CURRENT OPINION

Optimizing continuous renal replacement therapy in the ICU: a team strategy

Olivier Joannes-Boyau[a], Lionel Velly[b], and Carole Ichai[c]

Purpose of review
The consideration of acute kidney injury, its incidence and its impact on the outcome of patients has grown continuously in recent years, leading to an increase in the use of renal replacement therapy (RRT) techniques. However, the successful conduct of RRT depends on the effectiveness of the entire team, doctors and nurses. It is therefore important to know the essential elements to be implemented in the ICU to ensure optimal RRT.

Recent findings
Recent studies show that the successful conduct of a RRT session requires a good knowledge of the principles of the technique, regular basic training, identification of experts, drafting clear and well followed protocols and good communication between the various stakeholders. In addition, the use of the latest advances, such as regional citrate anticoagulation, allows further optimization of therapy, only if, again, both physicians and nurses are properly trained and highly involved.

Summary
We now have a better understanding of the measures to be deployed to optimize RRT. Organization, training, evaluation and protocols are the key points of the team's efficiency for a safe and effective implementation of RRT.

Keywords
citrate, continuous renal replacement therapy, education, nurses, performance, protocol, quality, renal replacement therapy, safety, training

INTRODUCTION

The incidence of acute kidney injury (AKI) in critically ill patients still increases, reaching 25–57% and is due to growing number of older and more severe patients with more comorbidities [1]. Moreover, the diagnosis of AKI and its severity is consensual thanks to international classification (Kidney Disease Improving Gloval Outcomes) [2], the emergence of new biomarkers, and the awareness of doctors [3]. Approximately 8–12% of patients presenting AKI receive renal replacement therapy (RRT) [4]. Such a growing utilization was facilitated by a continuous improvement in RRT's machine technology, in terms of ergonomics, and automation. As a consequence, the implementation of RRT is safer and easier allowing to develop more efficient technical approaches such as regional citrate anticoagulation (RCA) [5,6▪▪]. Despite the absence of real difference in terms of mortality, continuous RRT (CRRT) is recommended, especially initially in hemodynamically unstable patients and those at risk of intracranial hypertension [2,7]. Moreover, CRRT might be associated with a better renal function recovery and a lower risk a chronic dialysis need [1,8▪]. Therefore, CRRT is the preferred modality used in at least 70% of critically ill patients [6▪▪,8▪,9].

Despite the large progress in CRRT and international guidelines, a wide variability persists in practice. Obviously, the worldwide development and utilization of CRRT in most ICUs requires urgently to target a quality assurance and control [6▪▪]. Such a

[a]Service d'Anesthésie-Réanimation SUD, Hôpital Magellan, CHU de Bordeaux, Bordeaux, France, [b]Department of Anesthesiology and Critical Care Medicine, Institut de Neuroscience de la Timone (INT), Aix Marseille University, University Hospital La Timone, Marseille, France and [c]Department of Anesthesiology and Critical Care Medicine, Universite Côte d'Azur, CHU de Nice, Hôpital Pasteur 2, Nice, France

Correspondence to Olivier Joannes-Boyau, MD, Service d'Anesthésie-Réanimation SUD, Hôpital Magellan, CHU de Bordeaux, Avenue Magellan, 33600 Pessac, Bordeaux, France. Tel: +33 557656866; e-mail: olivier.joannes-boyau@chu-bordeaux.fr

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KEY POINTS

- The successful completion of a RRT session is extremely dependent on the team's experience and the involvement of physicians and nurses.
- Organization, training, evaluation and protocols are the key points of the team's efficiency.
- The training should be repeated, including basic principles and more advanced concepts. Simulation will probably become the cornerstone of the training program in the future, especially in ICUs with high nurse's turnover.
- RRT experts and champions should be identified and trained to write protocols, provide hands-on training and evaluate the team's performance.
- This complex approach is now encouraged and facilitated by the implementation of platforms addressing the problem of data collection and management with current machines.

goal is only possible thanks to a team strategy in which physicians and nurses fully collaborate and cooperate [10]. Indeed, numerous studies have shown that high-quality CRRT is a major factor that determines both the effectiveness and safety of the technique and is in turn associated with an improved patient's outcome [5,6■■,11■,12]. A special effort is now mandatory to implement a special competent team thanks to comprehensive and practical training, educational programs and management protocols.

QUALITY MEASURES AND CONTROL SYSTEMS OF CONTINUOUS RENAL REPLACEMENT THERAPY

The importance of a well delivered CRRT treatment is not just a matter of economizing equipment or nursing time, but an essential challenge to improve the patient's outcome. Many factors are identified as substantial causes of alterations in CRRT performance: unexpected interruption of treatment, poor management of anticoagulation, of fluid balance or of electrolytes supplementation, bleeding and infectious complications. All of them may generate additional costs, overload of work for both nurses and doctors, and may worsen patient's outcome (longer length of stay in ICU or hospital, persistent renal dysfunction and lower survival) [6■■,10,13■,14].

Recent studies have validated 18 quality indicators for CRRT that are classified into three domains: structure, process and outcome [11■,12,13■]. Quality indicators are mainly related to the performance and complications of CRRT (prescription, delivery and complications of the technique). The most relevant criteria are filter life span, low solute clearance, bleeding, dose delivered and downtime [13■]. The second domain is focused on the structure which includes the human, material and organizational system. The third one is related to the patient's outcome including survival and renal function recovery. It is essential to encourage the team to evaluate regularly the achievement of these parameters. Such a quality control system can be summarized in '6P' CRRT items: Prescription, Provider, Precondition, Purpose, Performance and Prognosis (Table 1) [13■].

Table 1. Quality control system including three domains (structure, process and outcome) based on quality indicators

Quality system: structure			
Quality indicators	Provider Specialized expert team and its assessment Education and training program	Prescription Modality Blood, dialysis, ultrafiltration flows Pre/postdilution Fluid loss Anticoagulation	Precondition Catheter (diameter, site, length) Membrane Machine
Quality system: process			
Quality indicators	Purpose Prevention of patient's complications Fluid overload Hypovolemia Hypotension Bleeding Dialysis catheter-related infection Hypothermia	Performance Delivered & prescribed treatment Filter lifespan Duration and causes of downtime (unplanned interruptions, clotting and clogging) Duration of effective treatment Causes and management of alarms	
Quality system: outcome			
Quality indicators	Prognosis in term of survival and recovery of renal function		

Adapted with permission from [11■].

Creation and implementation of continuous renal replacement therapy protocols

To optimize the performance of CRRT and the patient's outcome, rigorous clinical practice guidelines have been published [2,7]. However, a wide variability in CRRT prescription and delivery persists due to controversies and noncompliance to these recommendations by the ICU teams [8■,15]. Many practical technical aspects are misunderstood and might be easily corrected. For example, in half of the time, the reason for unexpected treatment discontinuation is a catheter dysfunction, which can be due to multiple causes: thrombosis, kinking during movement of the patient or mobilization by the nurses, suction on the wall of the vessel leading to reduce or stop blood flow or to increase filtration fraction and the risk of clogging of the filter. Therefore, the type, diameter, length and site of insertion as well as the management of the catheter are essential. The lifespan and the exchange through the filter can be easily improved by limiting clotting and clogging of the circuit. A poor anticoagulation management increases the risk of bleeding (overdosage) or of clotting (underdosage) resulting in a shorter lifespan of the circuit and creating metabolic disorders especially when using RCA. In recent years, thanks to technological improvement of new devices, RCA has become the first-line technique in most recommendations [2,7]. However, its efficiency requires simultaneous safety rules. Indeed, the implementation of specific protocols (Supplementary material, additional file 1, http://links.lww.com/COCC/A19) associated with education and training of both physicians and nurses are needed to prevent citrate accumulation and overdoses which are responsible for serious metabolic and clinical complications [15]. In continuous venovenous hemofiltration with unfractionated heparin, clogging can be dramatically decreased by maintaining filtration fraction 25% or less. The protocol must include the choice of solution replacement as well as the management of electrolytes supplementation. All of the most frequent technical problems and the way to prevent them are summarized in recent reviews and recommendations [2,6■■,7,15,16,17■].

The negative impact on the patient's outcome can be the consequence of the inability to achieve essential parameters such as the recommended dose of treatment, the fluid and metabolic balances. Again, repeated treatment interruptions will cause a reduction in the exchange delivered compared with those prescribed: a delivered volume of exchange below 20 ml/kg/h might have a negative impact on renal recovery, length of stay and on survival [2,7]. Fluid overload has been also reported to be an independent risk factor of an increased mortality and morbidity [18]. Iterative clotting or clogging of the circuit can be responsible for relevant blood losses and anemia, requiring transfusions with their related risks of infection, immunization or allergy.

Collaborative efforts are needed to draft a protocol by both doctors and nurses to optimize and secure therapy. Despite recommendations applicable to any ICU, an in-house procedure considering local specificities of the team is required with a final validation. Therefore, the best is to develop its appropriate and personalized protocol with a consensual validation of the entire team. Preferably, the protocol should be formalized, attached to each machine and integrated into the dedicated ICU software or computer used by the healthcare professionals. The set-up protocol is now directly included in the software and on the machine screen to guide the nurse or doctor step-by-step. The protocol should also include at least the prescription of CRRT with targets, catheter and alarm management. In addition, the latest machines go even further by providing directly on the screen the possible causes of malfunctions and suggesting ways to correct them. Specific management related to the initiation, the maintenance and the discontinuation of CRRT are included in the protocol too, as well as the device's and patients monitoring must also be included in the protocol. It is essential to identify clearly the role of physicians and nurses, and in which circumstances a physician's assistance is required.

Despite a large experience of CRRT with unfractionated heparin, the growing first-line use of RCA is the best example of the absolute need to formalize an in-home protocol. The therapeutic range of ionized postfilter calcium concentration is narrow (0.3–0.4 mmol/l): a value below this range exposes to a risk of citrate overdose and above it to a risk of filter coagulation. Ionized hypocalcemia for the patient with its severe hemodynamic consequences may occur in case of insufficient calcium supplementation. At last, citrate can accumulate or be overdosed leading to severe metabolic complications. Therefore, RCA requires a protocol with precise prescriptions, adjustments and a close biological monitoring (Supplementary material, additional file 1, http://links.lww.com/COCC/A19) [16].

STAFF TRAINING, EDUCATION AND TEAM PROGRAM

The worldwide development of CRRT in critically ill patients with AKI requires a major effort to upgrade and educate healthcare staff. Due to its beneficial impact on the outcome of patients, on the efficiency (lower down-time, longer filter lifespan) and safety of CRRT (lower bleeding complications and transfusion), the implementation of such a specialized education and training is now recommended [10,14,19▪,20–25]. However, the creation of consistent formal training programs is a complex and time-consuming challenge which remains insufficiently developed [26]. Each team must develop its own program considering the local manpower, the type of patients and the medical choice of techniques. However, all programs must consider mutual goals and require a close collaboration and cooperation of physicians and nurses. The first step consists to educate and train a special CRRT team, that is 'super-users' composed of doctors and nurses with an optimal knowledge and competence for the technique [10,19▪]. The role of this referent team is essential to draft and update protocols and checklists, and to provide teaching for all the staff. Thanks to a special advanced and prolonged education by other experts, these 'super-users' are responsible to organize the training and continuing education program of all the healthcare staff of the ICU. Such a team can be helped by a small number of nurses identified as CRRT 'champions' for initial training. Education requires initially teaching aiming to optimize the operators' knowledge. Variable learning methods can be associated and facilitate teaching: theoretical and didactic courses, on-line learning, demonstrations and hand's on session. The recent development of high-fidelity simulation is a very practical training which confronts the actors to daily scenarios. Indeed, recent studies reported that simulation sessions in association with theoretical courses, increased filter lifespan, reduced unplanned interruptions of CRRT and help requested assistance, leading to improve the quality of cares and the satisfaction of nurses [27,28▪▪] and survival [22]. In addition, CRRT machine manufacturers facilitate the training of the team by giving practical CRRT management related to their devices. The duration of this comprehensive initial training varies among the units from 4 to 50 h. It must cover the set-up of the machine, the troubleshooting skills, the management of catheter, of anticoagulation, of alarms and the setting of the parameters. After the initial training is completed, competences must be maintained by a frequent and regular exposure of the team to the technique and by the organization of regular and repetitive refresher courses and training sessions. At last competences require a regular assessment. This complex approach is now encouraged and facilitated by the implementation of platforms addressing the problem of data collection and management with current CRRT machines [29].

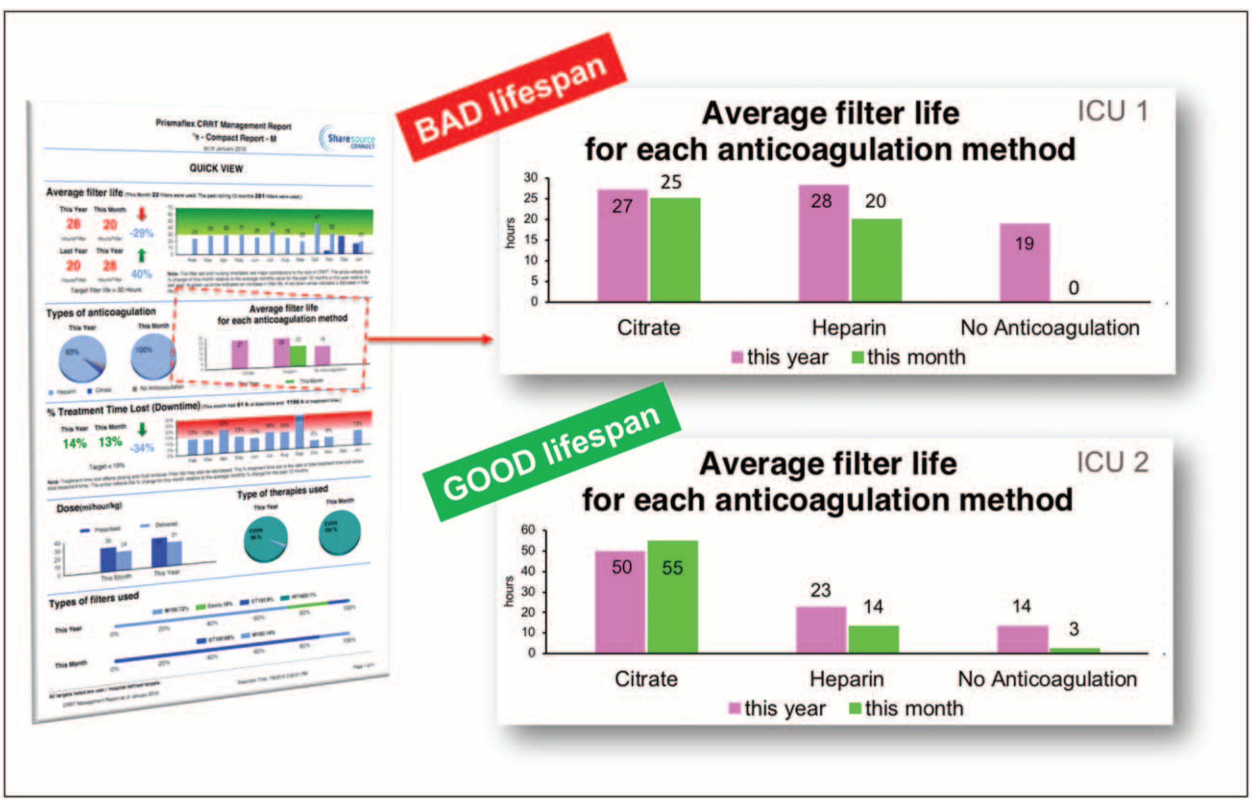

FIGURE 1. Complete evaluation report with a focus on the comparison of two ICUs, one with minimal training and low experience on citrate and the other being well established with this therapy for several years.

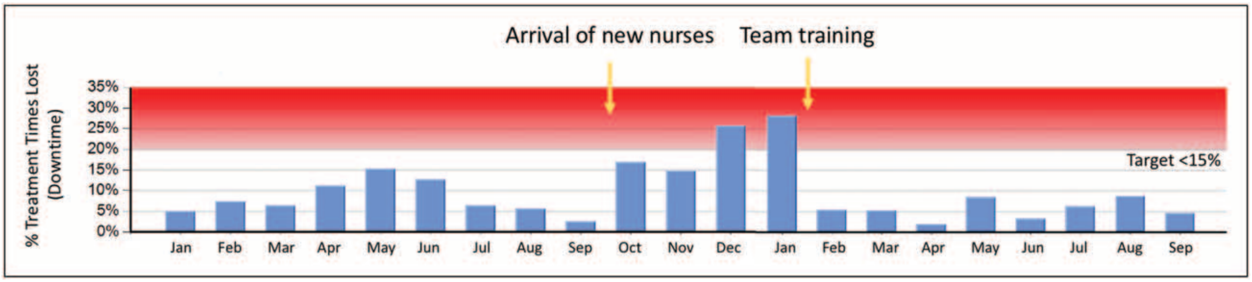

FIGURE 2. Percentage of downtime over several months. There is a significant increase in this downtime with the arrival of new and inexperienced nurses, which only returns to the usual level after training or education sessions.

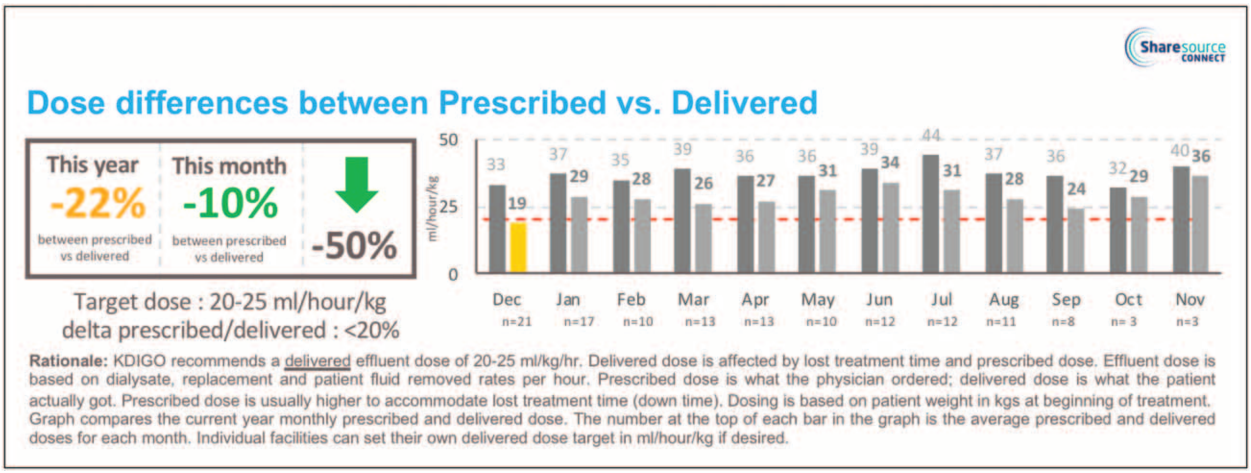

FIGURE 3. Evaluation of the dose delivered to the patient in comparison with the prescribed dose.

Sharesource system (Baxter Healthcare, Deerfield, Illinois, USA) provides connectivity for the Prismaflex CRRT machine and enables both electronic medical records connectivity and therapy analytics. The extraction and collection of numerous parameters of the therapies performed are released as an instructive report which gives the possibility to appreciate the achievement of quality indicators and the persistence of good practices. As an example, Fig. 1 presents the complete evaluation report with a focus on the comparison of two ICUs, one with minimal training and low experience on RCA

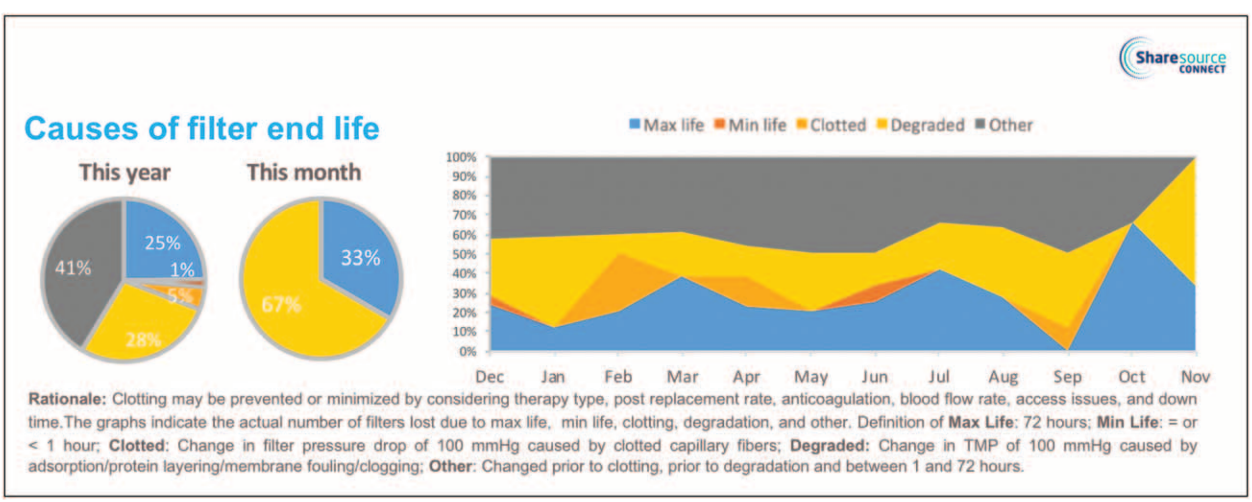

FIGURE 4. Causes of treatment interruptions.

and the other being well established with this anticoagulation for several years, Fig. 2 shows that the percentage of downtime overtime is perfectly linked to the experience of the nursing staff. The percentage of downtime increases rapidly with new inexperienced nurses and return to the previous low level only after training/education sessions. Figure 3 shows the evaluation of the dose delivered to the patient in comparison with the prescribed dose and Fig. 4 lists the causes of treatment interruptions.

Recent CRRT machines also enable to decrease the gap between the delivered and prescribed dose thanks to an automatically compensation (incrementation of the dose of 5% per hour) based on the lost dose during iterative stops. Schläpfer *et al.* [30], have shown that with this system, the delivered dose was 96% of the prescribed one, the best performance reported so far. Other CRRT machines enable to reduce downtime thanks to a strategy that improves the management of alarms and a self-effluent system that avoids stops for emptying the effluent bag [31].

CONCLUSION

Despite recommendations, the practical management of CRRT in ICU remains heterogenous and suboptimal with possible major deleterious effects in terms of survival, renal function recovery and safety of the techniques. Therefore, enormous but still insufficient efforts have been made to provide a high-quality and performance of CRRT in critically ill patients. The first step consisted to identify quality and performance indicators to implement a quality system control. A complex cooperation and collaboration of all the healthcare professionals is needed to achieve an optimal human, material and organizational program. The team strategy is a real challenge which requires to encourage the implementation of a specialized competent team, to create consensual, formalized and personalized protocols, to educate and train both nurses and physicians. Finally, knowledge and performances need to be regularly assessed allowing to maintain within time the optimal practical management of CRRT.

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Conflicts of interest

There are no conflicts of interest.

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