Original Article

Management of renal replacement therapy among adults in French intensive care units: A bedside practice evaluation

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A B S T R A C T

Background: This study aimed to investigate renal replacement therapy (RRT) practices in a representative nationwide sample of French intensive care units (ICUs).

Methods: From July 1 to October 5 2021, 67 French ICUs provided data regarding their ICU and RRT implementation. We used an online questionnaire to record general data about each participating ICU, including the type of hospital, number of beds, staff ratios, and RRT implementation. Each center then prospectively recorded RRT parameters from 5 consecutive acute kidney injury (AKI) patients, namely the indication, type of dialysis catheter used, type of catheter lock used, type of RRT (continuous or intermittent), the RRT parameters initially prescribed (dose, blood flow, and duration), and the anticoagulant agent used for the circuit.

Results: A total of 303 patients from 67 ICUs were analyzed. Main indications for RRT were oligo-anuria (57.4%), metabolic acidosis (52.1%), and increased plasma urea levels (47.9%). The commonest insertion site was the right internal jugular (45.2%). In 71.0% of cases, the dialysis catheter was inserted by a resident. Ultrasound guidance was used in 97.0% and isovolumic connection in 90.1%. Citrate, unfractionated heparin, and saline were used as catheter locks in 46.9%, 24.1%, and 21.1% of cases, respectively.

Conclusions: Practices in French ICUs are largely compliant with current national guidelines and international literature. The findings should be interpreted in light of the limitations inherent to this type of study.

Introduction

Acute kidney injury (AKI) affects 30–60% of patients admitted to the intensive care unit (ICU) and is associated with increased morbidity and mortality, with one quarter of AKI patients requiring renal replacement therapy (RRT).[1] Numerous studies have investigated the optimal time for RRT initiation and compared the different RRT techniques available in the ICU. However, actual practices at the bedside remain heterogeneous and warrant further study. Indeed, most reports about RRT use in routine ICU practice are based on self-reported questionnaires distributed by post or email, with low response rates or estimated responses.[2–4] As a result, there was significant potential for bias in those studies resulting from a lack of representativeness and generalizability with a mismatch between physicians' declarations (no doubt, believed to be ideal) and real-life bedside practices. Similarly, other surveys of practices have only investigated specific aspects of RRT, such as the type of technique used[5–7] or net ultrafiltration prescribed.[8,9] Although the ongoing progress in managing

AKI patients requiring RRT is quickly captured in the scientific literature[10] and clinical practice guidelines,[11] this is not always immediately translated into the daily practice of ICU physicians, partly due to the wide heterogeneity in observed practices.[5,12] This heterogeneity may also be explained by the fact that international recommendations only partially address the question of RRT and were developed >10 years ago.[13,14]

In France, national guidelines for RRT in the ICU were published in 2015.[15] A recent survey of practices using an online self-reported questionnaire found a good level of reported compliance with these recommendations.[16] In view of the limitations of previous studies and online self-report questionnaires, there is a compelling need to observe and report real-life bedside practices in managing patients with RRT using a large-scale, representative and nationwide sample of hospitals with ICUs of varying sizes and specificity. Therefore, this study aimed to perform a practice evaluation to describe real-life RRT practices at the patient's bedside in French ICUs.

Methods

Participating centers

The READIAL study was performed from July 1 to October 5 2021, in France. All 80 ICUs that participated in the previous DIAM study[16] were contacted again by email with an invitation to participate in the present READIAL study. ICUs that accepted to participate were sent a unique identifier to access an initial online questionnaire (using the LimeSurvey platform), which collected general data on their ICU (e.g., the type of hospital [private, public, academic, and non-academic], number of beds, physician-to-bed ratio, and nurse-to-bed ratio); characteristics of staff responsible for implementing RRT (physician's department and number of years of experience); and the conditions in which RRT is implemented (presence of a reference person trained in RRT, a department protocol or procedure for RRT management, type of equipment available, and conditions of use).

RRT data recorded

After completing the online questionnaire, each participating ICU was requested to designate a lead investigator responsible for using the CleanWeb platform to prospectively record data on 5 consecutive patients with AKI requiring a first RRT session in the ICU. The data recorded were the indication, type of dialysis catheter used, type of catheter lock used, type of RRT (continuous or intermittent), the RRT parameters initially prescribed (dose, blood flow, and duration), and the anticoagulant agent used for the circuit. The questions for this part of the study were developed based on existing national guidelines for all these points[15] and were tested by a panel of ICU physicians at the bedside to guarantee applicability and relevance. The study questionnaire is in the Supplementary material.

Data management

Data collection was protected by the use of unique codes for each investigator. Individual patient data was rendered anonymous by using a code comprising the participating center number and a number from 1 to 5 (for the 5 consecutive patients) corresponding to the order of patient inclusion. For some questions, the investigators could choose several options, explaining why the total exceeds 100% for these questions. The clinical investigation center of our hospital was responsible for data management (certified ISO 9001 V2015).

Ethical considerations

According to French legislation, no individual patient consent was required as no personal patient data were recorded. Only technical data relating to the RRT procedure were recorded to be compared with recommended practices.[15] Each participating ICU was informed about the objectives and procedures for the study, and their agreement to participate was inferred from the fact that they voluntarily connected to the study questionnaires and provided the study information.

Results

Of the 80 ICUs contacted, 67 (83.8%) accepted to participate in the READIAL study. In total, 303 patients were included and analyzed. Fifty-five centers included 5 consecutive patients, while 12 centers included between 1 and 4 patients. The characteristics of the participating centers are described in Table 1.

Among the participating centers, there was an existing reference physician in 74.6% of centers and a reference paramedical staff member in 92.5% of centers. In addition, 82.1% of participating centers had a departmental protocol for managing the connection and disconnection of the RRT circuit and monitoring alarms. Intermittent RRT and continuous RRT were available 24 hours×7 days in 77.6% and 92.5% of the centers, respectively.

Figure 1 presents the main indications for initiating RRT. The most common indications for RRT were oligo-anuria (57.4%), metabolic acidosis (52.1%), and an increase in plasma urea levels (47.9%). Of note, patients could have multiple indications for initiating RRT. Among the 295 patients who received a RRT catheter, the most common insertion site was the right internal jugular approach (45.2%). Other insertion sites included the femoral veins (49.2%), left internal jugular vein (5.1%), and

Table 1

Characteristics of participating insitutions and ICUs (*n*=67).

Characteristics	Data
Type of hospital	
University hospital	29 (45.3)
Public non-university hospital	33 (51.6)
Private non-university hospital	2 (3.1)
Type of ICU	
Medical	30 (44.8)
Surgical	3 (4.5)
Mixed	34 (50.7)
Beds in ICU	15.6 ± 7.7
Total admissions in 2019	712.1 ± 323.8
Number of full-time physicians	7.3 ± 2.6
Number of full-time nurses	42.4 ± 14.9
Patients/attending nurse ratio	2.7 ± 0.4
Number of patients treated by intermittent RRT in 2019*	86.2 ± 124.5
Number of intermittent RRT sessions in 2019*	333.1 ± 322.7
Number of patients treated by continuous RRT in 2019*	57.6 ± 69.7
Number of continuous RRT sessions in 2019*	223.5 ± 233.7

Data are expressed as *n* (%) or Mean±standard deviation.
ICU: intensive care unit; RRT: Renal replacement therapy.
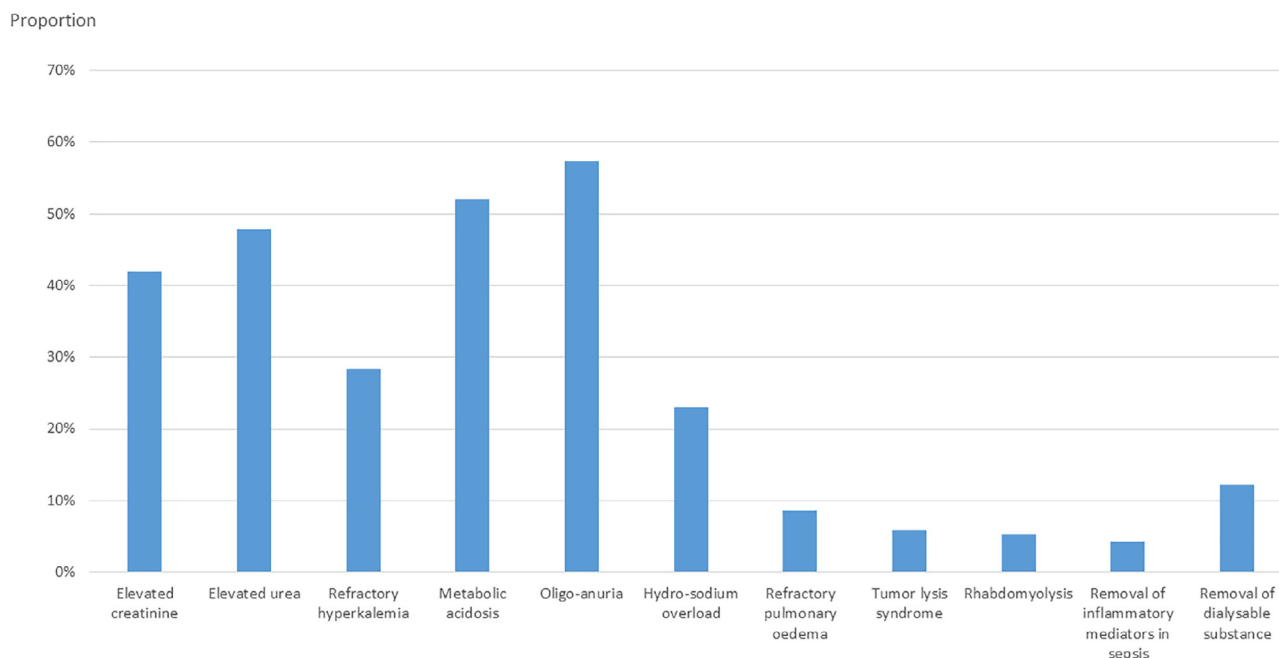* Mean per center.

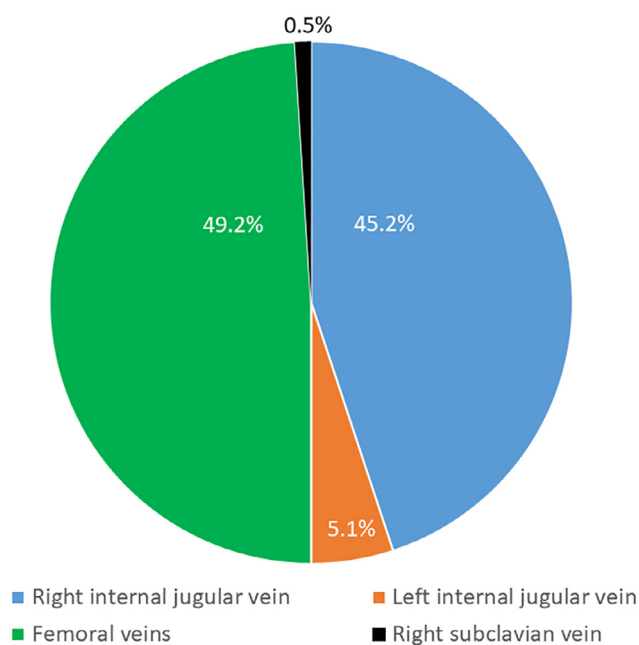**Figure 1.** Main indications for initiating renal replacement therapy.

Figure 2. Insertion sites of the first hemodialysis catheter for initiation of renal replacement therapy.

right subclavian vein (0.5%) (Figure 2). The use of an approach other than the right internal jugular was chiefly due to limited possibilities for using alternative approaches (Figure 3).

In the vast majority of cases (95.0%), double-lumen catheters were used, of which 81.9% had a diameter of 12 French or more. Catheters shorter than 24 cm were predominant (89.0%) when the insertion site was the internal jugular veins (right or left), while catheters 24 cm or longer were used for the femoral vein (95.0%). The specific characteristics of the catheters are detailed in Figure 4. Coaxial catheters seem to be most commonly used

(26.4%), most often with a shotgun tip (45.7%). A resident inserted the dialysis catheter in 71.0% of the cases, and ultrasound was used to identify landmarks or guide insertion in almost all cases (97.0%). The insertion of the catheter without ultrasound guidance was justified by the experience of the operator.

An isovolumic connection was used in 90.1% of cases and immediately after catheter insertion in 70.0% of cases. Two nurses connected the circuit in 43.6% of cases, one nurse in 30.4%, a nurse with a physician in 21.6%, and a nurse with a nurse's aide in 4.4%.

Citrate, unfractionated heparin, and saline 0.9% were the catheter locks used in 46.9%, 24.1%, and 21.1% of cases, respectively. An antibiotic catheter lock was used in 3.4% and ethanol in 1.7% of cases.

Intermittent RRT was administered to 50.2% of cases during the first session. In most cases, the physician considered this technique to be the most suited for the indication (71.7%) and patient characteristics (30.3%). However, in 15.1% of patients, intermittent RRT was chosen by default in the absence of access to continuous RRT. The mean duration, blood flow, and dialyzate flow of intermittent RRT sessions were 4.5 ± 2.5 h, 241.6 ± 39.0 mL/min, and 469.5 ± 127.8 mL/min, respectively. In addition, the mean ultrafiltration volume during the sessions was 438.0 ± 241.3 mL/h, with a mean circuit temperature of 36.0 ± 0.8 °C.

Regarding anticoagulation in intermittent RRT, 33 patients (21.7%) received curative systemic anticoagulation. Unfractionated heparin (81.8%) was the most commonly used anticoagulant and was administered intravenously, by an electric syringe pump, or subcutaneously. In addition, 6 patients received oral anticoagulation with vitamin K antagonists or direct oral anticoagulants. In total, 111 (73.0%) patients received anticoagulation during RRT sessions. Low-molecular-weight heparin was commonly used (80.2%), while unfractionated heparin (15.3%) or citrate-containing dialyzate was less common. In contrast,
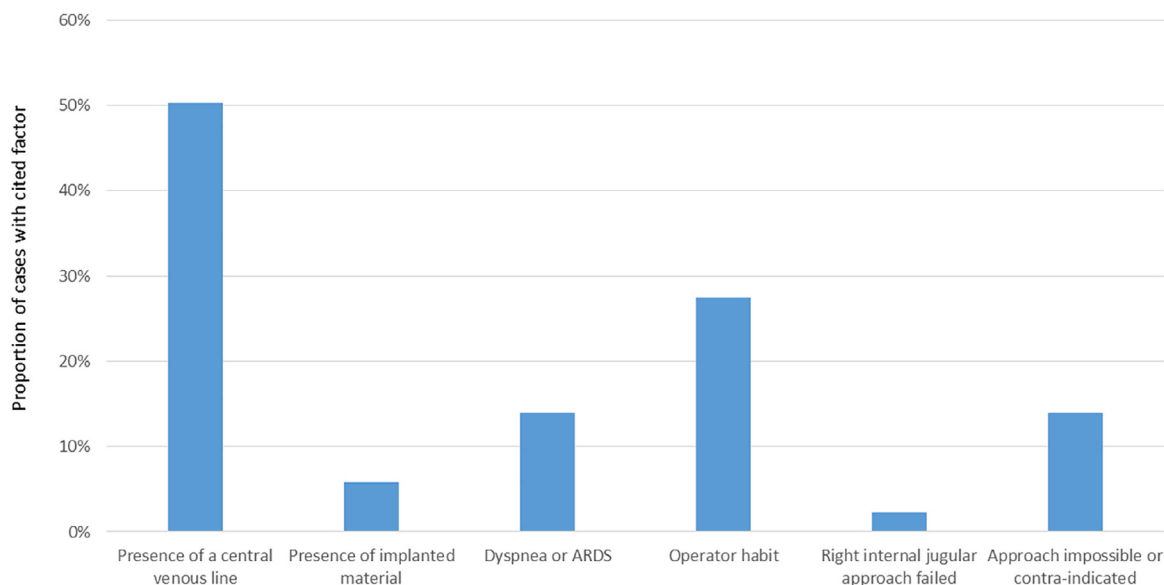
Figure 3. Factors explaining the insertion of the hemodialysis catheter via an approach other than the right internal jugular. ARDS: Acute respiratory distress syndrome.
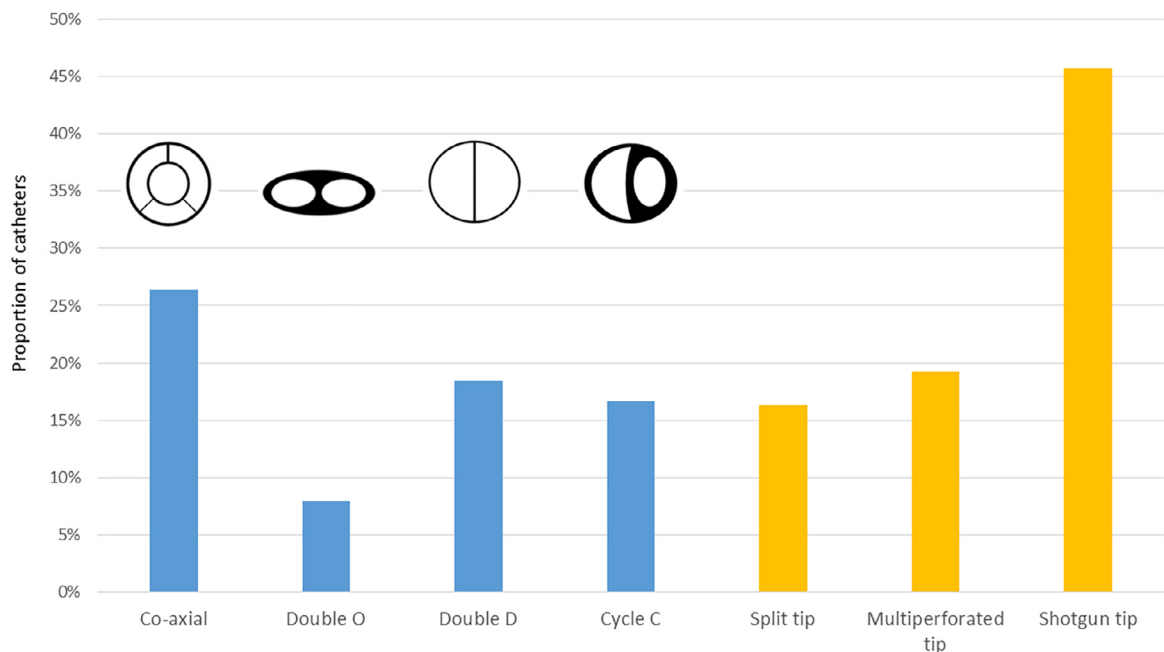

Figure 4. Characteristics of the catheters used for renal replacement therapy.

no anticoagulation was used in 10.7% of intermittent RRT sessions because the physician estimated a significantly high risk of bleeding. In patients who did not receive anticoagulant, 37.5% had intermittent rinsing of the circuit.

Continuous RRT was administered to 49.8% of cases during the first session. The most commonly used form was continuous veno-venous hemofiltration (51.3%), followed by continuous veno-venous hemodialysis (31.8%) and continuous veno-venous hemodiafiltration (16.9%). The physician considered the chosen technique to be best suited for patient characteristics (47.7%) and best mastered by the medical (45.6%) and paramedical team (39.6%). Finally, this technique was chosen by default in 10.0% of patients due to a lack of access to intermittent RRT. The main characteristics of the continuous RRT sessions were reported to be as follows: mean blood flow of 171.5 ± 56.2 mL/min; mean dialyzate flow of 2054.3 ± 902.7 mL/min; mean effluent flow of 2442 ± 824 mL/h; mean ultrafiltration flow of 119.2 ± 77.5 mL/h; and mean circuit temperature of 37.9 ± 2.2 °C.

Forty-two patients (28.6%) received curative systemic anticoagulation at the initiation of continuous RRT. Unfractionated heparin was administered in 85.7% of cases, which was connected directly to the circuit in a third of cases. Ninety-two patients (62.2%) had specific anticoagulation of the circuit with citrate (63.7%), unfractionated heparin (35.2%), and heparin-

protamine sulfate in one case. In contrast, 27 patients (18.9%) had no anticoagulation owing to an elevated risk of bleeding in 85.2% of cases. Two of the patients who did not receive anticoagulants had intermittent rinsing of the circuit. The characteristics of the sessions and anticoagulation according to the type of RRT (intermittent and continuous) are detailed in Table 2.

Discussion

The READIAL study highlights two types of practice gaps: first, the mismatch between the practices declared by physicians in the prior DIAM study[16] and, second, the gap between actual practices at the bedside and national guidelines[15] or the latest international publications on the use of RRT in the ICU.[10,11] This type of study is of paramount importance for evaluating the uptake of guidelines developed by experts and professional societies, whatever the setting. It enables the assessment of how well ICU physicians have integrated the latest developments in their field, as published in the scientific literature, into their management of patients in daily practice. In this regard, the READIAL study is the first to be performed in France using this methodology.

In this study, oligo-anuria was the main motive for initiating RRT in the ICU. This could be because most ICU patients who develop AKI and need RRT have septic shock.[17] Septic shock is responsible for circulatory failure, characterized by arterial hypotension with signs of tissue hypoperfusion, ultimately leading to major kidney dysfunction; the first sign of this is a sudden and substantial drop in glomerular filtration.[14] Initiation of RRT in case of oligo-anuria and hydro-sodium overload may be indicated in this context and most often occurs outside the context of a metabolic emergency (noticeable hyperkalaemia or treatment-resistant metabolic acidosis) or clinical emergency (refractory pulmonary edema); although, both these situations were cited as frequent indications in our study. Nevertheless, initiation of RRT may have been decided by the participants based on de-

velopments in their clinical situation or biological parameters, outside of any emergency initiation criteria.

Similar to findings from the DIAM study, elevated plasma urea level was another key indication for RRT initiation in this study.[16] A "wait and see" approach to initiating RRT in the ICU in patients with AKI was purported to be safe, as long as the emergency criteria mandating immediate RRT were respected,[18] with a reduction in the frequency of RRT use with the watchful waiting strategy.[19,20] The more recent AKIKI 2 study,[21] which evaluated the interest of delaying RRT initiation in patients with KDIGO stage 3 and no emergency RRT criterion, reported an increased risk of death with the more-delayed *vs.* the delayed strategy in multivariate analysis (hazard ratio for death at 60 days 1.65, 95% confidence interval: 1.09–2.50, *P*=0.018).

The exception to the waiting strategy is the study published by Zarbock et al.,[22] in which a significant reduction in mortality was observed in the early initiation group. However, criticisms were leveled about the population of this study, including post-cardiac surgery patients, with a theoretical indication for RRT due to pulmonary congestion. In contrast, older surveys of practices found that physicians in Europe[12] and the United States[23] tended to initiate RRT earlier, undoubtedly influenced by several meta-analyses performed several years ago.[24–26]

Using "care bundles" including biomarkers may help stratify patients at risk of developing AKI, thereby reducing the frequency of AKI and the subsequent need for RRT. However, no effect on mortality has been demonstrated to date.[27,28] Conversely, Mendu et al.[29] reported that using an algorithm to guide ICU physicians in deciding when to initiate or interrupt RRT was associated with lower in-hospital mortality. According to this study, RRT no longer appears to be initiated to maintain "inflammatory homeostasis", which is in line with the literature[30–32] and results of the previous DIAM study.[16]

Regarding the criteria for the choice of RRT technique, we observed equal rates of use of intermittent and continuous techniques. The reasons cited by the respondents for using one or other of these techniques are quite pragmatic. Indeed, physicians tend to choose the technique best suited to the patient's characteristics and the indication for RRT. In the DIAM study,[16] respondents reported a clear preference for continuous RRT to ensure better fluid management, especially in hemodynamically unstable patients. French guidelines[15] and published literature[33–36] do not reach a clear consensus regarding the superiority of one technique over the other and recommend that the best technique is the one that is available and best mastered by the clinical team. In this context, both techniques may be used indiscriminately, taking into account the local availability of resources and the experience of the medical team caring for the patient.[33] There are conflicting results regarding renal function recovery according to the type of RRT used,[37,38] although recently published multicenter randomized controlled trials have shown no significant difference between techniques.[39,40] In addition, the choice of RRT technique may also be dictated by familiarity and proficiency with the technique. Indeed, there may be no designated reference person or expert in RRT in the ICU, or staff may suffer from a lack of training, particularly for continuous RRT. In France, there is a tendency to work closely with nephrologists specialized in in-

Table 2

Characteristics of the sessions and anticoagulation therapy according to the type of RRT (intermittent *vs.* continuous).

Characteristics	Intermittent RRT (*n*=152)	Continuous RRT (*n*=151)
Session characteristics		
Blood flow (mL/min)	241.6 ± 39.0	171.1 ± 56.2
Dialyzate flow (mL/min)	469.5 ± 127.8	2054.3 ± 902.7
Net ultrafiltration (mL/h)	438.0 ± 241.3	119.2 ± 77.5
Circuit temperature (°C)	36.0 ± 0.8	37.9 ± 2.2
Anticoagulation		
Curative systemic anticoagulation	33 (21.7)	42 (28.6)
Unfractionated heparin	27 (81.8)	36 (85.7)
Low molecular weight heparin	0	3 (7.1)
Other	6 (18.2)	3 (7.1)
Specific circuit anticoagulation	111 (73.0)	92 (62.2)
Unfractionated heparin	17 (15.3)	32 (35.2)
Low molecular weight heparin	89 (80.2)	0 (0)
Citrate	5 (4.5)	58 (63.7)
Heparin – protamine sulfate	0	1 (1.1)
No anticoagulation	16 (10.7)	27 (18.9)
High risk of hemorrhage	8 (50.0)	23 (85.2)
Recent hemorrhage	4 (25.0)	2 (7.4)
Other (coagulation disorder)	4 (25.0)	2 (7.4)

Data are expressed as *n* (%) or Mean±standard deviation.
RRT: Renal replacement therapy; SD: Standard deviation.

termittent techniques for managing patients with chronic renal insufficiency. There are usually mandatory training sessions in a dialysis center to gain proficiency in implementing the intermittent technique, but this is less common for continuous RRT. This may be reflected in daily practice.

We found that regardless of the RRT technique chosen, the parameters reported by the respondents are in line with French recommendations,[15] most likely because these guidelines are based on a solid body of evidence in the literature.[41,42] The dialysis circuits are connected by two members of the caregiving team in the majority of cases, as recommended by the guidelines.[15] In addition, isovolumic connections were used, enabling better hemodynamic tolerance when the circuit starts to function.[43] Furthermore, the average temperature was about 2 °C lower during intermittent RRT, with frequent use of a high sodium concentration in the dialyzate to ensure optimal hemodynamic tolerance.[43]

Results concerning the insertion site of the RRT catheter and the use of ultrasound guidance are also in line with recommendations. Similarly, there was high compliance to the catheter size, i.e., >12 French, and length adapted to the insertion site to limit recirculation.[15] The preferential use of citrate as a catheter lock solution (around 50% of cases) in this study is likely related to its innocuousness compared with heparin, which can affect hemostatics parameters and increase the risk of bleeding.[44,45] However, it should be noted that there are no clear recommendations or data on the most appropriate type of catheter lock or whether citrate is superior to other lock solutions.[46,47]

In this study, anticoagulation of the RRT circuits was performed in accordance with the guidelines, notably regarding contra-indications of certain treatments. In line with published data, citrate was preferentially used in continuous RRT in the absence of systemic anticoagulation to prolong the duration of the filter.[48–50] Our study also highlights the efforts that have been made in practice over the last few years to improve the level of training among caregiving staff (physicians and nurses) and to prepare and implement written procedures, which are generally accompanied by a significant reduction in complications during the initiation of RRT in the ICU.[43,51]

This study has several strengths. The participation of centers with heterogeneous volumes of activity and levels of expertise, thus improving the representativeness of practices nationwide. In addition, data were collected prospectively and consecutively by the investigators in each center, ensuring an accurate representation of real-life practices. Nevertheless, our study has some limitations. The centers that accepted to participate in this study, as in the previous DIAM study,[16] may have been particularly motivated and interested in RRT practices. In addition, we did not record technical details of the RRT sessions due to potential difficulties related to the different equipment in use across participating ICUs, rendering standardized data collection difficult. Furthermore, some centers did not achieve the target accrual of five consecutive patients; so, the practices may not be generalizable to all units or hospitals. Finally, we did not collect data about the patients (clinical status or outcomes), the dialysis filters, or the substitution fluids.

In terms of perspectives, this study raises interesting avenues for improvement for French ICU doctors to improve compliance with existing guidelines. There is a clear need for more training among medical and paramedical staff on RRT techniques. In addition, it would be helpful to have designated reference persons who can provide advice, as well as written protocols that are regularly updated, in critical care units. Furthermore, there is a need to monitor staff turnover and absenteeism, high workload, and slipshod training of newly appointed staff, which may culminate in situations where practices are at odds with recommendations, thus jeopardizing patient safety. The evaluation of professional practices should be a key part of the physician's profession, with a view to improving the quality of care and the safety of patient management in the ICU. Finally, regular critical appraisal of the literature and participation in formal continuing medical education sessions is essential to maintain staff competencies in this and other areas.

Conclusions

This study collected prospective and consecutive data about real-life RRT bedside practices in 67 ICUs across France. It shows that practices are largely compliant with current national guidelines and the latest international literature. Nonetheless, the findings should be interpreted in light of the limitations inherent to this type of study.

Ethics Statement

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.

Data Availability Statement

All the data collected in this study are summarized and presented in the manuscript. Data are available from the corresponding author on written request.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jointm.2022.10.005.

References

[1] Ronco C, Bellomo R, Kellum JA. Acute kidney injury. Lancet 2019;394(10212):1949–64. doi:10.1016/S0140-6736(19)32563-2.
[2] RENAL Study InvestigatorsRenal replacement therapy for acute kidney injury in Australian and New Zealand intensive care units: a practice survey. Crit Care Resusc 2008;10(3):225–30.
[3] Gatward JJ, Gibbon GJ, Wrathall G, Padkin A. Renal replacement therapy for acute renal failure: a survey of practice in adult intensive care units in the United Kingdom. Anaesthesia 2008;63(9):959–66. doi:10.1111/j.1365-2044.2008.05514.x.
[4] 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. doi:10.1371/journal.pone.0178509.
[5] 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;18(1):222. doi:10.1186/s12882-017-0650-2.
[6] 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. Blood Purif 2019 2018;47(1–3):113–19. doi:10.1159/000493724.
[7] Fealy N, Aitken L, Ed T, Baldwin I. Continuous renal replacement therapy: current practice in Australian and New Zealand intensive care units. Crit Care Resusc 2015;17(2):83–91.
[8] Chen H, Murugan R. Survey of U.S. Critical care practitioners on net ultrafiltration prescription and practice among critically Ill patients receiving kidney replacement therapy. J Crit Care Med (Targu Mures) 2021;7(4):272–82. doi:10.2478/jccm-2021-0034.
[9] 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;48(2):e87–97. doi:10.1097/CCM.0000000000004092.
[10] Pickkers P, Darmon M, Hoste E, Joannidis M, Legrand M, Ostermann M, et al. Acute kidney injury in the critically ill: an updated review on pathophysiology and management. Intensive Care Med 2021;47(8):835–50. doi:10.1007/s00134-021-06454-7.
[11] Evans L, Rhodes A, Alhazzani W, Antonelli M, Coopersmith CM, French C, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021. Intensive Care Med 2021;47(11):1181–247. doi:10.1007/s00134-021-06506-y.
[12] Legrand M, Darmon M, Joannidis M, Payen D. Management of renal replacement therapy in ICU patients: an international survey. Intensive Care Med 2013;39(1):101–8. doi:10.1007/s00134-012-2706-x.
[13] 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;181(10):1128–55. doi:10.1164/rccm.200711-1664ST.
[14] Kidney Disease: improving Global Outcomes (KDIGO) Acute Kidney Injury Work GroupKDIGO clinical practice guideline for acute kidney injury. Kidney Int 2012;2(Suppl):1–138.
[15] 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;5(1):58. doi:10.1186/s13613-015-0093-5.
[16] Quenot JP, Amrouche I, Lefrant JY, Klouche K, Jaber S, Du Cheyron D, et al. Renal replacement therapy for acute kidney injury in french intensive care units: a nationwide survey of practices. Blood Purif 2022;51(8):698–707. doi:10.1159/000518919.
[17] Quenot JP, Binquet C, Kara F, Martinet O, Ganster F, Navellou JC, et al. The epidemiology of septic shock in French intensive care units: the prospective multicenter cohort EPISS study. Crit Care 2013;17(2):R65. doi:10.1186/cc12598.
[18] Ostermann M, Lumlertgul N. Wait and see for acute dialysis: but for how long. Lancet 2021;397(10281):1241–3. doi:10.1016/S0140-6736(21)00466-9.
[19] 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;395(10235):1506–15. doi:10.1016/S0140-6736(20)30531-6.
[20] Bagshaw SM, Wald R, Adhikari N, 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;383(3):240–51. doi:10.1056/NEJMoa2000741.
[21] Gaudry S, Hajage D, Martin-Lefevre L, Lebbah S, Louis G, Moschietto S, et al. Comparison of two delayed strategies for renal replacement therapy initiation for severe acute kidney injury (AKIKI 2): a multicentre, open-label, randomised, controlled trial. Lancet 2021;397(10281):1293–300. doi:10.1016/S0140-6736(21)00350-0.
[22] 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;315(20):2190–9. doi:10.1001/jama.2016.5828.
[23] Thakar CV, Rousseau J, Leonard AC. Timing of dialysis initiation in AKI in ICU: international survey. Crit Care 2012;16(6):R237. doi:10.1186/cc11906.
[24] 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;52(2):272–84. doi:10.1053/j.ajkd.2008.02.371.
[25] 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. doi:10.1186/cc10061.

[26] 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. doi:10.3109/0886022X.2011.647371.

[27] Meersch M, Schmidt C, Hoffmeier A, Van Aken H, Wempe C, Gerss J, et al. Prevention of cardiac surgery-associated AKI by implementing the KDIGO guidelines in high risk patients identified by biomarkers: the PrevAKI randomized controlled trial. Intensive Care Med 2017;43(11):1551–61. doi:10.1007/s00134-016-4670-3.

[28] Göcze I, Jauch D, Götz M, Kennedy P, Jung B, Zeman F, et al. Biomarker-guided intervention to prevent acute kidney injury after major surgery: the Prospective Randomized BigpAK Study. Ann Surg 2018;267(6):1013–20. doi:10.1097/SLA.0000000000002485.

[29] Mendu ML, Ciociolo GR Jr, McLaughlin SR, Graham DA, Ghazinouri R, Parmar S, et al. A decision-making algorithm for initiation and discontinuation of RRT in severe AKI. Clin J Am Soc Nephrol 2017;12(2):228–36. doi:10.2215/CJN.07170716.

[30] 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;37(3):803–10. doi:10.1097/CCM.0b013e3181962316.

[31] 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;39(9):1535–46. doi:10.1007/s00134-013-2967-z.

[32] 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;41(12):2111–20. doi:10.1007/s00134-015-4056-y.

[33] 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;368(9533):379–85. doi:10.1016/S0140-6736(06)69111-3.

[34] 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;36(2):610–17. doi:10.1097/01.CCM.0B013E3181611F552.

[35] 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;3:CD003773. doi:10.1002/14651858.CD003773.pub3.

[36] Fathima N, Kashif T, Janapala RN, Jayaraj JS, Qaseem A. Single-best choice between intermittent versus continuous renal replacement therapy: a review. Cureus 2019;11(9):e5558. doi:10.7759/cureus.5558.

[37] Bell M, Granath F, Schön S, Ekbom 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;33(5):773–80. doi:10.1007/s00134-007-0590-6.

[38] 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;39(6):987–97. doi:10.1007/s00134-013-2864-5.

[39] 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;379(15):1431–42. doi:10.1056/NEJMoa1803213.

[40] 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;375(2):122–33. doi:10.1056/NEJMoa1603017.

[41] Palevsky PM, Zhang JH, O'Connor TZ, Chertow GM, Crowley ST, Choudhury D, et al. Intensity of renal support in critically ill patients with acute kidney injury. N Engl J Med 2008;359(1):7–20. doi:10.1056/NEJMoa0802639.

[42] Bellomo R, Cass A, Cole L, Finfer S, Gallagher M, et al., RENAL Replacement Therapy Study Investigators Intensity of continuous renal-replacement therapy in critically ill patients. N Engl J Med 2009;361(17):1627–38. doi:10.1056/NEJMoa0902413.

[43] 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;162(1):197–202. doi:10.1164/ajrccm.162.1.9907098.

[44] Weijmer MC, van den Dorpel MA, Van de Ven PJ, ter Wee PM, van Geelen JA, Groeneveld JO, et al. Randomized, clinical trial comparison of trisodium citrate 30% and heparin as catheter-locking solution in hemodialysis patients. J Am Soc Nephrol 2005;16(9):2769–77. doi:10.1681/ASN.2004100870.

[45] 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;188:82–4. doi:10.1016/j.thromres.2020.02.006.

[46] Quenot JP, Helms J, Bourredjem A, Dargent A, Meziani F, Badie J, et al. Trisodium citrate 4% versus heparin as a catheter lock for non-tunneled hemodialysis catheters in critically ill patients: a multicenter, randomized clinical trial. Ann Intensive Care 2019;9(1):75. doi:10.1186/s13613-019-0553-4.

[47] Souweine B, Lautrette A, Gruson D, Canet E, Klouche K, Argaud L, et al. Ethanol lock and risk of hemodialysis catheter infection in critically ill patients. A randomized controlled trial. Am J Respir Crit Care Med 2015;191(9):1024–32. doi:10.1164/rccm.201408-1431OC.

[48] 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;26(1):232–9. doi:10.1093/ndt/gfq575.

[49] 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;59(6):810–18. doi:10.1053/j.ajkd.2011.11.030.

[50] Zhang Z, Hongying N. Efficacy and safety of regional citrate anticoagulation in critically ill patients undergoing continuous renal replacement therapy. Intensive Care Med 2012;38(1):20–8. doi:10.1007/s00134-011-2438-3.

[51] Graham P, Lischer E. Nursing issues in renal replacement therapy: organization, manpower assessment, competency evaluation and quality improvement processes. Semin Dial 2011;24(2):183–7. doi:10.1111/j.1525-139X.2011.00835.x.