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# Management of renal replacement therapy in ICU patients: an international survey

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**Abstract** *Purpose:* The optimal management of renal replacement therapy (RRT) in critically ill patients remains a matter of debate, although insights have arisen from recent large trials. Nonetheless, little is known about the current practices and beliefs of intensivists. The goal of this study was to record current practices in RRT management among an international panel of intensivists. *Methods:* An online questionnaire that included questions about RRT management in critically ill patients with acute kidney injury was sent to European Society of Intensive Care Medicine members in 2010. *Results:* Two hundred and seventy-three intensivists from 50 countries responded. The respondents had an average of 12 (7–20) years of experience in ICUs, and most of them worked in mixed ICUs. Most of the intensivists were responsible for prescribing RRT (92.6 %). Half of the respondents reported using both intermittent haemodialysis and continuous renal replacement therapy techniques (CRRT), but most preferred using CRRT. The reasons for preferring CRRT were the perception of better haemodynamic stability, better therapeutic effect resulting from cytokine removal and easier fluid balance control. The intensivists used higher RRT doses in septic patients than in non-septic patients ($p = 0.03$). Finally, we observed an increasing inclination towards the early use of RRT among the intensivists. *Conclusion:* CRRT remains the preferred technique for most intensivists in Europe, and a large proportion of the participating intensivists used RRT prescription doses similar to those proposed a decade ago. Our results provide insights into the motivations of intensivists while presenting the technique that may help in selecting control groups for future trials.

**Keywords** Haemofiltration · Haemodialysis · Practice · Dose · Timing

## Introduction

Acute kidney injury (AKI) occurs in 5–45 % of critically ill patients, and renal replacement therapy (RRT) is needed in 4–10 % of patients with AKI [1]. Surveys about RRT have been published in the past, revealing considerable heterogeneity in RRT management among intensive care unit (ICU) physicians. Recent insights into

the management of RRT are lacking. Over the past decade, several large randomised controlled trials have been published that address important questions about the choice of the technique and the RRT dose in the ICU setting. These trials suggested that in critically ill patients, continuous and intermittent techniques have similar outcomes and tolerance when applied by trained staff members. In addition, the trials suggested that when the actual RRT dose is very close to the prescribed dose, the usual dialysis dose might be sufficient for most critically ill patients [2, 3]. Finally, two studies have underlined the absence of evidence supporting the use of continuous RRT (CRRT) over intermittent haemodialysis (IHD), even in critically ill patients presenting with septic shock [4, 5].

Whether input from recent literature has led to changes in RRT prescriptions remains unknown. Furthermore, important questions remain, especially regarding the indications and timing of RRT in ICU patients [6]. Therefore, it is of great importance to gain insights into ICU physicians' beliefs about RRT prescription, both for the design of future clinical trials and for medicoeconomic decision making and ICU organisation. To that end, we performed an international survey to evaluate the practices and beliefs regarding RRT management in ICU patients with AKI among an international panel of intensivists.

## Methods

The study was designed as an electronic survey addressed to ICU physicians. An electronic questionnaire was sent to members of the European Society of Intensive Care Medicine (ESICM) in June and July 2010 with the society's monthly. The members could respond to the survey by clicking on a link that was open between June and August 2010. The survey included 30 questions (see Online Supplement), most of them multiple choice, including 8 questions regarding the characteristics of the responders and the ICU they referred to in their answers. Questions 9–21 referred to the prescription of RRT (techniques, intensity and monitoring). Question 15 specifically referred to the reasons the responders would choose one technique (CRRT or IHD) over another. Questions 22–25 referred to the fluid balance, and questions 26–30 referred to the indications for initiating RRT.

### Statistical analysis

The results are reported as medians and interquartile range (IQR) or numbers and percentages (%). Continuous variables were compared using the non-parametric Wilcoxon test.

To evaluate the internal consistency of this survey, we performed a split-halves test on the part of questionnaire dedicated to factors influencing the decision to prefer one technique over another (Fig. 1). The internal consistency of this part of the survey, as evaluated by the Guttman split-half coefficient, was 0.96, suggesting a good internal consistency.

All tests were two-sided, and $p$ values less than 0.05 were considered statistically significant. Statistical tests were performed with the SAS 6.12 software package (SAS Institute, Inc. Cary, NC, USA).

## Results

### Respondents' characteristics

Of the 1,591 members who opened the newsletter, 272 physicians responded to the questionnaire (yielding a response rate of 17 %), including 218 from Europe and 54 from other continents. Ninety-seven respondents (35.7 %) were attending physicians and 88 (32.4 %) were heads of units. Two hundred and eight physicians (76.5 %) worked in an academic or a university-affiliated hospital. The respondents reported spending 80 % (IQR 50–100 %) of their working time in an ICU and had 12 years (7–20) of experience in ICUs. Most of the respondents (74.6 %) reported working in a mixed ICU. The average number of beds in the respondents' ICUs was 14 (10–20), with ratios of 5 (4–8) patients per senior physician and 2 (2–3) patients per nurse.

The main characteristics of the respondents and their ICUs are reported in Table 1. Most of the respondents reported working in European countries; the most commonly cited countries were France ($n = 51$; 18.8 %), the UK ($n = 31$; 11.4 %); Germany ($n = 24$; 8.9 %), Spain ($n = 18$; 6.6 %), Sweden ($n = 13$; 4.8 %) and Italy ($n = 10$; 3.7 %).

### Treatment doses

The respondents reported that the median prescribed ultrafiltration (UF) dose during CRRT was 35 ml/kg/h (25–35). Thirty-eight per cent of the respondents reported prescribing a UF rate of at least 35 ml/kg/h, and 15 % reported prescribing a standard fixed UF rate irrespective of the body weight. Forty-nine respondents (18 %) reported using haemodiafiltration and therefore adding dialysis to their reported UF dose. Among the respondents using CRRT, 60.8 % reported administering the restitution fluid in a combined pre- and post-dilution mode (prefilter ratio of 34 (30–50) %).

For patients with sepsis, the respondents reported using higher UF doses than in the general ICU population (35 ml/kg/h (35–35) vs. 35 ml/kg/h (25–35); $p = 0.03$)

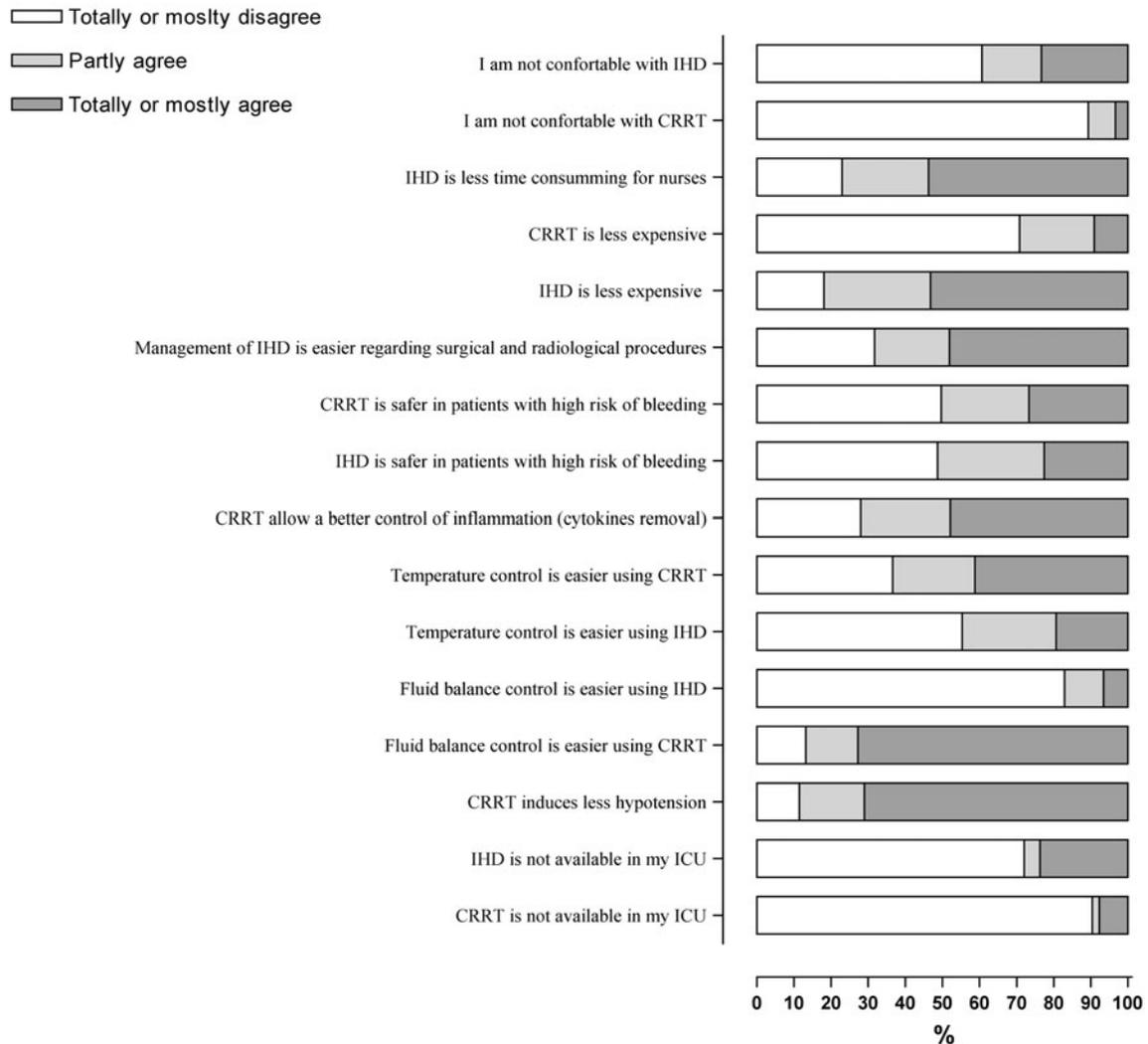## What are the most common reason for choosing the RRT modality?



**Fig. 1** Respondents' main reasons explaining their renal replacement therapy (RRT) modality preference. The results are expressed as percentage of respondents. *IHD* intermittent haemodialysis, *CRRT* continuous renal replacement therapy, *ICU* intensive care unit

with 54 % prescribing a UF dose of at least 35 ml/kg/h, including 20.5 % prescribing a UF dose of at least 45 ml/kg/h.

Interestingly, the reference body weight widely differed across respondents; 30.4 % based the UF rate prescription on the mean estimated body weight, 28.4 % on ideal body weight, 22.5 % on the actual body weight on the day of admission, and 21.6 % on the actual body weight the day of CRRT.

In patients requiring IHD, the median number of dialysis hours per week was 18 h (12–28). The median number of sessions was 4.5 (3–7), and the median duration of the sessions was 4 h (3–4). The urea reduction rate and Kt/V were used to monitor the treatment by 76 (27.9 %) and 38 (14 %) of the respondents, respectively.

Most of the respondents routinely evaluated the dialysis dose while using IHD (52.1 %).

### RRT technique and prescription selection

The intensivists' preferences and RRT prescriptions are reported in Table 2. One hundred and twenty-five respondents (46 %) reported treating 2–5 patients monthly with RRT, compared with 16 % who reported treating more than 10 patients monthly with RRT and 8 % who reported one patient per month or less.

CRRT was available at most ICUs (89 %), whereas only 62 % had access to IHD and 16 % had access to peritoneal dialysis. Most of the time, the intensivist was

**Table 1** Characteristics of respondents and institutions

| Respondents' characteristics | |
|---|---|
| Origin of respondents, *n* (%) | |
| Europe | 218 (80.1) |
| Asia | 29 (10.6) |
| America | 15 (5.5) |
| Oceania | 8 (2.9) |
| Africa | 2 (0.7) |
| Main area of specialisation, *n* (%) | |
| Critical care medicine | 171 (62.9) |
| Anaesthesiology | 70 (25.7) |
| Cardiology | 15 (5.5) |
| Nephrology | 7 (2.6) |
| Respiratory medicine | 6 (2.2) |
| Surgery | 2 (0.7) |
| Internal medicine | 1 (0.4) |
| Position, *n* (%) | |
| Senior physician | 238 (87.5) |
| Attending physician | 97 (35.7) |
| Faculty | 53 (19.5) |
| Head of unit | 88 (32.4) |
| Fellow | 19 (7) |
| Junior resident | 15 (5.5) |
| Experience in the ICU (years) | 12 (7–20) |
| Time spent in the ICU (%) | 80 (50–100) |
| Hospital and ICU characteristics | |
| Type of hospital, *n* (%) | |
| University hospital | 136 (50.0) |
| University-affiliated hospital | 72 (26.5) |
| Non-university hospital | 64 (23.5) |
| Type of ICU, *n* (%) | |
| Combined medical/surgical | 203 (74.6) |
| Medical | 33 (12.1) |
| Surgical | 16 (5.1) |
| Cardiac surgery unit | 12 (4.4) |
| Paediatric | 6 (2.2) |
| Neurosurgical | 2 (0.7) |
| Number of beds in the ICU (*n*) | 14 (10–20) |
| Patients/attending physician ratio | 5 (4–8) |
| Patients/junior physician ratio | 4 (3–6) |
| Patients/nurse ratio | 2 (2–3) |

Results are reported as *n* (%) or median (interquartile)

responsible for prescribing RRT (92.6 %). RRT could be initiated with no restriction on day and night shifts in the vast majority of the ICUs (96 %). Although most of the respondents (51.8 %) reported being comfortable with both CRRT and IHD, they also reported that most of the prescribed RRT was administered using CRRT (88 (IQR 50–100) %). The factors that favoured prescribing CRRT are reported in Fig. 1.

Regarding the CRRT modality, half of the respondents (50.9 %) reported using preferentially continuous venovenous haemodiafiltration (CVVHDF), 40.6 % reported using continuous venovenous haemofiltration (CVVH) and 9.0 % reported using continuous venovenous haemodialysis (CVVHD).

Fluid balance management

Sixty-two percent of the respondents considered achieving a neutral or negative fluid balance a major goal when managing patients with AKI. Nearly every respondent (97.8 %) reported assessing fluid balance at least once per day, and half of the respondents (52 %) reported that they assessed the fluid balance every 6 h. One-third (38.4 %) of the respondents reported that the patients were weighed daily. Finally, one-third of the respondents (30.3 %) reported prescribing diuretics before they consider RRT in critically ill patients with AKI and oliguria, whereas 54 (19.7 %) reported using diuretics only in cases of fluid overload.

The net fluid removal prescription was based on multiple factors, including the fluid balance the day before (40.6 %), the body weight gain (22.6 %), the anticipated amount of fluid delivered over the following 24 h (39.3 %), or empirically, based on the clinical assessment of extracellular fluid accumulation, as with oedema (40.2 %). Only 11.5 % of the respondents used a fixed formula (e.g. 2,000 ml/24 h). Only 6.8 % reported using an algorithm-based adjustment rate with modification of the ultrafiltration rate during the session. Most of the responders reported adjusting fluid removal in response to changes in the mean arterial pressure. However, a minority used other haemodynamic parameters to adjust fluid removal (see supplementary file).

Initiation of RRT

Not surprisingly, the most common reasons for initiating RRT were increased serum creatinine, azotemia, hyperkalaemia, fluid overload and oliguria. The respondents reported the following thresholds for initiating RRT: 300 µmol/l (251–400) for plasma creatinine, 40 mmol/l (30–45) for urea and 6.5 mmol/l (6–7) for hyperkalaemia. However, the urine output criteria for initiating RRT varied widely among the respondents (Fig. 2). Recent AKI classifications (RIFLE or AKIN) were considered by most of the respondents when determining the optimal timing for initiating RRT ($n = 109$; 40.2 %). When asked "What length of delay from the diagnosis of AKI to the initiation of RRT do you consider 'early initiation of RRT'?", the responders reported that 6 h (5.5–12) after AKI diagnosis constituted "early" RRT initiation.

## Discussion

This international survey assessed intensivists' current practices and beliefs regarding RRT initiation and prescription. In keeping with recent debates about the optimal technique, optimal timing and optimal dose of RRT, current practices vary widely, underscoring the need for further studies in this field.

Our study offers insights into intensivists' practices and beliefs about RRT. Several previous studies have addressed this question. More than 10 years ago, a survey

**Table 2** Intensivists' preferences regarding RRT

| | All respondents (n = 272) | ≤5 patients per month (n = 147) | >5 patients per month (n = 125) |
|---|---|---|---|
| Physician in charge of prescription | | | |
| Intensivist | 228 (83.8 %) | 123 (83.7 %) | 105 (84.0 %) |
| Nephrologist | 20 (7.4 %) | 9 (6.1 %) | 11 (8.8 %) |
| Intensivist (background in nephrology) | 24 (8.8 %) | 15 (10.2 %) | 9 (7.2 %) |
| Availability of RRT | | | |
| Daytime except weekends | 2 (0.7 %) | 2 (1.4 %) | 0 (0 %) |
| Daytime including weekends | 8 (2.9 %) | 5 (3.4 %) | 3 (2.4 %) |
| No restriction | 262 (96.3 %) | 140 (95.2 %) | 122 (97.6 %) |
| Preferred RRT method | | | |
| CRRT or IHD indifferently | 141 (51.8 %) | 74 (50.3 %) | 67 (53.6 %) |
| CRRT | 101 (37.1 %) | 56 (38.0 %) | 45 (36.0 %) |
| IHD (including SLED) | 30 (10.6 %) | 17 (11.6 %) | 13 (10.4 %) |
| Evaluation of dialysis dose (IHD) | | | |
| Kt/V | 38 (14.0 %) | 21 (14.3 %) | 17 (13.6 %) |
| URR | 76 (27.9 %) | 48 (32.7 %) | 28 (22.4 %) |
| None | 105 (38.6 %) | 45 (30.6 %) | 60 (48.0 %) |
| NA | 53 (19.5 %) | 33 (22.4 %) | 20 (16.0 %) |
| Routine prescription of CRRT | | | |
| Pre-filter ratio (%) | 34 (30–50 %) | 40 (30–60 %) | 33 (30–50 %) |
| UF dose (ml/kg/h) | 35 (25–35) | 35 (25–35) | 35 (25–35) |
| UF dose (ml/kg/h) in septic patients | 35 (35–35) | 35 (35–37.5) | 35 (25–35) |
| Add dialysis dose to UF | 49 (18.0 %) | 30 (20.4 %) | 19 (15.2 %) |
| Same UF dose for every patient | 34 (17.1 %) | 19 (17.9 %) | 15 (16.1 %) |
| Routine prescription of IHD | | | |
| Number of sessions per week | 4.5 (3–7) | 4 (3–7) | 5 (3–7) |
| Session duration (h) | 4 (3–4) | 4 (3–4) | 4 (3–4.5) |
| Number of hours per week | 18 (12–28) | 16 (12–24) | 21 (12–28) |

Responses were compared according to the number of patients treated in the respondents' ICUs (median number of patients = 5)

*RRT* renal replacement therapy, *CRRT* continuous renal replacement therapy, *IHD* intermittent haemodialysis, *SLED* sustained low-efficiency dialysis, *URR* urea reduction dose, *NA* not available (no use of IHD or missing data), *UF* ultrafiltration

**Fig. 2** Main factors leading to RRT initiation in critically ill patients, according to the respondents. The results are expressed as the percentage of responders
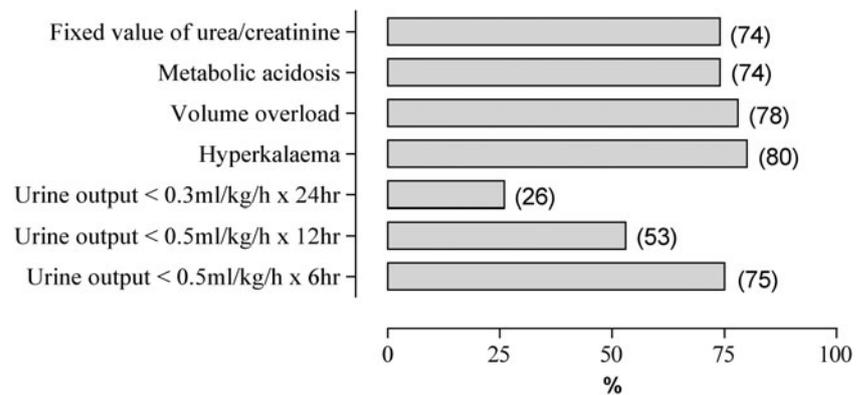


of 345 participants at a critical care nephrology congress suggested that IHD, peritoneal dialysis and CRRT were used equally for RRT [7]. At that time, the respondents reported prescribing rather low doses of treatment. In contrast, studies performed in the last decade confirm that CRRT was the intensivists' preferred technique [8–10]. These more recent surveys also suggested that intensivists were more likely to use high CRRT or IHD doses after the release of randomised controlled trials suggesting that higher treatment doses were associated with a better prognosis [11–13]. The results from the Beginning and Ending Supportive Therapy for the Kidney project revealed variable practices in RRT worldwide [14, 15]. Since then, large clinical trials have been published addressing the optimal technique (i.e. CRRT, IHD) and dialysis dose for RRT [2–5, 16]. Our study suggests that little has changed regarding intensivists' declared practices and beliefs regarding RRT, indicating that

established treatment patterns are not readily modified, even after the publication of clinical trials that recommend the modification of currently established practices.

A striking finding of this study is the intensivists' considerable preference for CRRT. Indeed, despite the lack of evidence that CRRT contributes to a better prognosis than IHD does, most of the respondents reported using primarily continuous techniques. CRRT has long been considered to provide better haemodynamic stability than IHD does, making it the technique of choice for patients in shock. Recent evidence suggests that simple measures can dramatically decrease the incidence of hypotension during IHD sessions [4, 16, 17]. These studies demonstrated that improved haemodynamic tolerance could be achieved using IHD when teams were trained and simple prescription rules were applied. Our study suggests, however, that intensivists remain more comfortable with continuous techniques and that most patients were treated with CRRT despite the availability of intermittent techniques. Similar observations have been made in the field of mechanical ventilation. Indeed, several studies showed that few physicians implemented lung-protective strategies even after the ARDSNet trial, which demonstrated the benefit of low tidal volume in patients with acute respiratory distress syndrome. Several barriers to change were found, including the physician's unwillingness to relinquish control over mechanical ventilation and diagnostic uncertainty [18]. Processes based on experience rather than evidence may limit the implementation of recent scientific insights in clinical practice. The fact that the intensivists who were primarily in charge of RRT prescriptions had limited experience with IHD may explain why most of them chose to use CRRT. In comparison, recent studies have suggested that IHD may be associated with an increased prevalence of persistent renal failure [19]. Although these data should still be considered preliminary, the possibility of that IHD use may impair the long-term outcome of AKI may still contribute to physicians' reluctance to use IHD as a first-choice modality.

Interestingly, it seems that publication of recent randomised clinical trials [2, 3] had little influence on RRT prescriptions. Indeed, most of the respondents reported using high haemofiltration doses with CRRT, and one-fifth of the respondents reported that they added the dialysis dose to haemofiltration. Moreover, despite the paucity of clinical evidence supporting the use of CRRT in septic patients with no or mild AKI [5, 20, 21], most of the respondents considered CRRT an adjunctive therapy that might clear inflammatory mediators in septic patients. Although a large RCT failed to demonstrate any benefit of high dialysis doses in critically ill patients, most of the intensivists continue to use a high dialysis dose in septic patients. Interestingly, the respondents reported using different reference body weights when prescribing RRT. Most studies have used the body weight at the time of randomisation. Such discrepancies in the prescribed doses resulting from the use of different reference body weights introduce further heterogeneity into RRT management and the possibility that when the body weight on the day of treatment is used, higher doses will be delivered because of fluid overload. The definition of fluid overload is itself problematic without a standardised measure for body weight, as a recent study in children demonstrated [22].

Another interesting aspect of our study relates to the criteria that the respondents reported using to determine when to initiate RRT. The classical criteria for initiation of RRT, namely fluid overload, azotemia, acidosis and hyperkalaemia [1], were reported as most the frequently used and were equally applied. A new aspect, however, is the initiation of RRT when patients show a urinary output of less than 0.5 ml/kg/h for at least 6 h, which was not reported in previous surveys, such as the BEST kidney survey. This urinary output correlates with the RIFLE risk, which three-fourths of the respondents used as a criterion for starting RRT, indicating the intensivists' increasing inclination towards a very early initiation of RRT. The benefit of such an early start for RRT has not been substantiated by any randomised trial; even the most recent meta-analysis could not convincingly show that such an early initiation might contribute to improved survival [23] because of significant publication bias and the heterogeneity of the studies, which were almost exclusively observational trials.

Our study has several limitations. First, the number of respondents was low. However, our response rate was close to that reported by previous studies [24–26]. This low response rate is undoubtedly a limit to our study and may be explained by several factors. First, the survey invitation was included in the ESICM letter, and the visibility of the invitation was low. Second, a selection bias was undoubtedly present, as physicians who have a special interest in RRT were far more likely to respond. As in many surveys, it is likely that the respondents had a specific interest in RRT, suggesting a bias that should be taken into account when interpreting our results. Despite this bias, we believe that the data collected from the respondents provide additional information about the current practices and beliefs of intensivists regarding RRT management in Europe. Furthermore, in this study, we chose to evaluate reported practices and beliefs rather than actual practices. Therefore, the reported responses may reflect the politically desirable answer rather than the respondents' actual beliefs. We therefore believe that further studies are needed to evaluate current European practices regarding RRT. A cross-sectional study has been planned and is currently on-going. The results of that study, together with the results of this survey, will help provide information about physicians' beliefs and actual practices regarding RRT. Moreover, only 7.4 % of the respondents reported that RRT was prescribed by

nephrologists. In more than 95 % of cases, intermittent RRT is managed by the nephrologist's team. Presumably, the intensivists in units where nephrologists are in charge of RRT will be less inclined to answer a survey such as this one. Therefore, the survey reflects RRT as practised by intensivists themselves, and IHD use may be more prevalent than the survey reflects. Thus, the survey results are more characteristic of the European region than other regions of the world. Therefore, our results are unlikely to reflect practices in other countries or institutions. Finally, several unanswered questions remain in the field of RRT. These questions are likely to explain, at least partly, the heterogeneity of the current reported practices. Because our results present information about the current practices of intensivists, we believe that this study may help with designing control groups for future trials aimed at defining the optimal timing, modalities or doses of RRT.

The answers obtained from this survey reveal that a large proportion of European intensivists use CRRT as their first choice in critically ill patients developing AKI. Interestingly, treatment doses remain high in light of the results of recently published randomised controlled trials, and the practices differ from the data reported in the most recent literature. We also gained insights into intensivists' motivations for choosing CRRT over IHD.

## References

1. Joannidis M, Forni LG (2011) Clinical review: timing of renal replacement therapy. Crit Care 15:223

2. RENAL Replacement Therapy Study Investigators, Bellomo R, Cass A, Cole L, Finfer S, Gallagher M, Lo S, McArthur C, McGuinness S, Myburgh J, Norton R, Scheinkestel C, Su S (2009) Intensity of continuous renal-replacement therapy in critically ill patients. N Engl J Med 361:1627–1638

3. VA/NIH Acute Renal Failure Trial Network, Palevsky PM, Zhang JH, O'Connor TZ, Chertow GM, Crowley ST, Choudhury D, Finkel K, Kellum JA, Paganini E, Schein RM, Smith MW, Swanson KM, Thompson BT, Vijayan A, Watnick S, Star RA, Peduzzi P (2008) Intensity of renal support in critically ill patients with acute kidney injury. N Engl J Med 359:7–20

4. Vinsonneau C, Camus C, Combes A, Costa de Beauregard MA, Klouche K, Boulain T, Pallot JL, Chiche JD, Taupin P, Landais P, Dhainaut JF, Hemodiafe Study Group (2006) Continuous venovenous haemodiafiltration versus intermittent haemodialysis for acute renal failure in patients with multiple-organ dysfunction syndrome: a multicentre randomised trial. Lancet 368:379–385

5. Payen D, Mateo J, Cavaillon JM, Fraisse F, Floriot C, Vicaut E (2009) Impact of continuous venovenous hemofiltration on organ failure during the early phase of severe sepsis: a randomized controlled trial. Crit Care Med 37:803–810

6. Ricci Z, Ronco C (2011) Timing, dose and mode of dialysis in acute kidney injury. Curr Opin Crit Care 17:556–561

7. Ronco C, Zanella M, Brendolan A, Milan M, Canato G, Zamperetti N, Bellomo R (2001) Management of severe acute renal failure in critically ill patients: an international survey in 345 centres. Nephrol Dial Transplant 16:230–237

8. Ricci Z, Ronco C, D'Amico G, De Felice R, Rossi S, Bolgan I, Bonello M, Zamperetti N, Petras D, Salvatori G, Dan M, Piccinni P (2006) Practice patterns in the management of acute renal failure in the critically ill patient: an international survey. Nephrol Dial Transplant 21:690–696

9. Ricci Z, Picardo S, Ronco C (2007) Results from international questionnaires. Contrib Nephrol 156:297–303

10. Ronco C, Ricci Z, Bellomo R (2006) Current worldwide practice of dialysis dose prescription in acute renal failure. Curr Opin Crit Care 12:551–556

11. Schiffl H, Lang SM, Fischer R (2002) Daily hemodialysis and the outcome of acute renal failure. N Engl J Med 346:305–310

12. Ronco C, Bellomo R, Homel P, Brendolan A, Dan M, Piccinni P, La Greca G (2000) Effects of different doses in continuous veno-venous haemofiltration on outcomes of acute renal failure: a prospective randomised trial. Lancet 356:26–30

13. Saudan P, Niederberger M, De Seigneux S, Romand J, Pugin J, Perneger T, Martin PY (2006) Adding a dialysis dose to continuous hemofiltration increases survival in patients with acute renal failure. Kidney Int 70:1312–1317

14. Uchino S, Kellum JA, Bellomo R, Doig GS, Morimatsu H, Morgera S, Schetz M, Tan I, Bouman C, Macedo E, Gibney N, Tolwani A, Ronco C, Beginning and Ending Supportive Therapy for the Kidney (BEST Kidney) Investigators, (2005) Acute renal failure in critically ill patients: a multinational, multicenter study. JAMA 294:813–818

15. Uchino S, Bellomo R, Morimatsu H, Morgera S, Schetz M, Tan I, Bouman C, Macedo E, Gibney N, Tolwani A, Oudemans-van Straaten H, Ronco C, Kellum JA (2007) Continuous renal replacement therapy: a worldwide practice survey. The beginning and ending supportive therapy for the kidney (BEST kidney) investigators. Intensive Care Med 33:1563–1570

16. Lins RL, Elseviers MM, Van der Niepen P, Hoste E, Malbrain ML, Damas P, Devriendt J, SHARF investigators, (2009) Intermittent versus continuous renal replacement therapy for acute kidney injury patients admitted to the intensive care unit: results of a randomized clinical trial. Nephrol Dial Transplant 24:512–518

17. Schortgen F, Soubrier N, Delclaux C, Thuong M, Girou E, Brun-Buisson C, Lemaire F, Brochard L (2000) Hemodynamic tolerance of intermittent hemodialysis in critically ill patients: usefulness of practice guidelines. Am J Respir Crit Care Med 162:197–202

18. Angus DC, Mira J-P, Vincent J-L (2010) Improving clinical trials in the critically ill. Crit Care Med 38:527–532

19. Bell M, Granath F, Schön S, Ekbom A, Martling C-R (2007) Continuous renal replacement therapy is associated with less chronic renal failure than intermittent haemodialysis after acute renal failure. Intensive Care Med 33:773–780

20. Cole L, Bellomo R, Hart G, Journois D, Davenport P, Tipping P, Ronco C (2002) A phase II randomized, controlled trial of continuous hemofiltration in sepsis. Crit Care Med 30:100–106

21. Joannidis M (2009) Continuous renal replacement therapy in sepsis and multisystem organ failure. Semin Dial 2:160–164

22. Lombel RM, Kommareddi M, Mottes T, Selewski DT, Han YY, Gipson DS, Collins KL, Heung M (2012) Implications of different fluid overload definitions in pediatric stem cell transplant patients requiring continuous renal replacement therapy. Intensive Care Med 38:663–669

23. Karvellas CJ, Farhat MR, Sajjad I, Mogensen SS, Leung AA, Wald R, Bagshaw SM (2011) A comparison of early versus late initiation of renal replacement therapy in critically ill patients with acute kidney injury: a systematic review and meta-analysis. Crit Care 15:R72

24. Csomos A, Varga S, Bertolini G, Hibbert C, Sandor J, Capuzzo M, Guidet BR (2010) Intensive care reimbursement practices: results from the ICUFUND survey. Intensive Care Med 36:1759–1764

25. Cannesson M, Pestel G, Ricks C, Hoeft A, Perel A (2011) Crit Care Hemodynamic monitoring and management in patients undergoing high risk surgery: a survey among north American and European anesthesiologists. Crit Care 15:R197

26. Beloucif S, Payen D (1998) A European survey of the use of inhaled nitric oxide in the ICU. Working group on inhaled NO in the ICU of the European Society of Intensive Care Medicine. Intensive Care Med 24:864–877