure)

<table>
<thead>
<tr>
<th>SOFA score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO₂/FIO₂ (mmHg) (kPa)</td>
<td>&gt; 400</td>
<td>301–400</td>
<td>201–300</td>
<td>101–200</td>
<td>≤ 100</td>
</tr>
<tr>
<td>Coagulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets (x10³/mm³)</td>
<td>&gt; 150</td>
<td>101–150</td>
<td>51–100</td>
<td>21–50</td>
<td>≤ 20</td>
</tr>
<tr>
<td>Liver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilirubin (mg/dl) (μmol/l)</td>
<td>&lt; 1.2</td>
<td>1.2–1.9</td>
<td>2.0–5.9</td>
<td>6.0–11.9</td>
<td>≥ 12.0</td>
</tr>
<tr>
<td>(μmol/l)</td>
<td>&lt; 20</td>
<td>(20–32)</td>
<td>(33–101)</td>
<td>(102–204)</td>
<td>≥ 204</td>
</tr>
<tr>
<td>Cardiovascular Hypotension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No hypotension</td>
<td>MAP &lt; 70 mmHg</td>
<td>Dopamine ≤ 5 or dobutamine (any dose)*</td>
<td>Dopamine &gt; 5</td>
<td>Dopamine &gt; 15</td>
<td></td>
</tr>
<tr>
<td>Central nervous system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glasgow coma score</td>
<td>15</td>
<td>13–14</td>
<td>10–12</td>
<td>6–9</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>Renal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creatinine (mg/dl) (μmol/l) or urine output</td>
<td>&lt; 1.2</td>
<td>1.2–1.9</td>
<td>2.0–3.4</td>
<td>3.5–4.9</td>
<td>&gt; 5.0</td>
</tr>
<tr>
<td>(μmol/l)</td>
<td>&lt; 110</td>
<td>(110–170)</td>
<td>(171–299)</td>
<td>(300–440)</td>
<td>&gt; 440</td>
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<tr>
<td>or urine output</td>
<td>&lt; 500 ml/day</td>
<td>&lt; 200 ml/day</td>
<td>&lt; 200 ml/day</td>
<td>&lt; 200 ml/day</td>
<td>&lt; 200 ml/day</td>
</tr>
</tbody>
</table>

*α-adrenergic agents administered for at least 1 h (doses given are in μg/kg/min)

**Introduction**

Acute renal failure (ARF) is a common and serious complication in critically ill patients. The incidence of ARF in intensive care unit (ICU) patients varies from 3 to 16%, depending on the population studied and the criteria used to define ARF [1, 2, 3]. The mortality rate in ARF patients remains high [1, 4, 5, 6, 7, 8, 9, 10, 11] despite improvements in renal replacement techniques. Possible explanations for this finding include the fact that ICU patients today are older and more debilitated than previously [12], and that the same pathophysiologic factors involved in the development of ARF are also implicated in the failure of other organs, so that ARF is often part of the multiple organ failure (MOF) syndrome [1, 13]. The aim of the present study was to define the profile of ARF patients in the critical care setting and to identify the risk factors related to the development of, and mortality from, ARF, and the association of ARF with failure of other organs. We used a large database to evaluate organ dysfunction/failure using a newly described organ failure assessment score [14] developed by consensus and validated by retrospective (1643 patients [15]) and prospective (1449 patients [14]) data collection.

**Patients and methods**

Forty participating centers in 16 countries (see Appendix) enrolled all patients admitted to the ICU during May 1995, excluding patients under 12 years of age and those remaining in the ICU for less than 48 h after uncomplicated elective surgery. A total of 1449 patients were included. Thirty-eight patients with chronic renal failure requiring renal replacement therapy were eliminated from this study population. For the remaining 1411 patients, admission data related to demography, previous health status and presence of infection were obtained. Daily evaluation of organ function was performed based on a set of clinical and laboratory parameters and the most abnormal value for each system in each 24 h period was noted according to the sequential organ failure assessment score (SOFA, Table 1).

The patients were separated into two groups, depending on the presence or absence of ARF at any time during their ICU stay. ARF was defined by a creatinine concentration of 300 μmol/l (3.5 mg/dl) or more, and/or oliguria (a daily urine output < 500 ml). The previous health status of each patient was determined on admission: CHF was defined as the presence of Class III or IV symptoms of the New York Heart Association classification, while the definitions of acquired immunodeficiency syndrome (AIDS), cancer, cirrhosis, chronic obstructive pulmonary disease (COPD) and diabetes were left to each physician. Infection, on admission and/or during the ICU stay, was assessed by each physician according to clinical, laboratory and microbiological parameters following the criteria of the Center for Disease Control. Organ failure was defined as a SOFA score (Table 1) of 3 or more for any system. MOF was defined as the simultaneous presence of two or more organ failures, other than renal, at any time during the ICU stay. We identified individual risk factors for developing ARF and, in patients with ARF, predictors of MOF and mortality.

Data were analyzed using a Statistical Package for Social Sciences (SPSS, release 5.0.1 for Windows, SPSS, Chicago, Ill.) software. Categorical data were expressed in proportion, and subgroups were analyzed by a χ² statistic (with Yates’ correction where applicable). Continuous data were expressed as median and subgroups were evaluated by a non-parametric rank test (Mann-Whitney-U, Wilcoxon). Risk factors were evaluated in univariate analysis, and in multivariate analysis by a multiple logistic stepwise regression procedure [16]. The relationship between different factors and mortality was evaluated by a Cox Proportional Hazards Model [17], and survival curves were constructed. Variables with p less than 0.05 were included in the model. Odds ratios were estimated from the b coefficients obtained, with respective