



HAL
open science

Renal Replacement Therapy for Acute Kidney Injury in French Intensive Care Units: A Nationwide Survey of Practices

Jean-Pierre Quenot, Idris Amrouche, Jean-Yves Lefrant, Kada Klouche, Samir Jaber, Damien Du Cheyron, Jacques Duranteau, Julien Maizel, Eric Rondeau, Etienne Javouhey, et al.

► **To cite this version:**

Jean-Pierre Quenot, Idris Amrouche, Jean-Yves Lefrant, Kada Klouche, Samir Jaber, et al.. Renal Replacement Therapy for Acute Kidney Injury in French Intensive Care Units: A Nationwide Survey of Practices. *Blood Purification*, 2022, 51 (8), pp.698-707. 10.1159/000518919 . hal-03418023

HAL Id: hal-03418023

<https://hal.science/hal-03418023>

Submitted on 4 Dec 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Renal Replacement Therapy for Acute Kidney Injury in French Intensive Care Units: A Nationwide Survey of Practices

Jean-Pierre Quenot a, b, c Idris Amrouche a Jean-Yves Lefrant d, e Kada Klouche f
Samir Jaber g Damien Du Cheyron h Jacques Duranteau i Julien Maizel j Eric Rondeau k, l,
m Etienne Javouhey n, o Théophile Gaillot p, q René Robert r Jean Dellamonica s Bertrand
Souweine t Julien Bohé u Saber Davide Barbar v Caroline Sejourneé w Christophe Vinsonneau
w for the DIAM Trial Investigators, in collaboration with the BOREAL research network

a Service de Médecine Intensive-Réanimation, CHU Dijon Bourgogne, Dijon, France;

b Equipe Lipness, Centre de Recherche INSERM UMR1231, LabEx LipSTIC, Université de Bourgogne-Franche Comté, Dijon, France;

c INSERM CIC 1432, Module Epidémiologie Clinique, Université de Bourgogne-Franche Comté, Dijon, France;

d EA 2992 IMAGINE, Université de Montpellier, Montpellier, France;

e Pôle Anesthésie Réanimation Douleur Urgence, CHU, Nîmes, France;

f Intensive Care Unit, Anaesthesiology and Intensive Care Department, Lapeyronie Hospital University Hospital and INM University Montpellier, INSERM, Montpellier, France;

g Department of Anesthesia and Critical Care Medicine, University of Montpellier Saint Eloi Hospital, and PhyMedExp, University of Montpellier, INSERM, CNRS, Montpellier, France;

h BoReal Study Group, Medical Intensive Care Unit, Caen University Hospital, Caen, France;

i Anesthesia and Intensive Care Department, Hôpitaux Universitaires Paris Sud, Université Paris-Sud, Université Paris-Saclay, Hôpital de Bicêtre, Assistance Publique Hôpitaux de Paris (APHP), Le Kremlin-Bicêtre, France;

j BoReal Study Group, Medical Intensive Care Unit and EA7517, Amiens University Hospital, Amiens, France;

k Department of Nephrology and Transplantation, AP-HP, Hôpital Tenon, Paris, France;

l INSERM UMR-S 1155, Hospital Tenon, Paris, France;

m Urgences Néphrologiques et Transplantation Rénale, Sorbonne Université, Paris, France;

n Paediatric Intensive Care Unit, Hospices Civils de Lyon, University of Lyon, Lyon, France;

o Hospices Civils of Lyon, University Claude Bernard Lyon 1, Lyon, France;

p Service de Pédiatrie, Hôpital Sud, CHU de Rennes, Rennes, France;

q CIC-P Inserm 0203 Université Rennes, Rennes, France;

r Réanimation Médicale, CHU La Milétrie, Poitiers, France;

s Medical Intensive Care Unit, l'Archet Hospital, University Hospital of Nice, Nice, France;

t Service de Réanimation Médicale, CHU de Clermont- Ferrand, Clermont Ferrand, France;

u Service d'Anesthésie-Réanimation-Médecine Intensive, Centre Hospitalier Lyon-Sud, Hospices Civils de Lyon, Pierre Bénite, France;

v Department of Anaesthesiology, Critical Care and Emergency Medicine, CHU Nîmes, University Montpellier, Nîmes, France;

w BoReal Study Group, Intensive Care Unit, Hôpital de Bethune, Bethune, France

Correspondence to:

Jean-Pierre Quenot, jean-pierre.quenot @ chu-dijon.fr

Keywords

Renal replacement therapy · Acute kidney injury · Intensive - care unit · Survey of practice

Abstract

Background:

The frequency of acute kidney injury (AKI) can be as high as 50% in the intensive care unit (ICU). Despite the publication of national guidelines in France in 2015 for the use of RRT, there are no data describing the implementation of these recommendations in real-life.

Methods:

We performed a nationwide survey of practices from November 15, 2019, to January 24, 2020, in France. An electronic questionnaire based on the items recommended in the national guidelines was sent using an online survey platform, to the chiefs of all ICUs in France. The questionnaire comprised a section for the Department Chief about local organization and facilities, and a second section destined for individual physicians about their personal practices.

Results:

We contacted the Department Chief in 356 eligible ICUs, of whom 88 (24.7%) responded regarding their ICU organization. From these 88 ICUs, 232/285 physicians (82%) completed the questionnaire regarding individual practices. The practices reported by respondent physicians were as follows: intermittent RRT was first-line choice in >75% in a patient with single organ (kidney) failure at the acute phase, whereas continuous RRT was predominant (>75%) in patients with septic shock or multi-organ failure. Blood and dialysate flow for intermittent RRT were 200–300 mL/min and 400–600 mL/min, respectively. The dose of dialysis for continuous RRT was 25–35 mL/kg/h (65%). Insertion of the dialysis catheter was mainly performed by the resident under echographic guidance, in the right internal jugular vein. The most commonly used catheter lock was citrate (53%). The most frequently cited criterion for weaning from RRT was diuresis, followed by a drop in urinary markers (urea and creatinine).

Conclusion:

This study shows a satisfactory level of reported compliance with French guidelines and recent scientific evidence among ICU physicians regarding initiation of RRT for AKI in the ICU.

Background

The frequency of acute kidney injury (AKI) can be as high as 50% in the intensive care unit (ICU) and is an independent risk factor for mortality [1–5]. Mortality is reported to be between 40% and 60% in ICU patients with AKI [6, 7] despite recent improvements in our understanding of the pathophysiological mechanisms [8] and the implementation of renal protective measures [9]. If uncorrected, and/or in the presence of metabolic disorders refractory to medical therapy, AKI may necessitate renal replacement therapy (RRT), in about 20% of ICU situations [1–3, 10]. However, practices are extremely heterogeneous [11–17], likely due to the fact that most international guidelines date from 10 or more years ago, and do not focus on RRT in detail [18, 19]. In addition, it may be difficult to integrate more recent literature on this topic into routine clinical practice.

In France, national recommendations for RRT in the ICU were published in 2015 [20] but it remains unclear how they are applied in daily practice. While there is little debate about the emergency indication for RRT, there is much greater controversy regarding other points [21], such as the timing of RRT initiation, the technique to use, the dose of dialysis, anticoagulation of the dialysis circuits, and the type of catheter. In order to obtain insights into actual current practices in terms of RRT for AKI in the ICU in France, we performed a national survey of practices among a nationwide network of experts.

Methods

The study was performed from November 15, 2019, to January 24, 2020. Using the SurveyMonkey platform (www.surveymonkey.com), we sent an electronic questionnaire to all the chiefs of ICU in France caring for patients with AKI and who were equipped with facilities to provide RRT (continuous or intermittent). The questionnaire was developed on the basis of the different recommendations stipulated in the national guidelines [20]. It was piloted on a group of ICU physicians (the scientific committee of the study, comprising the authors of the present publication) to verify readability and feasibility. The Scientific Committee for the study comprising experts in the field of intensive care verified the exhaustiveness of the list of centers to be contacted throughout the country, using mailing lists of physicians and departments affiliated to national professional societies. The scientific committee members also sent reminders to colleagues who did not respond after the first contact.

Questionnaire Structure

The questionnaire comprised 2 sections. The first section of the questionnaire was completed by the Department Chief and comprised 42 questions about the organizational aspects of the ICU, standard procedures, and training. Once the Department Chief had completed the first section and provided consent for the second stage, the second section of the questionnaire was completed by the ICU physicians in the participating departments (designated by the Department Chief). This section investigated individual practices in terms of prescription and implementation of RRT in the ICU. The second section was only made available to the

designated physicians in the ICU after the Department Chief had completed Section 1. A total of 4 reminders were sent during the study period to ensure a maximum response rate.

In response to multiple-choice questions, we categorized responses with a frequency of response >75% as representing “the majority of cases,” and between 50 and 75%, the predominant modality. For questions concerning indications, characteristics, and the choice of RRT technique, responses were categorized into “Strongly or moderately agree,” “Strongly or moderately disagree,” and “Neutral.”

Data on the volume of activity (admissions and number of RRT sessions) date from 2018 since the activity of 2019 was not available at the time this study was initiated. Given the design of the study as a survey of professional practices, informed consent was not required in accordance with the French law. Quantitative data are reported as medians and interquartile range or numbers and percentage (%).

Table 1. Characteristics of respondents and institutions

Respondents' characteristics	
Main area of specialization, <i>n</i> (%)	
Critical care medicine	102 (44)
Anesthesiology	56 (24.1)
Nephrology	22 (9.5)
Pediatrics	5 (2.1)
Other	47 (20.3)
Experience in the intensive care unit, <i>n</i> (%)	
<5 years	61 (26.3)
5–10 years	49 (21.2)
>10 years	122 (52.5)
Type of hospital, <i>n</i> (%)	
University hospital	35 (39.8)
Public non-University hospital	47 (53.4)
Private non-University hospital	5 (5.6)
Military hospital	1 (1.2)
Type of critical care unit, <i>n</i> (%)	
Medical	26 (29.6)
Surgical	5 (5.6)
Mixed	49 (55.6)
Pediatric	4 (4.6)
Acute care nephrology	4 (4.6)
Beds in intensive care unit, <i>n</i> (%)	
<11	32 (36.4)
11–15	25 (28.4)
16–20	17 (19.2)
>20	14 (16)
Patients/attending nurse ratio, <i>n</i> (%)	
2–3	84 (95.5)
>3	4 (4.5)
Patients/attending physician ratio, <i>n</i> (%)	
1–6	67 (76)
>6	21 (24)
Total admissions in 2018, <i>n</i> (%)	
<600	43 (49)
601–1,000	30 (34)
>1,000	15 (17)

Table 2. Organization of renal replacement therapy (RRT) in respondent intensive care units (ICU)

The RRT technique is mainly chosen by, <i>n</i> (%)	
The ICU physician	84 (95)
A nephrologist	4 (5)
The continuous RRT circuit is mainly prepared by, <i>n</i> (%)	
The ICU physician	4 (5)
An ICU nurse	80 (91)
A nurse from the nephrology department	4 (4)
The intermittent RRT circuit is mainly prepared by, <i>n</i> (%)	
The ICU physician	5 (6)
An ICU nurse	72 (82)
A nurse from the nephrology department	11 (12)
There is a written protocol for dialysate production during RRT, <i>n</i> (%)	64 (73)
There is a written protocol for, <i>n</i> (%)	
Catheter insertion	26 (30)
Preparing or connecting the machine	63 (72)
Surveillance	70 (78)
Discontinuation	19 (22)
Type of membrane usually used for intermittent RRT, <i>n</i> (%)	
Low permeability	17 (19)
High permeability	63 (72)
High porosity	8 (9)
Type of membrane usually used for continuous RRT, <i>n</i> (%)	
Low permeability	9 (10)
High permeability	69 (79)
High porosity	10 (11)
Type of catheter lock usually used, <i>n</i> (%)	
Isotonic saline solution	14 (16)
Heparin	23 (26)
Ethanol	0 (0)
Taurolidine	4 (5)
Citrate	47 (53)
Dialysate production system during intermittent RRT, <i>n</i> (%)	
Local water treatment	9 (14)
Fixed on-site	28 (44)
Mobile device	34 (53)

Results

Questionnaire Section 1: Participating Institutions

We identified 356 ICUs, and among these, 88 (24.7%) Department Chiefs completed Section 1 of the questionnaire, corresponding to 88 ICUs. From these 88 ICUs, 285 physicians were contacted to complete Section 2, of whom a total of 232 responded (82%). The characteristics of the participating ICUs ($N = 88$) and physicians ($N = 232$) are shown in Table 1.

Questionnaire Section 1: RRT Practices at ICU Level

Among the 88 ICUs participating in the study, 48% (42/88) of Department chiefs declared that RRT (either continuous or intermittent) had been used in fewer than 100 patients, and 9% (8/88) declared the use of RRT in more than 200 patients during the year 2018. The availability of continuous and intermittent RRT was 79% (69/88) and 87% (76/88), respectively, among participating institutions. Regarding Sustained Low-Efficiency Dialysis (SLED), it was used in only 14% (12/88) of responding ICUs. Of note, a written protocol existed for management of AKI in only 37% (33/88) of ICUs. The organization of RRT initiation (continuous or intermittent), the type of material used (membrane, lock, and catheter insertion), and the management of dialysate production for intermittent RRT are detailed in Table 2.

For intermittent RRT, the ICU nurses were reported to monitor the sessions in 83% (73/88) of centers. An operational roster for a nurse to be on duty at night and during the weekends for the implementation of RRT was available in 20% (18/88) of participating ICUs. According to the Department Chiefs who responded to this survey, training in RRT was made available to physicians in <20% of cases, whereas 80% (70/88) of units organized training for nurses in RRT via expert practitioners, simulation, and/or a specific university diploma.

In terms of individual practices, regarding the preferred vascular approach for RRT, the right internal jugular vein was most popular (82%), followed by the femoral vein (16%) and in very few cases the left internal jugular vein (2%). No respondent cited use of the subclavian approach. The most commonly used diameter was >12 Fr in 70% of cases, with length >24 cm via the femoral approach in 92% of cases. The use of antimicrobial-impregnated catheters was not cited. According to 62% of respondent physicians, insertion of the RRT catheter is mainly performed by the resident and largely under echographic guidance (96%). In pediatrics, the size of the dialysis catheters was predominantly 6.5 Fr for children weighing 3–6 kg (76%) and 7–10 kg (50%), and 8 Fr for children weighing 11–20 kg (72%) or 20–30 kg (50%), and 11.5 Fr for children weighing >30 kg (51%).

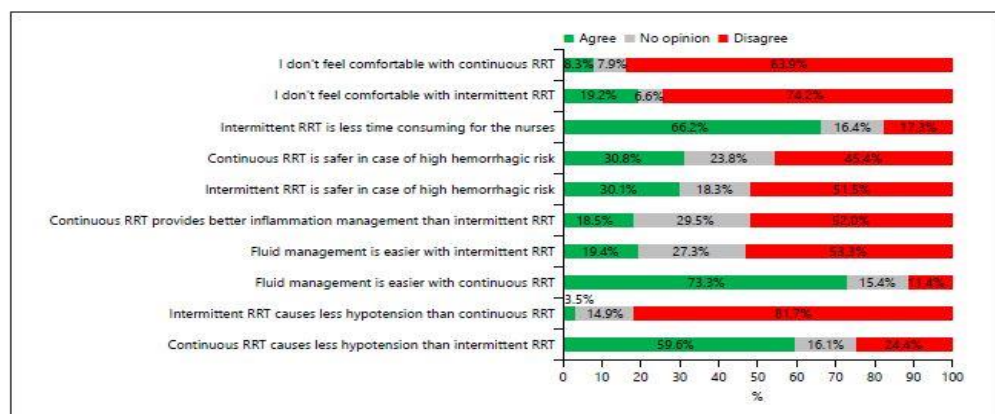


Fig. 1. Illustration of the main reasons justifying the choice of renal replacement therapy (RRT).

Individual Practices Reported in Terms of RRT Technique and Prescription

The main reasons justifying the choice of RRT and the criteria for initiating RRT (emergency or nonemergency) are presented in Figures 1–3. Intermittent RRT was preferred as the first-line option (56%) in a patient with single organ failure (i.e., kidney) at the acute phase, followed by continuous RRT in 33% and SLED in only 4%. In patients with septic shock, continuous RRT was predominantly used, with continuous veno-venous hemofiltration in 46%, continuous veno-venous hemodialysis in 33%, continuous veno-venous hemodiafiltration in 17%, and HVCVVH (4%).

In patients with multi-organ failure, the techniques of choice were mainly continuous veno-venous hemofiltration (25%), intermittent RRT (19%), continuous venovenous hemodialysis (17%), and continuous veno-venous hemodiafiltration (13%). In hemodynamically stable patients, intermittent RRT was predominantly preferred (47%) over continuous RRT (26%) and SLED (2.7%).

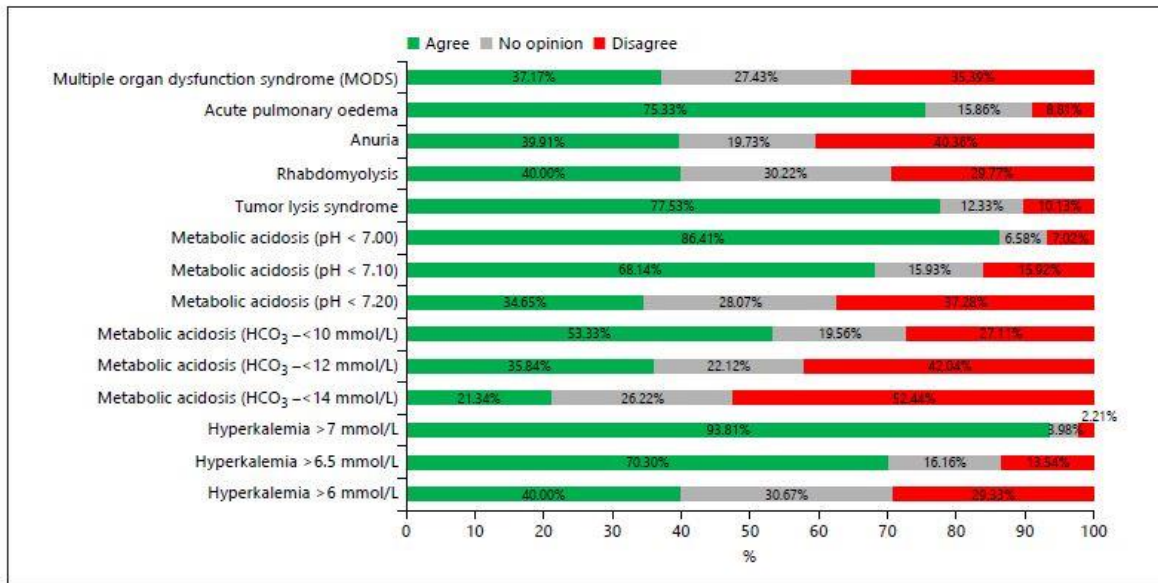


Fig. 2. The most frequently cited criteria for initiating emergency renal replacement therapy (after optimal medical therapy).

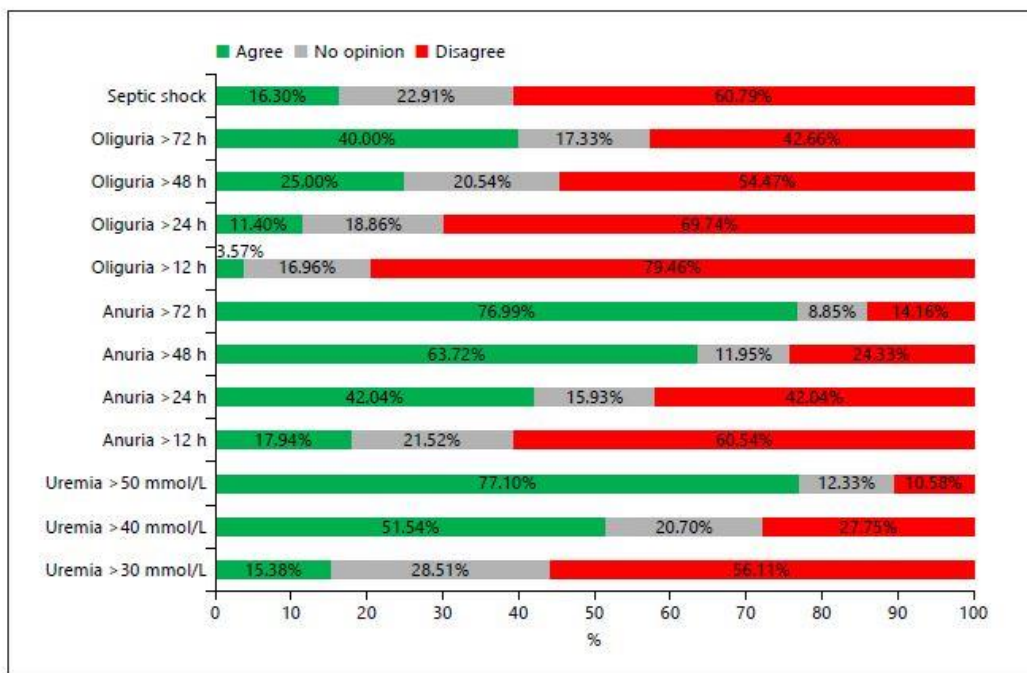


Fig. 3. The most frequently cited criteria for initiating nonemergency renal replacement therapy.

In pediatrics, 51% of responding physicians reported that they used peritoneal dialysis in case of the need for RRT. In case of heparin-induced thrombocytopenia, danaparoid sodium was predominantly used (77%). The most frequent criterion for weaning from RRT was diuresis, followed by a drop in urea, and urinary markers (urea and creatinine) (Fig. 4). Of note, assessment of renal function recovery is usually performed at the end of the ICU stay (35%), or after discharge from the ICU during a consultation with a nephrologist (74%).

Individual Practices in Terms of Prescription according to the Technique Used

Intermittent RRT

Intermittent RRT for AKI is prescribed by 72% of physicians according to the patient's needs, 3 times a week by 20% and daily by 8%. Blood flow and dialysate for intermittent RRT are prescribed at, respectively, 200–300 mL/ min and between 400 and 600 mL/min. The majority of physicians (94%) prescribe an intermittent RRT duration of between 3 and 6 h, and 62% of physicians using a membrane surface area between 1.3 m² and 2 m². In patients at high hemorrhagic risk, 32% performed filter rinsing. In patients at low risk of hemorrhage, low molecular weight heparin (73%) and unfractionated heparin (25%) are preferred over citrate (2%). Intermittent RRT performed on an arteriovenous fistula is possible in the ICU (71%) and requires the involvement of a nurse from the nephrology unit, to puncture and attach the machine (62%). Of note, when an arteriovenous fistula is present, intermittent RRT sessions are prescribed by the ICU physicians in 86% of cases.

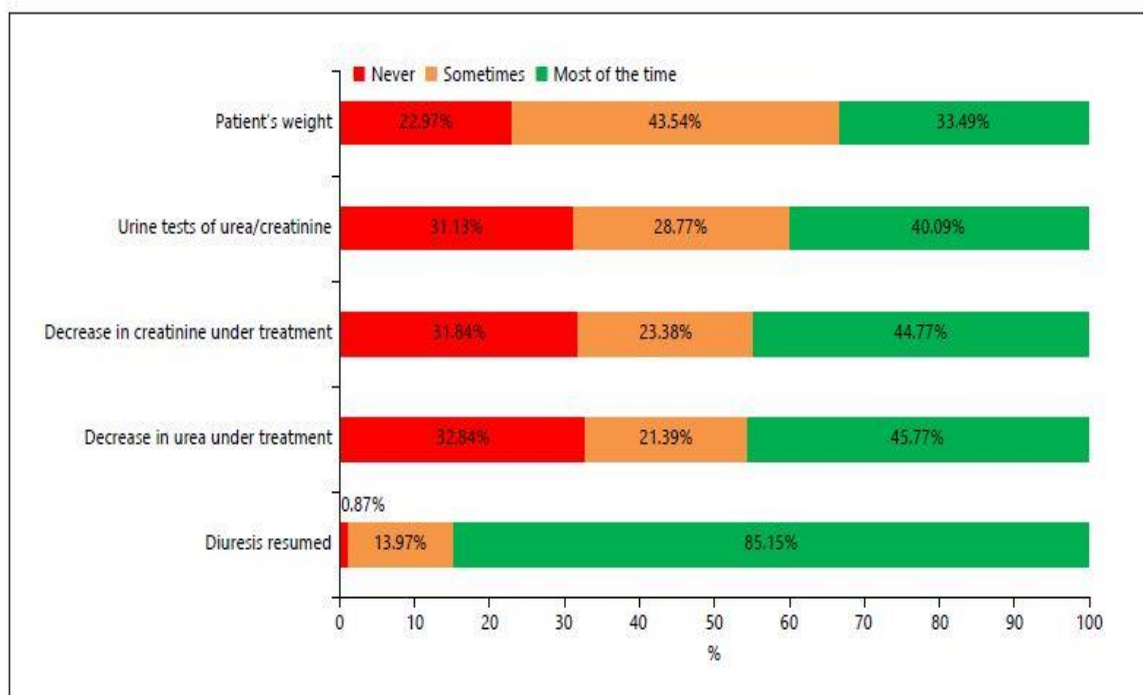


Fig. 4. The most frequently cited criteria for weaning from renal replacement therapy.

Continuous RRT

Prescribed blood flow was between 100 and 250 mL/ min (83%) and dialysate flow was predominantly prescribed according to the patient's weight (80%). The effluent flow rate (substitution fluid + dialysate + net ultrafiltration) is set between 1,000 and 4,000 mL/h (93%) and pre- or post-dilution was reportedly performed by 60% of respondents. The dialysis dose was 25–35 mL/kg/h for 65% of respondents. The RRT circuit was generally anticoagulated using citrate, both in patients with high hemorrhagic risk (79%) and in those with low hemorrhagic risk (67%).

Discussion

The DIAM study is the first survey of practices to be performed in France since the publication of the national guidelines for RRT in adults and children in the ICU [20]. Our study provides insights into current practices, which may have evolved in recent years in response to new publications in the literature.

In particular, a point where the state of knowledge has evolved is the timing of RRT initiation in the ICU. In emergency situations (e.g., hyperkalemia, metabolic acidosis, pulmonary edema refractory to medical therapy, or lysis syndrome), the findings reported in our survey regarding prescription of RRT are coherent with guidelines [20], even though these guidelines were based on expert consensus at the time of publication. Randomized trials are not ethically possible in this specific situation as they would incur a major risk of death for patients. Outside of the emergency situations, however, a number of studies have been published in recent years. At the time when the questionnaire was sent out, 3 key studies investigating the optimal timing of nonurgent RRT initiation in the ICU had been published [22–24]. These publications came after the development of the French guidelines, and thus, could not be included in them. Even more recently, a meta-analysis [25] and a large international study including 3,019 patients corroborated previous results regarding the lack of difference in mortality according to the time when RRT was initiated in patients with AKI [26]. The study by Zarbock et al. [23] is an exception, in that they demonstrated a significant reduction in mortality in the early-initiation group, but there was some debate regarding the study population (post-cardiac surgery), and the theoretical indication for RRT due to signs of pulmonary congestion.

The results of this survey of practices regarding the criteria for initiating RRT are in line with published data, notably in case of urea >40 mmol/L (51% agreed) or >50 mmol/L (77% agreed), and oliguria >72 h (40% agreed) and anuria >72 h (72% agreed). Older surveys of practices reported a stronger tendency of ICU physicians in both Europe [11] and the United States [27] to initiate RRT earlier. This position was undoubtedly influenced by several meta-analyses whose publication now dates from around 10 years ago [28–30]. The ongoing AKIKI 2 study [31] is evaluating a strategy of RRT initiation at KDIGO stage 3 with urea >40 mmol/L or oligo-anuria >72 h at the time of randomization, with an early arm (RRT <6 h) and a deferred arm (urea >50 mmol/L). The results of this trial will undoubtedly provide novel evidence regarding the ideal time to initiate RRT for AKI in the ICU. Other studies are also in the pipeline regarding the use of predictive models to personalize RRT prescription in patients with KDIGO stage 3 AKI hospitalized in the ICU.

The presence of septic shock does not appear to be retained as an indication for RRT in our survey (with only 16% in agreement and 23% neutral). This is contrary to the hypotheses advanced several years ago, notably in animal models [32, 33] regarding the interest of maintaining “inflammatory homeostasis,” likely in the absence of an efficacious immunomodulating agent. Studies performed in the last 10 years have confirmed that there is no benefit, and it may even be harmful [34] to initiate RRT in the aim of removing mediators of inflammation to improve patient prognosis in the ICU [35, 36]. Multi-organ failure

was reported by 37.5% of our respondents to be an indication for RRT, no doubt due to the severe metabolic disturbances it precipitates.

Regarding the choice of RRT technique (continuous vs. intermittent), this survey reveals a preference for continuous RRT, notably for fluid management, according to the Department Chiefs (73% in agreement), as it induces less hypotension than intermittent RRT (59% in agreement). French guidelines [20] and literature data [37–39] do not make it possible to draw any conclusion regarding the superiority of either technique and suggest in fact that the technique that is available and in which the staff are most competent should be used. Further, data are conflicting regarding renal function recovery according to the technique used [40, 41], although new evidence has emerged from recent studies on the timing of RRT initiation showing no difference in recovery of renal function (although data were from secondary endpoints in those studies) [22–24, 26].

The results of our survey are in line with French guidelines regarding the dose of dialysis and the modalities of its implementation, be it for intermittent or for continuous RRT. This is likely because the data in the literature are sufficiently robust to be adopted without question by prescribers [42–45]. Of note, typical CRRT doses were reported to be 25–35 mL/kg/h despite recommendations that they be in range of 20–25 mL/kg/h based on the ATN and RENAL trials [43, 45]. It is likely that physicians prescribed a slightly higher dose in order to be sure that the actual dose delivered would be 20–25, when one takes into account potential interruptions over 24 h. Regarding the site of RRT catheter insertion, and the use of echographic guidance, the responses to our survey are also in conformity with national guidelines [20], and probably also common sense, taking into account the patient's morphology and the risk of local infection [46].

High-permeability membranes should be used for continuous RRT and in intermittent RRT (if ultrapure dialysate) [20] and were reported to be the case for around 3-quarters of the Department Chiefs who responded. According to encouraging results in ICUs and in hemodialysis patients with tunneled dialysis catheters [47, 48], the use of citrate as a catheter lock for RRT catheters seems to be preferred in our study (53% in agreement), despite a recent study [49] and guidelines [20] that preclude any firm conclusion about the best catheter lock to use (isotonic saline solution, ethanol, heparin, citrate, and taurolidine). Heparin remains the only catheter lock with marketing authorization at present, despite the absence of any benefit on catheter survival, and the existence of doubts regarding its innocuousness [50].

Regional anticoagulation with citrate in continuous RRT is predominantly preferred according to our respondents, which is congruent with French commendations [20], in patients with both high and low hemorrhagic risks. In those at low bleeding risk, filter duration is longer, in line with some publications in the literature [51–53]. This survey also shows that there remains considerable margin for improvement of practices in terms of training for ICU staff (physicians and nurses) and in terms of the development and implementation of standard operating procedures, which are recommended by French guidelines [20]. The use of best practice has been shown to lead to a significant reduction in complications [54, 55].

Our study has several limitations. First, the number of participating ICUs is relatively low compared to the overall number in France. However, this level of response is classic in this type of study [56, 57] and our response rate is similar to that reported in another study on the same theme [11]. The dissemination of the questionnaire by the Department Chiefs among their ICU physicians was excellent (82% of responses), and completion rates were almost

100% on all questions. Second, the ICUs that answered the questionnaires may be those that are particularly highly motivated and interested in this topic, and therefore, results should be extrapolated with caution to other ICUs in France or abroad. Third, this was a survey of practices that aimed to record actual practices in ICUs, but there may be some potential for social desirability bias, whereby physicians may have answered what they thought would be the expected or “right” answer, especially since national guidelines exist for this topic [20]. For this reason, a further study is ongoing on the ground to compare the results of this survey of practices to actual practices in ICUs across France. Finally, the Likert scales for response to the questions do not allow for detailed granularity in the responses but reveal mainly trends at a given time. It would likely be necessary to update the guidelines in light of recent evidence and to repeat this survey in the future to more accurately evaluate the translation of knowledge into practice at the bedside.

Conclusion

In summary, our study shows a satisfactory level of compliance with French guidelines and recent scientific evidence regarding initiation of RRT for AKI in the ICU. However, these self-declared results warrant confirmation by future observational studies of actual practices.

Acknowledgments

The authors thank Fiona Ecartot, PhD (EA3920, University Hospital Besancon, France) for translation and editorial assistance. We are also grateful to all the physicians for their participation. We also thank David Attaf, Fabien Berthy, and Laure Cornillac (Fresenius) for their assistance in preparing the survey online.

Statement of Ethics

Since this study was a survey of practices and did not involve patients, the need for informed consent and ethics approval was waived according to French legislation. Consent to participate was assumed by the fact that physicians completed the survey.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

This study received no extramural funding.

Author Contributions

Study conception and design were performed by J.-P.Q., C.S., and C.V. Acquisition and analysis of data were performed by J.- P.Q., I.A., J.-Y.L., K.K., S.J., D.D.C., J.D., J.M., E.R., E.J., T.G., R.R., J.D., B.S., J.B., S.D.B., C.S., and C.V. Interpretation of data was performed by J.-P.Q., C.S., and C.V. Drafting of the first draft of the manuscript was performed by J.-P.Q., C.S., and C.V. Final approval of the version submitted by J.-P.Q., I.A., J.-Y.L., K.K., S.J., D.D.C., J.D., J.M., E.R., E.J., T.G., R.R., J.D., B.S., J.B., S.D.B., C.S., and C.V.

References

- 1 Clec'h C, Gonzalez F, Lautrette A, Nguile-Makao M, Garrouste-Orgeas M, Jamali S, et al. Multiple-center evaluation of mortality associated with acute kidney injury in critically ill patients: a competing risks analysis. *Crit Care*. 2011; 15(3): R128.
- 2 Poukkanen M, Koskenkari J, Vaara ST, Pettilä V, Karlsson S, Korhonen AM, et al. Variation in the use of renal replacement therapy in patients with septic shock: a substudy of the prospective multicenter observational FINNAKI study. *Crit Care*. 2014 Feb 5; 18(1): R26.
- 3 Hoste EA, Bagshaw SM, Bellomo R, Cely CM, Colman R, Cruz DN, et al. Epidemiology of acute kidney injury in critically ill patients: the multinational AKI-EPI study. *Intensive Care Med*. 2015 Aug; 41(8): 1411–23.
- 4 Mehta RL, Cerdá J, Burdmann EA, Tonelli M, García-García G, Jha V, et al. International Society of Nephrology's 0by25 initiative for acute kidney injury (zero preventable deaths by 2025): a human rights case for nephrology. *Lancet*. 2015 Jun 27; 385(9987): 2616–43.
- 5 Ronco C, Bellomo R, Kellum JA. Acute kidney injury. *Lancet*. 2019 Nov 23; 394(10212): 1949–64.
- 6 de Mendonca A, Vincent JL, Suter PM, Moreno R, Dearden NM, Antonelli M, et al. Acute renal failure in the ICU: risk factors and outcome evaluated by the SOFA score. *Intensive Care Med*. 2000 Jul; 26(7): 915–21.
- 7 Uchino S, Kellum JA, Bellomo R, Doig GS, Morimatsu H, Morgera S, et al. Acute renal failure in critically ill patients: a multinational, multicenter study. *JAMA*. 2005 Aug 17; 294(7): 813–8.
- 8 Gomez H, Ince C, De Backer D, Pickkers P, Payen D, Hotchkiss J, et al. A unified theory of sepsis-induced acute kidney injury: inflammation, microcirculatory dysfunction, bioenergetics, and the tubular cell adaptation to injury. *Shock*. 2014 Jan; 41(1): 3–11.
- 9 Mehran R, Dangas GD, Weisbord SD. Contrast-associated acute kidney injury. Reply. *N Engl J Med*. 2019 May 30; 381(22): 1296–7.
- 10 Nisula S, Kaukonen KM, Vaara ST, Korhonen AM, Poukkanen M, Karlsson S, et al. Incidence, risk factors and 90-day mortality of patients with acute kidney injury in Finnish intensive care units: the FINNAKI study. *Intensive Care Med*. 2013 Mar; 39(3): 420–8.
- 11 Legrand M, Darmon M, Joannidis M, Payen D. Management of renal replacement therapy in ICU patients: an international survey. *Intensive Care Med*. 2013 Jan; 39(1): 101–8.
- 12 Jamal JA, Mat-Nor MB, Mohamad-Nor FS, Udy AA, Lipman J, Roberts JA. A national survey of renal replacement therapy prescribing practice for acute kidney injury in Malaysian intensive care units. *Nephrology*. 2014 Aug; 19(8): 507–12.

- 13 Fealy N, Aitken L, Toit E, Baldwin I. Continuous renal replacement therapy: current practice in Australian and New Zealand intensive care units. *Crit Care Resusc.* 2015 Jun; 17(2): 83–91.
- 14 Clark WR, Ding X, Qiu H, Ni Z, Chang P, Fu P, et al. Renal replacement therapy practices for patients with acute kidney injury in China. *PLoS One.* 2017; 12(7): e0178509.
- 15 Heung M, Bagshaw SM, House AA, Juncos LA, Piazza R, Goldstein SL. CRRTnet: a prospective, multi-national, observational study of continuous renal replacement therapy practices. *BMC Nephrol.* 2017 Jul 6; 18(1): 222.
- 16 Digvijay K, Neri M, Fan W, Ricci Z, Ronco C. International survey on the management of acute kidney injury and continuous renal replacement therapies: year 2018. *Blood Purif.* 2019; 47(1–3): 113–9.
- 17 Murugan R, Ostermann M, Peng Z, Kitamura K, Fujitani S, Romagnoli S, et al. Net ultrafiltration prescription and practice among critically ill patients receiving renal replacement therapy: a multinational survey of critical care practitioners. *Crit Care Med.* 2020 Feb; 48(2):e87–97.
- 18 Brochard L, Abroug F, Brenner M, Broccard AF, Danner RL, Ferrer M, et al. An official ATS/ERS/ESICM/SCCM/SRLF statement: prevention and management of acute renal failure in the ICU patient: an international consensus conference in intensive care medicine. *Am J Respir Crit Care Med.* 2010 May 15; 181(10): 1128–55.
- 19 Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO clinical practice guideline for acute kidney injury. *Kidney Int.* 2012; 2(Suppl): 1–138.
- 20 Vinsonneau C, Allain-Launay E, Blayau C, Darmon M, Ducheyron D, Gaillot T, et al. Renal replacement therapy in adult and pediatric intensive care: recommendations by an expert panel from the French Intensive Care Society (SRLF) with the French Society of Anesthesia Intensive Care (SFAR) French Group for Pediatric Intensive Care Emergencies (GFRUP) the French Dialysis Society (SFD). *Ann Intensive Care.* 2015 Dec; 5(1): 58.
- 21 Ahmed AR, Obilana A, Lappin D. Renal replacement therapy in the critical care setting. *Crit Care Res Pract.* 2019; 2019: 6948710.
- 22 Gaudry S, Hajage D, Schortgen F, Martin- Lefevre L, Pons B, Boulet E, et al. Initiation strategies for renal-replacement therapy in the intensive care unit. *N Engl J Med.* 2016 Jul 14; 375(2): 122–33.
- 23 Zarbock A, Kellum JA, Schmidt C, Van Aken H, Wempe C, Pavenstädt H, et al. Effect of early vs delayed initiation of renal replacement therapy on mortality in critically ill patients with acute kidney injury: the ELAIN randomized clinical trial. *JAMA.* 2016 May 24–31; 315(20): 2190–9.
- 24 Barbar SD, Clere-Jehl R, Bourredjem A, Hernu R, Montini F, Bruyère R, et al. Timing of renal-replacement therapy in patients with acute kidney injury and sepsis. *N Engl J Med.* 2018 Oct 11; 379(15): 1431–42.

- 25 Gaudry S, Hajage D, Benichou N, Chaïbi K, Barbar S, Zarbock A, et al. Delayed versus early initiation of renal replacement therapy for severe acute kidney injury: a systematic review and individual patient data meta-analysis of randomised clinical trials. *Lancet*. 2020 May 9; 395(10235): 1506–15.
- 26 STARRT-AKI Investigators, Canadian Critical Care Trials Group, Australian and New Zealand Intensive Care Society Clinical Trials Group, United Kingdom Critical Care Research Group, Canadian Nephrology Trials Network, Irish Critical Care Trials Group; Bagshaw SM, Wald R, Adhikari NKJ, Bellomo R, da Costa BR, Dreyfuss D, et al. Timing of initiation of renal-replacement therapy in acute kidney injury. *N Engl J Med*. 2020 Jul 16; 383(3): 240–51.
- 27 Thakar CV, Rousseau J, Leonard AC. Timing of dialysis initiation in AKI in ICU: international survey. *Crit Care*. 2012 Dec 19; 16(6): R237.
- 28 Seabra VF, Balk EM, Liangos O, Sosa MA, Cendoroglo M, Jaber BL. Timing of renal replacement therapy initiation in acute renal failure: a meta-analysis. *Am J Kidney Dis*. 2008 Aug; 52(2): 272–84.
- 29 Karvellas CJ, Farhat MR, Sajjad I, Mogensen SS, Leung AA, Wald R, et al. 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*. 2011; 15(1): R72.
- 30 Wang X, Jie Yuan W. Timing of initiation of renal replacement therapy in acute kidney injury: a systematic review and meta-analysis. *Ren Fail*. 2012; 34(3): 396–402.
- 31 Gaudry S, Hajage D, Martin-Lefevre L, Louis G, Moschietto S, Titeca-Beauport D, et al. The artificial kidney initiation in kidney injury 2 (AKIKI2): study protocol for a randomized controlled trial. *Trials*. 2019 Dec 16; 20(1): 726.
- 32 Staubach KH, Rau HG, Kooistra A, Schardey HM, Hohlbach G, Schilberg FW. Can hemofiltration increase survival time in acute endotoxemia – a porcine shock model. *Prog Clin Biol Res*. 1989; 308: 821–6.
- 33 Rimmelé T, Assadi A, Cattenoz M, Desebbe O, Lambert C, Boselli E, et al. High-volume haemofiltration with a new haemofiltration membrane having enhanced adsorption properties in septic pigs. *Nephrol Dial Transplant*. 2009 Feb; 24(2): 421–7.
- 34 Payen D, Mateo J, Cavaillon JM, Fraisse F, Floriot C, Vicaut E, et al. Impact of continuous venovenous hemofiltration on organ failure during the early phase of severe sepsis: a randomized controlled trial. *Crit Care Med*. 2009 Mar; 37(3): 803–10.
- 35 Joannes-Boyau O, Honoré PM, Perez P, Bagshaw SM, Grand H, Canivet JL, et al. High-volume versus standard-volume haemofiltration for septic shock patients with acute kidney injury (IVOIRE study): a multicentre randomized controlled trial. *Intensive Care Med*. 2013 Sep; 39(9): 1535–46.
- 36 Quenot JP, Binquet C, Vinsonneau C, Barbar SD, Vinault S, Deckert V, et al. Very high volume hemofiltration with the Cascade system in septic shock patients. *Intensive Care Med*. 2015 Dec; 41(12): 2111–20.

- 37 Vinsonneau C, Camus C, Combes A, Costa de Beauregard MA, Klouche K, Boulain T, et al. Continuous venovenous haemodiafiltration versus intermittent haemodialysis for acute renal failure in patients with multiple-organ dysfunction syndrome: a multicentre randomised trial. *Lancet*. 2006 Jul 29; 368(9533): 379–85.
- 38 Rabindranath K, Adams J, Macleod AM, Muirhead N. Intermittent versus continuous renal replacement therapy for acute renal failure in adults. *Cochrane Database Syst Rev*. 2007 Jul 18; (3): CD003773.
- 39 Bagshaw SM, Berthiaume LR, Delaney A, Bellomo R. Continuous versus intermittent renal replacement therapy for critically ill patients with acute kidney injury: a meta-analysis. *Crit Care Med*. 2008 Feb; 36(2): 610–7.
- 40 Bell M, Swing, Granath F, Schön S, Ekblom A, Martling CR. Continuous renal replacement therapy is associated with less chronic renal failure than intermittent haemodialysis after acute renal failure. *Intensive Care Med*. 2007 May; 33(5): 773–80.
- 41 Schneider AG, Bellomo R, Bagshaw SM, Glassford NJ, Lo S, Jun M, et al. Choice of renal replacement therapy modality and dialysis dependence after acute kidney injury: a systematic review and meta-analysis. *Intensive Care Med*. 2013 Jun; 39(6): 987–97.
- 42 Schiffh H, Lang SM, Fischer R. Daily hemodialysis and the outcome of acute renal failure. *N Engl J Med*. 2002 Jan 31; 346(5): 305–10.
- 43 VA/NIH Acute Renal Failure Trial Network; Palevsky PM, Palevsky PM, Zhang JH, O'Connor TZ, Chertow GM, Crowley ST, et al. Intensity of renal support in critically ill patients with acute kidney injury. *N Engl J Med*. 2008 Jul 3; 359(1): 7–20.
- 44 Faulhaber-Walter R, Hafer C, Jahr N, Vahlbruch J, Hoy L, Haller H, et al. The Hannover dialysis outcome study: comparison of standard versus intensified extended dialysis for treatment of patients with acute kidney injury in the intensive care unit. *Nephrol Dial Transplant*. 2009 Jul; 24(7): 2179–86.
- 45 Investigators RRTS, Bellomo R, Cass A, Cole L, Finfer S, Gallagher M, et al. Intensity of continuous renal-replacement therapy in critically ill patients. *N Engl J Med*. 2009 Oct 22; 361(17): 1627–38.
- 46 Parienti JJ, Thirion M, Mégarbane B, Souweine B, Ouchikhe A, Polito A, et al. Femoral vs jugular venous catheterization and risk of nosocomial events in adults requiring acute renal replacement therapy: a randomized controlled trial. *JAMA*. 2008 May 28; 299(20): 2413–22.
- 47 Hermite L, Quenot JP, Nadji A, Barbar SD, Charles PE, Hamet M, et al. Sodium citrate versus saline catheter locks for non-tunneled hemodialysis central venous catheters in critically ill adults: a randomized controlled trial. *Intensive Care Med*. 2012 Feb; 38(2): 279–85.

- 48 Parienti JJ, Deryckère S, Mégarbane B, Valette X, Seguin A, Sauneuf B, et al. Quasi-experimental study of sodium citrate locks and the risk of acute hemodialysis catheter infection among critically ill patients. *Antimicrob Agents Chemother*. 2014 Oct; 58(10): 5666–72.
- 49 Quenot JP, Helms J, Bourredjem A, Dargent A, Meziani F, Badie J, et al. Trisodium citrate 4% versus heparin as a catheter lock for nontunneled hemodialysis catheters in critically ill patients: a multicenter, randomized clinical trial. *Ann Intensive Care*. 2019 Jul 1; 9(1): 75.
- 50 Bovet J, Soudry-Faure A, Merdji H, Ksiazek E, Quenot JP, Meziani F, et al. Evaluation of anti-Xa activity after injection of a heparin lock for dialysis catheters in intensive care: a prospective observational study. *Thromb Res*. 2020 Apr; 188: 82–4.
- 51 Hetzel GR, Schmitz M, Wissing H, Ries W, Schott G, Heering PJ, et al. Regional citrate versus systemic heparin for anticoagulation in critically ill patients on continuous venovenous haemofiltration: a prospective randomized multicentre trial. *Nephrol Dial Transplant*. 2011 Jan; 26(1): 232–9.
- 52 Wu MY, Hsu YH, Bai CH, Lin YF, Wu CH, Tam KW. Regional citrate versus heparin anticoagulation for continuous renal replacement therapy: a meta-analysis of randomized controlled trials. *Am J Kidney Dis*. 2012 Jun; 59(6): 810–8.
- 53 Zhang Z, Hongying N. Efficacy and safety of regional citrate anticoagulation in critically ill patients undergoing continuous renal replacement therapy. *Intensive Care Med*. 2012 Jan; 38(1): 20–8.
- 54 Schortgen F, Soubrier N, Delclaux C, Thuong M, Girou E, Brun-Buisson C, et al. Hemodynamic tolerance of intermittent hemodialysis in critically ill patients: usefulness of practice guidelines. *Am J Respir Crit Care Med*. 2000 Jul; 162(1): 197–202.
- 55 Graham P, Lischer E. Nursing issues in renal replacement therapy: organization, manpower assessment, competency evaluation and quality improvement processes. *Semin Dial*. 2011 Mar–Apr; 24(2): 183–7.
- 56 Beloucif S, Payen D. 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*. 1998 Aug; 24(8): 864–77.
- 57 Cannesson M, Pestel G, Ricks C, Hoeft A, Perel A. Hemodynamic monitoring and management in patients undergoing high risk surgery: a survey among North American and European anesthesiologists. *Crit Care*. 2011 Aug 15; 15(4): R197.