The clinical relevance of oliguria in the critically ill patient: analysis of a large observational database

Jean-Louis Vincent 1*, Andrew Ferguson 2, Peter Pickkers 3, Stephan M. Jakob 4, Ulrich Jaschinski 5, Ghaleb A. Almekhlafi 6, Marc Leone 7, Majid Mokhtari 8, Luis E. Fontes 9, Philippe R. Bauer 10, Yasser Sakr 11 for the ICON Investigators

Abstract

Background: Urine output is widely used as one of the criteria for the diagnosis and staging of acute renal failure, but few studies have specifically assessed the role of oliguria as a marker of acute renal failure or outcomes in general intensive care unit (ICU) patients. Using a large multinational database, we therefore evaluated the occurrence of oliguria (defined as a urine output < 0.5 ml/kg/h) in acutely ill patients and its association with the need for renal replacement therapy (RRT) and outcome.

Methods: International observational study. All adult (> 16 years) patients in the ICON audit who had a urine output measurement on the day of admission were included. To investigate the association between oliguria and mortality, we used a multilevel analysis.

Results: Of the 8292 patients included, 2050 (24.7%) were oliguric during the first 24 h of admission. Patients with oliguria on admission who had at least one additional 24-h urine output recorded during their ICU stay (n = 1349) were divided into three groups: transient—oliguria resolved within 48 h after the admission day (n = 390 [28.9%]), prolonged—oliguria resolved > 48 h after the admission day (n = 141 [10.5%]), and permanent—oliguria persisting for the whole ICU stay or again present at the end of the ICU stay (n = 818 [60.6%]). ICU and hospital mortality rates were higher in patients with oliguria than in those without, except for patients with transient oliguria who had significantly lower mortality rates than non-oliguric patients. In multilevel analysis, the need for RRT was associated with a significantly higher risk of death (OR = 1.51 [95% CI 1.19–1.91], p = 0.001), but the presence of oliguria on admission was not (OR = 1.14 [95% CI 0.97–1.34], p = 0.103).

Conclusions: Oliguria is common in ICU patients and may have a relatively benign nature if only transient. The duration of oliguria and need for RRT are associated with worse outcome.

Keywords: Urine output, Renal replacement therapy, Mortality

* Correspondence: jlvincent@intensive.org

© The Author(s). 2020 Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.
**Introduction**

Regardless of the exact criteria used to define it, oliguria is often observed in critically ill patients, and yet there are many questions regarding its clinical relevance and impact on outcomes. Reduced urine output can be a physiological response or a reflection of altered tissue perfusion or renal dysfunction [1–3].

Although urine output is now widely used as one of the criteria for the diagnosis and staging of acute renal failure [4–7], there are relatively few studies that have specifically assessed urine output or oliguria as a marker of acute renal failure or outcomes in general populations of intensive care unit (ICU) patients [2, 8, 9]. The clinical importance of oliguria likely depends on its duration. For example, a 1-h period of oliguria during an emergency admission is less important than if the symptom persists for longer periods, when it is more likely to reflect impaired renal function [10, 11].

To provide some global insight into the impact of oliguria and its persistence on outcomes in general ICU patients, we reviewed the large, international Intensive Care over Nations (ICON) database to evaluate the occurrence of oliguria and its association with the need for renal replacement therapy (RRT) and mortality.

**Patients and methods**

This study is a substudy of the ICON audit [12]. All adult (> 16 years) patients admitted to a participating ICU (see the list in the “Acknowledgements”) between May 8 and May 18, 2012, were included in the audit, except those who stayed in the ICU for < 24 h for routine postoperative surveillance. Participation was voluntary, with no financial incentive. Ethics committee approval was obtained by the participating institutions according to local ethical regulations.

Data were collected daily for a maximum of 28 days in the ICU and entered using electronic case report forms via a secured internet-based website. Survival data were collected at the time of ICU and hospital discharge, or at 60 days, whichever occurred first. Detailed instructions and definitions were available through a secured website for all participants before starting data collection and throughout the study period. Any additional queries were answered on a per case basis. Validity checks were made at the time of electronic data entry, including plausibility checks within each variable and between variables. Data were further reviewed by the coordinating center for completeness and plausibility, and any doubts clarified with the participating center. There was no on-site monitoring.

Data collection on admission included demographic data and comorbidities. Clinical and laboratory data for the SAPS II score [13] were reported as the worst values within the first 24 h after admission. A daily evaluation of organ function was performed according to the Sequential Organ Failure Assessment (SOFA) score [5]; organ failure was defined as a SOFA subscore ≥ 2 for the organ in question. ICU interventions, including RRT and mechanical ventilation, were recorded daily.

Clinical and microbiologically proven infections were reported daily as well as antimicrobial therapy. Infection was defined according to the criteria of the International Sepsis Forum [14]. Sepsis was defined as the presence of infection with associated organ failure [15]. Septic shock was defined as sepsis associated with cardiovascular failure requiring vasopressor support (SOFA cardiovascular score ≥ 3). The presence of a decision to withhold/withdraw a life-sustaining measure at any time during the ICU stay was also recorded.

On the case report form, investigators recorded urine output in milliliters as a total for each 24-h period. On the day of admission, urine output data were recorded for the period from the time of admission till the start of the next ICU day. For the purposes of this study, oliguria was defined as a calculated urine output < 0.5 ml/kg/h averaged over a 24-h period [2]. To calculate the urine output for the 24-h admission day period, if full urine output data for the first 24 h of admission were recorded, these data were used for the determination of oliguria “on admission.” If data were provided for only X hours on the day of admission (because, for example, the patient was admitted at 10 pm and 24-h urine measurement started at midnight so only 2-h urine output were noted), the estimation of urine output on admission was averaged from the data for the X hours and the data from the first full day on the ICU (2nd day 24-h urine output/24 × [24 − X]). If no data were recorded for the admission day, we were unable to estimate an admission urine output and the patient was not included. The methods of measuring urine output or of assessing body weight were not recorded. Patients with comorbid chronic renal failure were excluded.

For analysis of evolution during the ICU stay, we included only patients who had a urine output recorded on the day of admission and at least one other 24-h urine output value, and separated them into three groups:

- **Transient oliguria**—oliguria resolved within 48 h after the 24-h admission day
- **Prolonged oliguria**—oliguria resolved more than 48 h after the 24-h admission day and not present at the end of the ICU stay
- **Permanent oliguria**—oliguria present on the day of admission and persisting for the whole ICU stay or again present at the end of the ICU stay
Statistical analysis

Data are shown as means with standard deviation (SD) or 95% confidence intervals (CI), medians and interquartile ranges (IQR), numbers, and percentages. For the descriptive statistics, only available data were used so missing data were subtracted from the denominator when calculating percentages. Differences between groups in distribution of variables were assessed using the analysis of variance (ANOVA), Kruskal-Wallis test, Student’s t test, Mann-Whitney test, chi-square test, or Fisher’s exact test as appropriate.

Individual countries were classified into three income groups according to the 2011 gross national income (GNI) per capita, calculated using the World Bank Atlas method [16]: GNI < $4035 = low and lower middle income, GNI $4036–12,475 = upper middle income, and GNI > $12,476 = high income.

To investigate the association between oliguria on admission and mortality, we used a three-level technique with the structure of an individual patient (level 1) admitted to a specific hospital (level 2) within a particular country (level 3). So patients were nested within hospitals within countries. The model includes hospital and country units as random effects to express the concept that patients from the same country and treated in the same hospital share a common environment. The dependency between patients in a hospital within a country is captured through the use of random intercepts. The explanatory variables considered in the model were:

- Individual-level factors: age, sex, SAPS II score, type of admission, source of admission, highest concentration of creatinine, daily fluid balance, mechanical ventilation or RRT at any time during the ICU stay, fluid balance, presence of recorded end-of-life decision, comorbidities, severity of sepsis during the ICU stay, oliguria on admission
- Hospital-level factors: type of hospital, ICU specialty, total number of ICU patients in the previous year, number of staffed ICU beds
- Country-level factors: GNI

Collinearity between variables was checked by inspection of the correlation between them, by looking at the correlation matrix of the estimated parameters, and by looking at the change in parameter estimates and at their estimated standard errors [17]. Q-Q plots were drawn to check for normality in the residuals. The results of fixed effects (measures of association) are given as odds ratios (OR) with their 95% CI. Random effects (measures of variation) measures included the variance (var) and its standard error (se). The restricted maximum likelihood (REML) procedure, which gives unbiased estimates of the model parameters, was used. The Wald test was used to assess the significance of included covariates. The percentage of cases correctly classified and the area under the receiver operating characteristic curve (AUC) are given to quantify the discriminating power of the model. Missing cases for the included variables were analyzed using the missing-value indicator method.

Data were analyzed using IBM® SPSS® Statistics software, version 26 for Windows and R software, version 3.6.1 (CRAN project). All reported p values are two-sided, and a p value < 0.05 was considered to indicate statistical significance.

Results

Of the 10,069 patients included in the ICON audit, 9148 had urine output data on the day of admission; 856 had comorbid chronic renal failure and were excluded, leaving 8292 patients for analysis (Fig. 1).

Patients with oliguria on admission

A total of 2050 (24.7%) patients had oliguria on the 24-h admission period, with a median urine output of 0.3 [IQR 0.1–0.4] ml/kg/h compared to 1.1 [IQR 0.8–1.6] ml/kg/h in patients who were not oliguric on admission (p < 0.001) (Table 1). Patients with oliguria on admission were older and more severely ill than those without, and a higher proportion had a medical diagnosis and comorbid heart failure, liver cirrhosis, and human immunodeficiency virus (HIV) infection (Table 1). They were more likely to have sepsis (24.5% vs 16.7%, p < 0.001) and to have all forms of organ failure, except hepatic (Table 1). Vasopressor use was higher in patients with oliguria at admission than in those without (36.9% vs 26.8%, p < 0.001).

ICU (26.8% vs 11.5%, p < 0.001) and hospital (34.5% vs 16.7%, p < 0.001) mortality rates were more than twice as high in patients with oliguria on admission than in those without (Table 1). End-of-life decisions were more common in oliguric patients than in the other patients (Table 2).

RRT was needed at some point during the ICU stay in 442 (21.6%) of the patients with and in 407 (6.5%) of the patients without oliguria on admission (p < 0.001) (Table 2). Multilevel analysis revealed that the need for RRT was associated with a statistically significant increased risk of death (OR = 1.51 [95% CI 1.19–1.91], p = 0.001), but the presence of oliguria on admission was not (OR = 1.14 [95% CI 0.97–1.34], p = 0.103) (Table 3). After controlling for patient and hospital factors and GNI, there was significant between-hospital (var = 0.5 [se = 0.09], p < 0.001) and between-country (var = 0.23 [se = 0.08], p = 0.004) variation in risks of in-hospital death (Table 3), indicating that the occurrence of in-hospital death was influenced by both hospital- and country-related factors.
Persistence of oliguria during ICU stay
A total of 1349 patients had at least one additional urine output measurement recorded during their ICU stay. Oliguria was transient in 390 (28.9%) of these patients, prolonged in 141 (10.5%), and permanent in 818 (60.6%) (Table 4). ICU mortality was 7.1% when oliguria was transient, significantly lower than in the patients without oliguria (11.5%, \( p = 0.037 \)); rates were 10.9% when oliguria was prolonged and 28.9% when permanent (Table 4).

RRT was used in the ICU in 48 (12.3%), 63 (44.7%), and 273 (33.4%) patients with transient, prolonged, and permanent oliguria, respectively; 102 (19%) patients with permanent oliguria died in the ICU without receiving RRT. RRT was started within 24 h in 72.4% of patients with oliguria (75.0% vs 73.0% vs 71.8% in patients with transient, prolonged, and permanent oliguria, respectively). Among patients receiving RRT, ICU mortality was higher in non-oliguric patients than in those with
### Table 1 Characteristics of the study cohort on admission to the ICU stratified according to whether or not oliguria was present

|                                      | All patients | Oliguria at admission | p value |
|--------------------------------------|--------------|-----------------------|---------|
|                                      | n = 8292     | No n = 6242 (75.3%)   | Yes n = 2050 (24.7) |
| Urine output (ml/kg/h) median [IQR]  | 0.9 [0.5–1.4] | 1.1 [0.8–1.6]         | 0.3 [0.1–0.4]  | < 0.001 |
| Age, years, mean ± SD                | 59.2 ± 18.2  | 58.1 ± 18.3           | 62.5 ± 17.4  | < 0.001 |
| Male, n (%)                          | 4928 (60.0)  | 3724 (60.2)           | 1204 (59.4)  | 0.55    |
| Severity scores, mean ± SD          |              |                       |         |
| SAPS II score                        | 40.8 ± 17.5  | 37.9 ± 15.1           | 49.8 ± 20.8  | < 0.001 |
| SOFA score at admission              | 6.2 ± 4.2    | 5.7 ± 3.8             | 7.6 ± 5.0    | < 0.001 |
| SOFA score at admission (without renal sub-score) | 5.3 ± 3.7   | 5.1 ± 3.5             | 5.8 ± 4.2    | < 0.001 |
| Type of admission, n (%)             |              |                       |         |
| Surgical (non-trauma)                | 2939 (37.2)  | 2374 (39.9)           | 565 (29.2)   | < 0.001 |
| Medical                              | 4335 (54.9)  | 3063 (51.4)           | 1272 (65.7)  |         |
| Trauma                               | 569 (7.2)    | 478 (8.0)             | 91 (4.7)     |         |
| Other                                | 48 (.6)      | 40 (.7)               | 8 (.4)       |         |
| Source of admission, n (%)           |              |                       |         |
| Other hospital                       | 825 (9.9)    | 625 (10.0)            | 200 (9.8)    | < 0.01  |
| ER/ambulance                         | 3151 (38.0)  | 2336 (37.4)           | 815 (39.8)   |         |
| OR/recovery room                     | 1569 (18.9)  | 1304 (20.9)           | 265 (12.9)   |         |
| Hospital floor                       | 2117 (25.5)  | 1529 (24.5)           | 588 (28.7)   |         |
| Other                                | 630 (7.6)    | 448 (7.2)             | 182 (8.9)    |         |
| Comorbidities, n (%)                 |              |                       |         |
| COPD                                 | 1012 (12.2)  | 737 (11.8)            | 275 (13.4)   | 0.06    |
| Cancer                               | 891 (10.7)   | 684 (11.0)            | 207 (10.1)   | 0.29    |
| Metastatic cancer                    | 288 (3.5)    | 205 (3.3)             | 83 (4.0)     | 0.11    |
| Hematologic cancer                   | 178 (2.1)    | 126 (2.0)             | 52 (2.5)     | 0.16    |
| Insulin                              | 682 (8.2)    | 496 (7.9)             | 186 (9.1)    | 0.12    |
| Heart failure, NYHA III/IV           | 648 (7.8)    | 445 (7.1)             | 203 (9.9)    | < 0.001 |
| HIV infection                        | 56 (.7)      | 33 (.5)               | 23 (1.1)     | < 0.01  |
| Cirrhosis                            | 283 (3.4)    | 188 (3.0)             | 95 (4.6)     | < 0.001 |
| Immunosuppression                     | 259 (3.1)    | 184 (2.9)             | 75 (3.7)     | 0.11    |
| Steroid therapy                      | 273 (3.3)    | 208 (3.3)             | 65 (3.2)     | 0.78    |
| Chemotherapy                         | 239 (2.9)    | 181 (2.9)             | 58 (2.8)     | 0.94    |
| Organ support, n (%)                 |              |                       |         |
| Mechanical ventilation               | 4227 (51.0)  | 3184 (51.0)           | 1043 (50.9)  | 0.92    |
| Renal replacement therapy            | 321 (3.9)    | 97 (1.6)              | 224 (10.9)   | < 0.001 |
| Vasopressor use                      | 2429 (29.3)  | 1672 (26.8)           | 757 (36.9)   | < 0.001 |
| Type of organ failure, n (%) (alone or in combination) | |         |         |
| Respiratory                          | 1867 (22.5)  | 1334 (21.4)           | 533 (26.0)   | < 0.001 |
| Coagulation                          | 530 (6.4)    | 345 (5.5)             | 185 (9.0)    | < 0.001 |
| Hepatic                              | 885 (10.7)   | 658 (10.5)            | 227 (11.1)   | 0.51    |
| CNS                                  | 1972 (23.8)  | 1435 (23.0)           | 537 (26.2)   | < 0.01  |
| Renal                                | 1341 (16.2)  | 524 (8.4)             | 817 (39.9)   | < 0.001 |
| Cardiovascular                       | 2296 (27.7)  | 1580 (25.3)           | 716 (34.9)   | < 0.001 |
transient or prolonged oliguria but lower than in those with permanent oliguria (Table 4). The maximum serum creatinine concentration was higher in patients with prolonged and permanent oliguria than in those with transient oliguria (Table 4). The mean daily fluid balance during the ICU stay was significantly higher in patients with permanent oliguria than in those with transient or prolonged oliguria (Table 4).

**Discussion**

The present study in a large cohort of ICU patients with urine outputs measured on admission and during the

### Table 1

Characteristics of the study cohort on admission to the ICU stratified according to whether or not oliguria was present (Continued)

|                          | All patients | Oliguria at admission | p value |
|--------------------------|--------------|-----------------------|---------|
|                          | n = 8292     | No n = 6242 (75.3%)   | Yes n = 2050 (24.7%)  |

| Number of organ failures, n (%) |               |                       |         |
|--------------------------------|---------------|-----------------------|---------|
| None                           | 1771 (21.4%)  | 1489 (23.9%)          | 282 (13.8%) | < 0.001 |
| 1 organ                        | 2344 (28.3%)  | 1805 (28.9%)          | 539 (26.3%) |
| 2 organs                       | 1693 (20.4%)  | 1302 (20.9%)          | 391 (19.1%)  |
| 3 organs                       | 1231 (14.8%)  | 883 (14.1%)           | 348 (17.0%)  |
| > 3 organs                     | 1253 (15.1%)  | 763 (12.2%)           | 490 (23.9%)  |

| Sepsis, n (%) | 1543 (18.6%) | 1041 (16.7%) | 502 (24.5%) | < 0.001 |
| ICU stay, median [IQR] | 3.0 [2.0–6.0] | 3.0 [2.0–6.0] | 3.0 [1.0–7.0] | < 0.001 |
| In survivors   | 3.0 [1.0–6.0] | 3.0 [1.0–6.0] | 3.0 [1.0–7.0] | 0.046 |
| In non-survivors | 3.0 [0.0–8.0] | 5.0 [1.0–10.0] | 2.0 [0.0–6.0] | 0.001 |
| Hospital stay, median [IQR] | 10.0 [5.0–20.0] | 10.0 [6.0–20.0] | 8.0 [2.0–18.0] | < 0.001 |
| In survivors   | 11.0 [2.0–21.0] | 11.0 [2.0–21.0] | 11.0 [1.0–22.0] | 0.075 |
| In non-survivors | 5.0 [0.0–14.0] | 7.0 [1.0–15.0] | 3.0 [0.0–10.0] | < 0.001 |
| ICU mortality, n (%) | 1234 (15.2%) | 700 (11.5%) | 534 (26.8%) | < 0.001 |
| Hospital mortality, n (%) | 1649 (21.1%) | 983 (16.7%) | 666 (34.5%) | < 0.001 |

**SD** standard deviation, SAPS II Simplified Acute Physiology Score II, SOFA Sequential Organ Failure Assessment, ER emergency room, OR operating room, COPD chronic obstructive pulmonary disease, NYHA New York Heart Association, HIV human immunodeficiency virus, CNS central nervous system, ICU intensive care unit, IQR interquartile range. Percentages are calculated after excluding missing data.

### Table 2

Interventions and occurrence of sepsis during the ICU stay

|                          | All patients | Oliguria | p value |
|--------------------------|--------------|----------|---------|
|                          | n = 8292     | No n = 6242 (75.3%) | Yes n = 2050 (24.7%)  |

| Creatinine, highest concentration (mg/dl), median [IQR] | 1.0 [0.8–1.5] | 0.9 [0.7–1.3] | 1.3 [0.9–2.4] | < 0.001 |
| Daily fluid balance, ml, median [IQR] | 81.0 [504.1–730.4] | 3.3 [612–605.7] | 356.3 [153.2–1116.7] | < 0.001 |
| Mechanical ventilation, n (%) | 4769 (57.5%) | 3579 (57.3%) | 1190 (58.0%) | 0.59 |
| RRT, n (%) | 849 (10.2%) | 407 (6.5%) | 442 (21.6) | < 0.001 |
| Hemofiltration, n (%) | 590 (7.1%) | 268 (4.3) | 322 (15.7) | < 0.001 |
| Hemodialysis, n (%) | 551 (6.6%) | 266 (4.3) | 285 (13.9) | < 0.001 |

| Sepsis severity, n (%) | 5718 (69%) | 4403 (70.5) | 1315 (64.1) | < 0.001 |
| Sepsis | 1104 (13.3%) | 858 (13.7%) | 246 (12.0)  |
| Shock | 1470 (17.7%) | 981 (15.7) | 489 (23.9) |
| Decision to withhold/withdraw life-sustaining therapy, n (%) | 1068 (12.9%) | 728 (11.7) | 340 (16.6) | < 0.001 |

*Total fluid balance divided by the length of ICU stay. RRT renal replacement therapy
ICU stay reveals that oliguria is present in about one fourth of critically ill patients on admission to the ICU. The presence of oliguria on admission was not independently associated with an increased risk of death, but the persistence of oliguria during the ICU stay was associated with higher ICU and hospital mortality rates.

There are relatively few published data on the frequency of oliguria in general ICU patients. Oliguria is frequently observed in the perioperative period and may be the consequence of hypovolemia and/or pain, both triggering the sympathetic nervous system, which in turn lead to activation of the renin-angiotensin-aldosterone system with ensuing oliguria. However, oliguria may also represent a warning of deteriorating renal function, especially in critically ill patients. Macedo et al. reported that 47% of their cohort of 317 surgical ICU patients had an episode of oliguria (urine output < 0.5 ml/kg/h for at least 6 consecutive

| Variables                                | OR (95% CI)          | p value |
|------------------------------------------|----------------------|---------|
| Fixed effects, varying within clusters   |                      |         |
| Age                                      | 1.00 (1.00–1.01)     | 0.19    |
| Sex, male                                | 0.99 (0.85–1.14)     | 0.848   |
| SAPS II                                  | 1.05 (1.05–1.06)     | < 0.001 |
| Type of admission (%)                    |                      |         |
| Surgical                                 | Ref                  | na      |
| Medical                                  | 1.53 (1.26–1.86)     | < 0.001 |
| Trauma                                   | 1.53 (1.14–2.05)     | 0.004   |
| Other                                    | 1.92 (0.71–5.17)     | 0.196   |
| Source of admission                      |                      |         |
| OR/recovery                              | Ref                  | na      |
| Other hospital                           | 1.17 (0.81–1.68)     | 0.404   |
| ER/ambulance                             | 1.12 (0.84–1.49)     | 0.458   |
| Hospital floor                           | 1.65 (1.26–2.16)     | < 0.001 |
| Other                                    | 1.20 (0.81–1.80)     | 0.366   |
| Comorbidities                            |                      |         |
| COPD                                     | 0.98 (0.73–1.31)     | 0.877   |
| Cancer                                   | 1.41 (1.15–1.74)     | 0.001   |
| Metastatic cancer                        | 1.20 (0.86–1.67)     | 0.281   |
| Hematologic cancer                       | 1.75 (1.25–2.44)     | 0.001   |
| Insulin                                  | 0.84 (0.64–1.09)     | 0.189   |
| Heart failure, NYHA III/IV               | 1.54 (1.19–1.99)     | 0.001   |
| HIV infection                            | 0.73 (0.27–1.94)     | 0.523   |
| Cirrhosis                                | 2.12 (1.45–3.10)     | < 0.001 |
| Immunosuppression                        | 1.19 (0.78–1.79)     | 0.419   |
| Steroid therapy                          | 1.17 (0.74–1.84)     | 0.497   |
| Chemotherapy                             | 0.92 (0.55–1.53)     | 0.748   |
| Creatinine, highest [mg/dl]              | 1.00 (0.97–1.02)     | 0.796   |
| Daily fluid balancea [l]                 | 1.37 (1.25–1.50)     | < 0.001 |
| Procedures during the ICU stay           |                      |         |
| Mechanical ventilation                   | 2.66 (2.12–3.34)     | < 0.001 |
| Renal replacement therapy                | 1.51 (1.19–1.91)     | 0.001   |
| Severity of sepsis                       |                      |         |
| No sepsis                                | Ref                  | na      |
| Sepsis without shock                     | 0.98 (0.75–1.28)     | 0.887   |
| Septic shock                             | 1.55 (1.25–1.92)     | < 0.001 |
| End-of-life decision                     | 11.82 (6.70–20.84)   | < 0.001 |
| Oliguria on admission                    | 1.14 (0.97–1.34)     | 0.103   |

| Variables                                | OR (95% CI)          | p value |
|------------------------------------------|----------------------|---------|
| Fixed effects, constant within clusters  |                      |         |
| Type of hospital                         |                      |         |
| University/academic                      | Ref                  | na      |
| Non-university                           | 1.16 (0.88–1.52)     | 0.293   |

*Total fluid balance divided by the length of ICU stay

OR odds ratio, SAPS II Simplified Acute Physiology Score II, ER emergency room, OR operating room, COPD chronic obstructive pulmonary disease, NYHA New York Heart Association, HIV human immunodeficiency virus. The percentage of cases correctly classified with this model is 88.6%. The AUC is 91.5% (95% CI 90.7–92.3%).
during the ICU stay [1]. In an analysis of data from the FINNAKI study, as many as 92% of patients had an episode of oliguria as defined by a urine output < 0.5 ml/kg/h for a minimum of 0.5 h [3]. From their large database, Kellum et al. reported that 59% of ICU patients with acute kidney injury (AKI) met the KDIGO urine output criteria [8]. In a smaller cohort, Md Ralib et al. reported that 61% of patients with AKI met urine output criteria (< 0.1 ml/kg/h) lasting > 3 h were independently associated with increased 90-day mortality. In an earlier analysis of the ICON database, patients who remained in stage 3 AKI (defined using the AKIN urine output or creatinine criteria) for a 7-day period had higher mortality rates than those in whom renal function recovered [20]. Prowle et al. [2] noted that although oliguria of longer than 1 h was significantly associated with the subsequent development of AKI diagnosed using creatinine criteria, short periods (1–6 h) of oliguria were not accurate at predicting AKI. In a cohort of patients undergoing major abdominal surgery, the presence of oliguria (urine output < 0.3 ml/kg/h) during surgery was indicative of an elevated probability of later AKI [21]. Similar results were recently published by Myles et al. [22] when a urine output < 0.5 ml/kg/h was used to define oliguria.

Our data also suggest that the increased mortality may be related more to the need for RRT than the oliguria itself, suggesting that other parameters, for example, high serum creatinine concentrations, may be better indicators for RRT than urine output. In an analysis of the MIMIC-II database, Mandelbaum et al. [9] reported that the increase in serum creatinine was a better predictor of the need for RRT than urine output, although urine output was a slightly better predictor of mortality. In their analysis, Kellum et al. reported that RRT use was more likely in patients diagnosed with AKI using urine output and creatinine concentration criteria than in patients diagnosed with AKI using just one of the two criteria [8]. We did not use the AKI criteria, preferring to

### Table 4 Creatinine concentrations, fluid balance, renal replacement therapy, and mortality rates in patients with transient, prolonged, and permanent oliguria

|                              | Non-oliguric on admission | Oliguria during ICU stay, n = 1349 | p value (across groups) |
|------------------------------|----------------------------|----------------------------------|-------------------------|
|                              | n = 6242                   | Transient n = 390 (28.9%)         |                         |
|                              |                            | Prolonged n = 141 (10.5%)         |                         |
|                              |                            | Permanent n = 818 (60.6%)         |                         |
| SAPS II score, mean ± SD     | 37.9 ± 15.1                | 47.1 ± 16.7*                      | < 0.0001                |
| Creatinine, highest concentration (mg/dl), median [IQR] | 0.9 [0.7–1.3]             | 1.2 [0.8–2.1]*                    |                         |
| Daily fluid balance, ml, median [IQR] | 3.3 [–612–605.7] | 49.9 [–521–650]                  |                         |
| RRT at admission, n (%)      | 97 (1.6)                   | 22 (5.6)*                         | < 0.0001                |
| RRT during ICU stay, n (%)   | 407 (6.5)                  | 48 (12.3)*                        | < 0.0001                |
| ICU mortality, n (%)         | 700 (11.5)                 | 27 (7.1)*                         | < 0.0001                |
| In non RRT patients, n (%)   | 580 (10.2)                 | 22 (6.0)                          |                         |
| In RRT patients, n (%)       | 120 (29.9)                 | 5 (10.9)*                         | < 0.0001                |
| End-of-life decision, n (%)  | 728 (11.7)                 | 47 (12.1)                         | < 0.0001                |
| In non RRT patients, n (%)   | 650 (11.1)                 | 43 (12.6)                         | 0.012                   |
| In RRT patients, n (%)       | 78 (19.2)                  | 4 (8.3)                           | < 0.0001                |
| Hospital mortality, n (%)    | 983 (16.7)                 | 53 (14.7)                         | 296 (37.7)*             | < 0.0001

Pairwise p values: *vs transient; †vs prolonged; ‡vs non-oliguric on admission. Total fluid balance divided by the length of ICU stay. RRT: renal replacement therapy, ICU: intensive care unit. Percentages are calculated after excluding missing data.
use the more global term of “acute renal failure” (defined by a renal SOFA score > 2) and need for RRT, because this puts the degree of renal impairment in relation to the dysfunction of the other organs. The SOFA criteria are actually more commonly used than AKI in the critical care literature [23]. Somewhat surprisingly, in the current analysis, RRT was used in only 33% of the patients with permanent oliguria; however, 66% of the patients with permanent oliguria who did not receive RRT were discharged to the hospital floor or another hospital and we have no information about ongoing patient management after ICU discharge. Patients with permanent oliguria were also more likely to have a recorded decision to withhold/withdraw a life-sustaining measure, possibly explaining why RRT was not used in some of these patients.

Recovery of a urine output is not itself a predictive factor, and urine output is not helpful in guiding fluid resuscitation [24]. Patients with permanent oliguria had a more positive fluid balance than those with transient or prolonged oliguria, which may explain in part the higher mortality rates in these patients, although it is not possible to determine whether these observations are epiphenomena or causal effects. Vaara et al. demonstrated an association between cumulative fluid overload (fluid accumulation > 10%) prior to RRT initiation and increased risk for 90-day mortality; the 90-day mortality rate of patients with fluid overload was 59.2% versus 31.4% without (difference of 27.8%, p < 0.001) [25]. In an earlier analysis of the ICON database, we reported that fluid balances became negative after the third ICU day in survivors but remained positive in non-survivors and that higher cumulative fluid balance at day 3 after ICU admission was independently associated with an increase in the hazard of death [26]. However, large randomized controlled trials have not shown a significant impact of fluid resuscitation strategy on clinical outcome or need for RRT [27].

Our study has several strengths but also some limitations. Strengths include the large database with patients from around the world, providing external validity, and the collection of data during the ICU stay. Limitations include the complexity of elements associated with oliguria that cannot be separated out, for example, we were unable to assess the need for fluids or diuretics or to assess the impact of different vasopressors. Moreover, criteria for RRT were not pre-defined due to the study design. Thus, RRT may have been used for fluid overload, increased urea and creatinine concentrations, electrolyte abnormalities, severe acidosis, and any combination of these. Another limitation is the lack of pre-admission data regarding the length of oliguria prior to ICU admission or the underlying reason for oliguria as well as the lack of post-discharge data. The methods of monitoring urine output and assessing body weight also likely varied across centers and may have influenced the accuracy of measurements. Finally, we chose a definition of oliguria using a cut-off of urine output of 0.5 ml/kg/h, but this degree of urine output may in fact be adequate for some patients, e.g., the very obese and the very old.

Conclusion
In conclusion, the present study demonstrates that oliguria is a common occurrence in ICU patients, and suggests that it may have a relatively benign nature if only transient. For prognostic assessment, it is more the duration of oliguria and need for RRT than oliguria per se that are associated with a worse outcome.

Abbreviations
AKI: Acute kidney injury; GNI: Gross national income; ICU: Intensive care unit; KDIGO: Kidney Disease Improving Global Outcomes; RRT: Renal replacement therapy; SOFA: Sequential Organ Failure Assessment

Acknowledgements
We would like to thank Hassane Njimi, MSc, PhD, Department of Intensive Care, Erasm University Hospital, Brussels, Belgium, for his help with the statistical analyses.

We also acknowledge the investigators at our participating centers: Angola: Clinica Sagrada Esperança (Esmael Tomas) Democratic Republic of Congo: Cliniques Universitaires De Kinshasa (Eric Amisi Bibonge) Morocco: Ibn Ibn Rochd Casablanca (Boubaker Charra); Ibn Sina Hospital (Mannoun Faroudy) South Africa: Chris Hani Baragwanath Academic Hospital (Linda Doedens); Grey’s Hospital (Zane Farina); Sandton Medi Clinic (David Adler); Tygerberg Hospital (Cecile Balkema); Union Hospital Alberton (Adri Kok) Tunisia: Bizerte Hospital (Sami Alaya); Military Hospital of Tunis (Hedi Gharrellas)

Albania: National Trauma Centre and Military Hospital, Tirana (Dritan Muzha) Bulgaria: Alexandrovskia University Hospital (Atanas Temelkov); Emergency University Hospital ‘Pirogov’ (Georgi Georgiev); Tokuda Hospital Sofia (Georgi Simeonov); Uch St Ekatertina Sofia (Georgi Tsaryanski); University Hospital for Obstetrics and Gynaecology (Silvi Georgiev); University Hospital Sveta Marina - Varna (Ali Sellman)

Croatia: General Hosp. Sibenik (Srdan Vrankovic); University Hospital Centre *Setre Milosrdnice* (Zeljko Vucicevic); University Hospital Centre Zagreb (Ivan Gornik); University Hospital for Infectious Diseases (Bruno Banic); University Hospital Dubrava (Ino Husedzinovic)

Czech Republic: Centre of Cardiovascular and Transplant Surgery (Pavel Pavlik); Charles University Hospital (Jan Manak); IKEM, Prague (Eva Kieslichova); KNTB Zlin a.s. (Radovan Turek); Krajiska Nemocnice Liberec (Michal Fischer); Masarykova Nemocnice V Lusi Nad Labern (Radka Valkova); St. Anne’s University Hospital Brno (Lukas Dedak); University Hospital Haradeck Králove (Pavel Dostal); University Hospital Brno (Jan Malaska); University Hospital Olomouc (Roman Haje); University Hospital Plzen (Alexandra Zidikova); Charles University Hospital Plzen (Pavel Lavicka)

Estonia: Tartu University Hospital (Joel Starkopp) Georgia: Critical Care Medicine Institute (Zurab Kheladze); Jo Ann Medical Centre (Marinka Chkhaidze); Kipsidize Central University Hospital (Vakhtang Kalajian)

Hungary: Dr. Kenessy Albert Hospital (Laszlo Medve); Fejer County St George Teaching Hospital (Agnes Sarkany); Flor Ferenc County Hospital (Idilko Kremen); Javonzky Odon Hospital (Zuzsa Maranek); Peterfy Hospital Budapest (Peter Tarnasi)

Latvia: Infectology Centre of Latvia (Inga Krupnova); Paul Stradins Clinical University Hospital (Indulis Vanags); Riga East Clinical University Hospital (Vesturs Liguts)

Lithuania: Hospital of Lithuanian University of Health Sciences Kauno Klinikos (Vidas Pilvintas); Vilnius University Hospital (Saulius Vosylus); Vilnius University...
Kunming Third People Guangdong General Hospital (Qin Tiehe); Henan Provincial People Shandong Province (Gengxihua Gengxihua); Fu Wai Hospital, Chinese People General Hospital (Liu Yuhong); Qilu Hospital Shandong University (Qian Zhai); (Zheng Wang); Peking University Third Hospital (Tie Hua Wang); Pla Navy People Sciences Guangxue); Beijing Luhe Hospital (Tieying Gao); Cancer Hospital, Chinese Academy Medical University (Yuan Xu); Beijing University People Friendship Hospital (Meili Duan); Beijing Tongren Hospital Affiliate of Capital Qingdao Universty (Sun Yunbo); Beijing Cancer Hospital,Beijing Institute for University Hospital Ruzinov Bratislava (Andrea Gebhardtova) University Hospital (Boris Uljarevic); Military Medical Academy (Maja Serbia (Bojan Jovanovic); Clinical Centre of Serbia (Milena Pandurovic); Vascular Surgery, Clinical Centre Nis (Radmilo Jankovic); Clinical Centre of Serbia Belotserkovskiy); State District Hospital (Konstantin Zolotukhin); Vishnevsky Institute for Surgery (Madinukulbakhov) Serbia: Clinic for Cardiac Surgery, Clinic Central Serbia (Ljiljana Sosic); Clinic for Digestive Surgery, Clinic Central Serbia (Ivan Palibrk); Clinic for Vascular Surgery, Clinic Central Nis (Radmilo Jankovic); Clinic Central of Serbia (Bojan Jovanovic); Clinic Central of Serbia (Milena Pandurovic); Emergency Centre, Clinic Central of Belgrade (Vesna Bumbasievic); General University Hospital (Boris UJarevic); Military Medical Academy (Maja Srbatovic); Urology Hospital (Nebojsa Ladjevic) Slowakia: District Hospital (Garr Slobodianik); Faculty Hospital (Viliam Sobona); University Hospital Bratislava-Hospital Rozinov ICU (Andrea Cikova); University Hospital Ruzinov Bratislava (Andrea Gebhardtova) China: A Tertiary Hospital (Cao Jun); Affiliated Hospital of Medical College Qingdao University (Sun Yunbo); Beijing Cancer Hospital(Beijing Institute for Cancer Research (Juan Dong); Beijing Chaoyang Hospital (Sui Feng); Beijing Friendship Hospital (Meili Duan); Beijing Tongren Hospital Affiliate of Capital Medical University (Yuan Xu); Beijing University People’s Hospital (Xiaoyan Xue); Beijing Luhe Hospital (Tieying Gao); Cancer Hospital, Chinese Academy of Medical Sciences (XueHong Xing); China Academy of Chinese Medical Sciences Guang (‘An Men Hospital (Xin Zhao); Chuxiong, Yunnan Province, People’s Hospital (ChaoHong Li); Donge County People’s Hospital of Shandong Province (Gengzhua Gengzhua); Fu Wai Hospital, Chinese Academy of Medical Sciences (Huqing Tan); Fujian Provincial Hospital (Jingxing Xue); Fuxing Hospital, Capital Medicine University (Li Jiang); Guangdong General Hospital (Qin Tiehe); Henan Provincial People’s Hospital (Qin Bingyu); Xian Jiaotong University College of Medicine (Qindong Shi); Kunming Third People’s Hospital (Zheng Lv); Lanzhou University Second Hospital (Liping Zhang); No.309th Hospital (Liu Jingtao); No.1 Hospital of China Medical University (Zheng Chen); Peking University Shougang Hospital (Zheng Wang); Peking University Third Hospital (Tie Hua Wang); Pla Navy General Hospital (Liu Yuhong); Qilu Hospital Shandong University (Qian Zhai); Ruijin Hospital Affiliated Medical School of Jiaotong University, Shanghai (Ying Chen); Shandong Provincial Hospital (Chunting Wang); Shanghai 10th People’s Hospital (Wei Jiang); Shanghai First People’s Hospital (Wang Rulian); Sichuan Provincial People’s Hospital (Youdal Chen); Sichuan Provincial People’s Hospital (Huang Xiaobo); Sir Run Run Shaw Hospital (Huiqing Ge); The Affiliated of Guangy Medical College (Tang Yan); The Fifth People’s Hospital of Shanghai, Fudan University (Cui Yuhua); The First Affiliated Hospital of Dalian Medical University (Jiuzi Zhang); The First Affiliated Hospital of Suzhou University (Fu Jian-Hong); The First Affiliated Hospital of Xiangjiang Medical University (Hong Zhu); The First Hospital of Jinlin University (Feifei Hua). The First Hospital of Jinlin University (Yushan Wang); The First People’s Hospital of Kunning (Chao Lo); The General Hospital of Shenyang Military Region, China (Wa Zhan); The People’s Hospital of Changzhou (Zengxian Ma); The Second Hospital of Jinlin University (Jian Sun); The Second People’s Hospital of Liaocheng City Shandong Province (Liuqiyue Liuqiyue); The Third Xiangya Hospital (Mingshi Yang); Tongde Hospital of Zhejiang Province (Jianabo Meng); Tongji University Shanghai East Hospital (Shao Lin Ma); West China Hospital, Sichuan University (Cun Yan Kang); Wuhan Centre Hospital (Li Yu); Xiangya Hospital, Changsha, Hunan Province, China (Qiany Peng); Yantai Yuhuangding Hospital (Yu We); Yantaiashan Hospital, Shandong Province (Wei Zhang); Zhejiang Provincial People’s Hospital (Renhuaxun) Hong Kong (China); Pamela Youde Nethersole Eastern Hospital (Alwin Yeung); Princess Margaret Hospital (Wing Lun Wan); Queen Elizabeth Hospital (Li Kae Cheuk Sin); United Christian Hospital of Hong Kong SAR (Kar Lung Lee) Indonesia: Anestesi (Meri Wijianti); Pku Muhammadiyah Bantul, Yogyakarta (Untung Widodo); Rd. Matahar Hospital Jambi (Halmis Samurion); Rumah Sakit Panti Indah Kapuk (Tantani Sugiman); Sardjito Hospital (Calcarina Wisudarti); School of Medicine Unpad - Hasan Sadikin Hospital (Tinno T Maskoen) Japan: Chiba Hokusou Hospital, Nippon Medical School (Noritaka Hata); Chiba University Hospital (Yoshiro Koke); Fujita Health University School of Medicine (Osamu Nishida); Japanese Red Cross Maebashi Hospital (Dai Miyazaki); Ichi Medical University Hospital (Shin Nunomiya); Jake University School of Medicine (Shigeiko Uchimoto); Kimitsu Chuo Hospital (Nobuya Kitamura); Kochi Medical School (Koichi Yamashita); Kyoto Prefectural University of Medicine (Satoru Hashimoto); Nara Medical University Hospital (Hidetada Fukushima) Malaysia: Hospital Sultanah Nur Zahirah, Kuala Terengganu, Terengganu, (Nik Azm Anik Adib); Kuala Lumpur Hospital (Li Ling Tal); Queen Elizabeth Hospital 2 (Bill Tony) Philippines: Cebu Velez General Hospital (Rodolfo Roman Bigonia); Chong Hua Hospital (Rodolfo Roman Bigonia); Perpetual Succour Hospital (Rodolfo Roman Bigonia); The Medical City (Jose Emmanuel Polo) Singapore: Alexandra Hospital (Sorathat Chatterjee); National University Health System (Bee Hong Tan); Singapore General Hospital (Andrew Kong); Tan Tock Seng Hospital (Shirley Goh) Taiwan: National Taiwan University Hospital (Chen-Chang Lee) Thailand: Maharaj Nakorn Chiangmai Hospital, Chiangmai University (Chacharn Potitit); Prince of Songkla University (Bodin Kwhannimit); Ramathibodi Hospital (Pongsdhep Theerawit); Siriraj Hospital, Mahidol University (Annop Pinyapatsak) Egypt: Cairo University (Ahmed Mukhtar); Demerdash Surgical Intensive Care Unit (Dsicu); Ain Shams Faculty of Medicine (Ahmed Nabil Hamdy); Zaitoun Specialized Hospital (Hisham Hosny) Iran: Gums (Ali Ashraf); Imam Hossein Hospital, Shiraz (Majid Mohktari); Imamreza Hospital (Shiva Nowruzinia); Leal Hospital (Amir Hossein Lotti); Shiraz Anesthesiology and Critical Care Research Center (Farid Zand); Shiraz University of Medical Sciences (Reza Nikandish); Tehran Medical Sciences University (Omid Moradi Moghaddam) Israel: Rabin Medical Centre (Jonathan Cohen); Sourasky Tel Aviv Medical Centre (Oded Sold); Lebanon: Centre Hospitalier Du Nord (Taci Sfeir) Oman: Sohar Hospital (Alaa Yasin Haran) Palestien Territories: Specialized Arab Hospital (Dena Abaguer) Saudi Arabia: Almana General Hospital (Habil Ahmad); KFSHRIC, Riyadh (Tarek Tantawy); King Abdulaziz Medical City Riyadh (Salim Baharoom); King Abdulaziz University Hospital (Haifa Alghethamy); King Saud Medical City (Anas Amri); Riyadh Military Hospital (Ghaleb Alsheikh); Turkey: Ercyes University Medical Faculty (Razamanz Coskun); Ercyes University Medical School (Murat Sungur); Gümhane Medical Military Academy (Ahmet Cosar); International Hospital, Istanbul (Bülent Güayetmez); Istanbul University Cerrahpasa Medical School Hospital (Oktay Demirkiran); Istanbul University Istanbul Medical Faculty (Evren Sencuk); Karadeniz Technical University, Medical Faculty (Hulya Ulusoy); Memorial Atasehir Hospital (Hakan Korkut Atalan); Pamukkale University (Simay Serin); Yuzuncu Yil University (Yuksek Sehen) United Arab Emirates: Dubai Hospital (Zainab Alnassrawi); Mafraq Hospital (Ayeshia Almameran); Sheikh Khalifa Medical City (Kalpana Krishnareddy); Tawam Hospital (Sayed Kashef); The City Hospital (Asad Alisabab) Canada: Hospital Charles Lemoyne (Germain Poirier); St. Michael’s Hospital (John C. Marshall); Toronto General Hospital (Margaret Herridge); Toronto Western Hospital (Margaret Herridge) Puerto Rico: San Juan Hospital (Rosangela Fernandez-Medero)
Authors' contributions

JLV conceived and participated in the original study, collected and analyzed the data, drafted this manuscript, and approved the submitted version of the manuscript. AF participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. PP participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. SMJ participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. UIJ participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. GAA participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. ML participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. MW participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. LEF participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. PB participated in the original study, revised the manuscript for critical content, and approved the submitted version of the manuscript. YS helped conceive the original study, participated in the original study, and revised the manuscript for critical content, and approved the submitted version of the manuscript.

Funding

None

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Ethics committee approval was obtained by the participating institutions according to local ethical regulations.

Consent for publication

Not applicable

Competing interests

Marc Leone reports receiving consulting fees from Amomed and Aeglettant; lecture fees from MSD, Pfizer, Octapharma, 3 M, Aspen, Orion; travel support from LFB; and grant support from PHRC IR and his institution. JLV is the Editor-in-Chief of Critical Care. The other authors declare that they have no relevant financial interests.

Author details

1Department of Intensive Care, Erasme University Hospital, Université Libre de Bruxelles, Route de Lennik, 808, 1070 Brussels, Belgium. 2Department of Intensive Care Medicine, Belfast City Hospital, Belfast, UK. 3Department of Intensive Care Medicine, Radboud University Medical Center, Nijmegen, The Netherlands. 4Department of Intensive Care Medicine, University Hospital Bern, University of Bern, Bern, Switzerland. 5Klinik für Anästhesiologie und Operative Intensivmedizin, Universitätsklinik Augsburg, Universität Augsburg, Augsburg, Germany. 6ICS Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia. 7Service d’Anesthésie et de Réanimation, APHM, Hôpital Nord, Aix Marseille Université, Marseille, France. 8Department of Internal Medicine, SBMU, Tehran, Iran. 9Departamento de Medicina Baseada em Evidências, Medicina Intensiva, Urgência e Emergência - Faculdade de Medicina de Petrópolis, Petrópolis, Brazil. 10Department of Internal Medicine, Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, MN, USA. 11Department of Anaesthesiology and Intensive Care, Uniklinikum Jena, Jena, Germany.

Received: 28 October 2019 Accepted: 30 March 2020 Published online: 23 April 2020

References

1. Macedo E, Malhotra R, Bouchard J, Vynyn SK, Mehta RL. Oliguria is an early predictor of higher mortality in critically ill patients. Kidney Int. 2011;80:760–7.

2. Prowle JR, Liu YL, Licari E, Bagshaw SM, Egi M, Haase M, et al. Oliguria as predictive biomarker of acute kidney injury in critically ill patients. Crit Care. 2011;15:R172.

3. Vaara ST, Parviainen I, Pettilä V, Nisula S, Inkinen O, Usuaro A. Association of oliguria with the development of acute kidney injury in the critically ill. Kidney Int. 2016;89:200–8.

4. Kidney Disease Outcomes Quality Initiative. KDIGO clinical practice guidelines for acute kidney injury. Kidney Int Suppl. 2012;2:1–138.

5. Vincent JL, Moreno R, Takala J, Willatts S, De Mendonca A, Bruining H, et al. The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. On behalf of the Working Group on Sepsis-Related Problems of the European Society of Intensive Care Medicine. Intensive Care Med. 1996;22:707–10.
6. Bellomo R, Ronco C, Kellum JA, Mehta RL, Palevsky P. 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:R204–12.

7. Mehta RL, Kellum JA, Shah SV, Molitoris BA, Ronco C, Warnock DG, et al. Acute kidney injury network: report of an initiative to improve outcomes in acute kidney injury. Crit Care. 2007;11:R31.

8. Kellum JA, Sileanu FE, Murugan R, Lucko N, Shaw AD, Clermont G. Classifying AKI by urine output versus serum creatinine level. J Am Soc Nephrol. 2015;26:2231–8.

9. Mandelbaum T, Lee J, Scott DJ, Mark RG, Malhotra A, Howell MD, et al. Empirical relationships among oliguria, creatinine, mortality, and renal replacement therapy in the critically ill. Intensive Care Med. 2013;39:414–9.

10. Leedahl DD, Frazier EN, Schramm GE, Dierkhising RA, Bergstralh EJ, Chawla LS, et al. Derivation of urine output thresholds that identify a very high risk of AKI in patients with septic shock. Clin J Am Soc Nephrol. 2014;9:1168–74.

11. Md RA, Pickering JW, Shaw GM, Endre ZH. The urine output definition of acute kidney injury is too liberal. Crit Care. 2013;17:R12.

12. Vincent JL, Marshall JC, Namendys-Silva SA, Francois B, Martin-Loeches I, Lipman J, et al. Assessment of the worldwide burden of critical illness: the intensive care over nations (ICON) audit. Lancet Respir Med. 2014;2:380–6.

13. Gall L Jr, Lerneshow S, Saulnier F. A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicenter study. JAMA. 1993;270:2957–63.

14. Calandra T, Cohen J. The international sepsis forum consensus conference on definitions of infection in the intensive care unit. Crit Care Med. 2005;33:1538–48.

15. Singer M, Deutschman CS, Seymour CW, Shankar-Hari M, Annane D, Bauer M, et al. The third international consensus definitions for sepsis and septic shock (Sepsis-3). JAMA. 2016;315:801–10.

16. The World Bank. GNI per capita, Atlas method (current US$). Available at: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD. Accessed 15 Mar 2020.

17. Martin-Loeches I, Nájera H, Vincent JL. Collinearity and multivariable analysis: response to comments by Claret et al. Intensive Care Med. 2016;42:1835.

18. Cordova-Sanchez BM, Herrera-Gomez A, Namendys-Silva SA. Acute kidney injury classified by serum creatinine and urine output in critically ill cancer patients. Biomed Res Int. 2016;2016:6805169.

19. Zhang Z, Xu X, Ni H, Deng H. Urine output on ICU entry is associated with hospital mortality in unselected critically ill patients. J Nephrol. 2014;27:65–71.

20. Peters E, Antonelli M, Wittebole X, Nanchal R, Francois B, Sarker Y, et al. A worldwide multicentre evaluation of the influence of deterioration or improvement of acute kidney injury on clinical outcome in critically ill patients with and without sepsis at ICU admission: results from The Intensive Care Over Nations audit. Crit Care. 2018;22:188.

21. Mizota T, Yamamoto Y, Hamada M, Matsukawa S, Shimizu S, Kai S. Intraoperative oliguria predicts acute kidney injury after major abdominal surgery. Br J Anaesthesia. 2017;119:1127–34.

22. Myles PS, McIlfroy DR, Bellomo R, Wallace S. Importance of intraoperative oliguria during major abdominal surgery: findings of the restrictive versus liberal fluid therapy in major abdominal surgery trial. Br J Anaesthesia. 2019;122:726–33.

23. da Hora PR, Ramos JGR, Gobatto A, Caldas J, Macedo E, Batista PB. Inclusion and definition of acute renal dysfunction in critically ill patients in randomized controlled trials: a systematic review. Crit Care. 2018;22:106.

24. Perner A, Prowle J, Joannidis M, Young P, Hjortrup P, Pettiti V. Fluid management in acute kidney injury. Intensive Care Med. 2017;43:807–15.

25. Vaara ST, Kotheron AM, Kaukonen KM, Nisula S, Irkinen O, Hoppu S, et al. Fluid overload is associated with an increased risk for 90-day mortality in critically ill patients with renal replacement therapy: data from the prospective FINNAKI study. Crit Care. 2012;16:R197.

26. Sarker Y, Rubatto Birri PN, Koifis K, Nanchal R, Shah B, Hugue S, et al. Higher fluid balance increases the risk of death from sepsis: results from a large international audit. Crit Care Med. 2017;45:386–94.

27. Rowan KM, Angus DC, Bailey M, Bamato AE, Bellomo R, Canter RR, et al. Early, goal-directed therapy for septic shock - a patient-level meta-analysis. N Engl J Med. 2017;376:2223–34.