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Renal replacement therapy modalities and techniques in intensive care units: An international survey

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ABSTRACT

Background and hypothesis: Up to 14 % of critically ill patients receive renal replacement therapy (RRT) during their ICU stay and are treated with intermittent hemodialysis (IHD) or one of the continuous renal replacement therapy (CRRT) techniques. The choice of a modality (IHD or CRRT) and technique (continuuous veno-venous -hemodialysis (CVVHD), –hemofiltration (CVVH), or - hemodiafiltration (CVVHDF)), and the way it is

Abbreviations: CRRT, Continuous Renal Replacement Therapy; CVVH, Continuous Veno Venous Hemofiltration; CVVHD, Continuous Veno Venous HemoDialysis; CVVHDF, Continuous Veno Venous HemoDiaFiltration; ICU, Intensive Care Unit; IHD, intermittent hemodialysis; IQR, Interquartile Range; PD, Peritoneal Dialysis; RCA, Regional Citrate Anticoagulation; SLED, Sustained Low Efficiency Dialysis.

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delivered, may have an impact on outcomes but only few studies addressed this question. We aimed to survey the availability, settings, and clinicians' preferences regarding RRT modalities and techniques in critically ill patients.

Methods: Between July 2021 and March 2022, we conducted an open online worldwide survey targeting ICU clinicians and consisting of 31 questions.

Results: Among the 1174 participants from 73 countries, 94 % indicated their ability to initiate RRT at any time. CRRT was more widely available than IHD (97 % vs 85 %). CVVHDF was the most frequently used CRRT technique (59 %), followed by CVVHD (26 %) and CVVH (16 %). Most participants (70 %) reported having access to at least two CRRT techniques in their unit. Preference for IHD or CRRT varied greatly, depending on the clinical situation. Among CRRT techniques, CVVHD was preferred for removal of small-sized molecules, better hemofilter lifespan and reduced nursing workload. The preferential indications for CVVH included septic shock, removal of middle-sized molecules and fluid overload. The technical settings for CVVH and CVVHDF were very heterogeneous.

Conclusion: This international survey underscores the large diversity in RRT practices wordlwide, as well as heterogeneity in beliefs and preferences among intensivists. These data highlight the need for robust comparative trials to identify the optimal RRT modality and technique to improve outcomes in specific clinical situations.

1. Background

Acute kidney injury (AKI) affects up to 75 % of critically ill patients, of whom 20 % receive renal replacement therapy (RRT) [1]. In the long term, AKI is associated with an increased risk of death and survivors have an increased risk of chronic kidney disease (CKD) [2]. These complications are particularly high for patients who received RRT, and some studies suggest that RRT *itself* may affect outcomes and renal recovery [3–5]. Optimization of RRT, including the choice of the modality and its settings, is therefore a priority and might be an opportunity to improve prognosis in patients with severe AKI.

In particular, a longstanding debate continues to highlight the uncertainties around the choice of modality (intermittent hemodialysis (IHD) versus continuous renal replacement therapy (CRRT)) [6,7]. Although the international Kidney Disease Improving Global Outcomes (KDIGO) Guidelines advocated the use of CRRT for hemodynamically unstable patients, the respective indications for these two modalities and how their use can influence outcomes remain unclear [8–10]. When considering CRRT specifically, uncertainty is even greater regarding the different techniques (e.g. mechanisms of solute removal). Ten years ago, convective techniques were most commonly used, accounting for >90 % of CRRT precriptions, either alone (continuous veno-venous hemofiltration - CVVH), or combined with diffusion (continuous veno-venous hemodiafiltration -CVVHDF) [11–13]. Since then, the use of continuous veno-venous hemodialysis (CVVHD) may have increased concomitantly to the increasing application of regional citrate anticoagulation (RCA). Each CRRT technique (CVVH, CVVHD and CVVHDF) has its own advantages and shortcomings and limited quality data suggest they may not be equivalent in terms of solute removal, circuit survival, and workload for healthcare practitioners [14–19]. In addition, techniques that are currently less described in the ICU, such as sustained low-efficiency dialysis (SLED) and peritoneal dialysis (PD), may become more important in the future to meet specific needs (e.g. increased RRT demands during health crisis, optimisation of patient rehabilitation with fluid overload).

The current paucity of comparative data on the effectiveness and impact on outcomes of different RRT modalities/techniques calls for more research. It is within this context that the proposal to do a survey was agreed at the AKI round table meeting of the European Society of Intensive Care Medicine (ESICM) AKI section in 2018 [20]. Our aim was to describe current RRT practices in ICUs worldwide, focusing on the availability of the different modalities and techniques (IHD, CVVH, CVVHD, CVVHDF, SLED and PD), and exploring the beliefs and preferences of clinicians regarding their respective indications, advantages and pitfalls, and the most commonly used technical settings.

2. Methods

2.1. Survey design and dissemination

We performed a survey-based study, addressed to ICU clinicians worldwide. This self-administered survey was open and available online, on the SurveyMonkey® platform, from July 2021 to March 2022. Based on the results of previous international surveys disseminated by ESICM, we planned to include a convenience sample of 800 respondents. This target seemed achievable, representative, and was more ambitious than the previous international survey on RRT practices conducted in ICU [11]. The survey was written in English and preceded by a cover letter presenting the context and indicating the estimated completion time (<15 min). To support participation in China, the survey was translated into Chinese.

Respondents were not able to review and change their answers after completion. Participation was voluntary, anonymous and completion implied consent to participate as specified in the cover letter. No incentives to participate were offered. No personal or patient data were collected. According to the French legislation, approval by an institutional review board was not required.

The survey was endorsed by the ESICM and disseminated to its members via the society's mailing list (70,000 contacts) and social media platforms (including Facebook, Instagram, Twitter and LinkedIn). An invitation to participate was sent in 4 eNewsletters and 3 mass e-mails during the study period and a link to the survey remained available on the ESICM website during the same period.

2.2. Survey development

The survey was developed according to the recommendations by Burns et al. to minimize bias and increase response rate [21]. In particular, the order of questions was carefully planned to reduce biases and respect the hourglass structure. The survey started with easy demographical and descriptive questions (questions 1 to 13). Then, the most critical questions followed (questions 14,15,18,19) and, to minimize response fatigue, easy questions were placed in the middle of those questions (questions 16 and 17). Finally, easier (questions 20 to 26) and less critical items (questions 27 to 31) were placed at the end of the survey. Question types varied, with multiple, single choice, or rating options. There were no adaptive questions and responses were mandatory to proceed to the following question, but all questions on RRT offered a non-response option ("other" or " do not know"). The final web version underwent functionality testing before being released.

Questions were developed after an extended literature review and the generation of research hypotheses, and focused on addressing our a priori chosen objectives. The first set of questions was submitted for revision to a panel of RRT experts. After obtaining a first consensus, pilot

testing was conducted and the survey was sent to ICU clinicians working in a university hospital ($n = 26$). Eight of them completed the survey and the clinical sensibility testing (CST) tool. Their mean completion time was 12 min. Their remarks were collected and analyzed. Item reduction and revision of questions took place after this pilot testing. The final version started with a request to confirm that the participant was a clinician and then consisted of 31 questions spread over 5 pages. The first set of questions referred to the participant and their institution, the following questions focused on the participant's beliefs and preferences regarding RRT in different clinical situations and the remaining questions explored the typical RRT settings used (Full list of questions available in the Supplemental Material).

2.3. Statistical analyses

At the end of the survey, responses were automatically captured and stored on a secure server. Categorical data were expressed as counts and percentages. All questionnaires with at least one answer were analyzed, including incomplete questionnaires due to early termination, regardless of the completion time. The percentages of responses to each question are provided based on the number of respondents who answered that specific question. No imputation for missing data was performed. Results from the Chinese translated survey were only available as aggregated data (percentages of answers per question) and thus these data could not be used for sub-group analyses (e.g. analysis among the respondents working in a university hospital vs. those working in a non-university hospital or nephrologists vs. non-nephrologists). Data curation and analyses were performed with STATA software, version 17.0 (StataCorp., College Station, TX), and XSLS, version 2022.1.2 (Addinsoft). Results are reported according to the Checklist for Reporting Results of Internet *E*-Surveys (CHERRIES) [22].

3. Results

3.1. Participants

Between July 2021 and March 2022, 1286 clinicians from 73 countries opened the survey. Among those, 1174 (91 %) answered the first question and 776 (60 %) completed the full survey. The completion

Table 1
Characteristics of respondents and hospitals, by continent.

	Africa	Asia	Europe	North-America	Oceania	South-America	All
	$N = 23$	$N = 277$	N = 724	$N = 45$	$N = 30$	$N = 75$	$N = 1174$
Number of countries	8	21	32	2	1	9	73
Respondent's age							
20–30	3 (13)	10 (4)	82 (11)	1 (2)	2 (7)	3 (4)	101 (9)
31–40	4 (17)	88 (32)	247 (34)	14 (31)	13 (43)	27 (36)	393 (33)
41–50	7 (30)	104 (38)	200 (28)	14 (31)	9 (30)	32 (43)	366 (31)
51–60	5 (22)	65 (23)	137 (19)	10 (22)	4 (13)	10 (13)	231 (20)
over 60	4 (17)	10 (4)	58 (8)	6 (13)	2 (7)	3 (4)	83 (7)
Clinical experience[a]							
Resident	1 (4)	13 (5)	38 (5)	0 (0)	0 (0)	4 (5)	56 (5)
Fellow	1 (4)	30 (11)	103 (14)	6 (13)	8 (27)	5 (7)	153 (13)
Attending clinician, <10 years of experience	6 (26)	50 (18)	199 (27)	14 (31)	8 (27)	26 (35)	303 (26)
Attending clinician, >10 years of experience	15 (65)	159 (57)	360 (50)	22 (49)	11 (37)	38 (51)	605 (52)
Others	0 (0)	25 (9)	24 (3)	3 (7)	3 (10)	2 (3)	57 (5)
Medical speciality[b]							
Critical care	7 (30)	202 (73)	555 (77)	33 (73)	30 (100)	46 (61)	873 (74)
Anesthesiology	10 (43)	56 (20)	396 (55)	2 (4)	2 (7)	4 (5)	470 (40)
Nephrology	8 (35)	60 (22)	84 (12)	23 (51)	2 (7)	24 (32)	201 (17)
Emergency medicine	0 (0)	49 (18)	58 (8)	4 (9)	2 (7)	4 (5)	117 (10)
Other medical specialities[c]	5 (22)	38 (14)	137 (19)	11 (24)	3 (10)	23 (31)	217 (18)
Training for RRT[b]							
Initial training during specialization	3 (33)	90 (45)	334 (72)	20 (61)	15 (65)	27 (63)	489 (63)
Additional academic training	4 (44)	102 (50)	172 (37)	17 (52)	6 (26)	20 (47)	321 (41)
Participation in congresses	3 (33)	47 (23)	208 (45)	16 (48)	5 (22)	16 (37)	295 (38)
Personal interest and self- education	5 (56)	65 (32)	314 (67)	20 (61)	14 (61)	24 (56)	442 (57)
Type of hospital							
University hospital	11 (58)	121 (49)	363 (56)	37 (93)	21 (70)	29 (43)	582 (55)
Non-university public hospital	3 (16)	92 (37)	245 (38)	2 (5)	9 (30)	12 (18)	363 (34)
Private or military hospital	5 (26)	36 (15)	40 (7)	1 (3)	0 (0)	26 (39)	108 (10)
Chronic dialysis center present within hospital (yes)	11 (58)	230 (92)	534 (82)	24 (60)	29 (97)	44 (66)	872 (83)
Number of ICU beds in unit[d]							
0–10	6 (32)	39 (23)	185 (29)	0 (0)	3 (10)	11 (16)	244 (25)
11–15	2 (11)	34 (20)	151 (23)	6 (15)	2 (7)	5 (7)	200 (21)
16–20	3 (16)	31 (18)	136 (21)	4 (10)	1 (3)	17 (25)	192 (20)
>20	8 (42)	67 (39)	176 (27)	30 (75)	24 (80)	34 (51)	339 (35)
Type of ICU							
Medical	6 (32)	55 (22)	125 (19)	13 (33)	6 (20)	20 (30)	225 (21)
Surgical	2 (11)	11 (4)	90 (14)	0 (0)	0 (0)	1 (1)	104 (10)
Medical-surgical	5 (26)	154 (62)	340 (52)	12 (30)	21 (70)	32 (48)	564 (54)
Other	4 (21)	18 (7)	57 (9)	8 (20)	3 (10)	5 (7)	95 (9)
Do not make RRT prescription in ICU regularly	2 (11)	11 (4)	32 (5)	7 (18)	0 (0)	9 (13)	61 (6)

Data are presented in numbers and percentages. Percentages are calculated in columns for the number of respondents to that question.
ICU = intensive care unit, RRT = renal replacement therapy, CRRT = continuous renal replacement therapy, CVVH = continuous veno venous hemofiltration, CVVHD = continuous veno venous hemodialysis, CVVHDF = continuous veno venous hemodiafiltration, RCA = regional citrate anticoagulation.

[a] Clinical experience categories: resident = medical specialty not chosen yet, fellow = medical specialty has been chosen.

[b] Several answers were possible (sum of percentages may be >100 %).

[c] Includes cardiology, pneumology, neurology, infectious diseases and internal medicine.

[d] Does not include the 78 respondents to the Chinese survey.

rate for each question is presented in Supplementary Table S1. The median (IQR) completion time was 9 (3; 15) minutes. Europe was the most represented continent, with 62 % of all participants (n = 724), spread over 32 countries. Distribution of participants by country is presented in Supplementary Table S2. The most represented countries were France (n = 180, 15 %), China (n = 94, 8 % - of whom 78 answered the translated survey), Japan (n = 81, 7 %), Italy (n = 79, 7 %), Austria (n = 70, 6 %) and Switzerland (n = 60, 5 %).

The majority of participants were employed in university hospitals (n = 582, 55 %) and were attending clinicians with over 10 years of clinical experience (n = 605, 52 %) (Table 1). Most were intensivists (n = 873, 74 %), 470 had a training in anesthesia (40 %) and 201 had a training in nephrology (17 %). Among the non-nephrologist respondents, 228 (36 %) had received additional academic training in RRT.

3.2. Description of practices

For most clinicians, RRT could be initiated in their ICU every day of the week and at any time (n = 968/1053, 92 %). CRRT and IHD were widely available, to 97 % and 85 % of respondents respectively, with a large heterogeneity in the frequency of use between continents (Table 2). Among respondents who prescribed both modalities (n = 675), 48 % (n = 323) prescribed more CRRT days than IHD sessions monthly, 16 % prescribed more IHD sessions (n = 106) and 36 % prescribed both modalities with the same frequency (n = 246). Among the 160 nephrologists who reported using both modalities, 72 % (n = 115) prescribed IHD sessions at least as often as CRRT days. SLED and PD were respectively available to 70 % and 58 % of the respondents, but *when available*, they were prescribed less than once a month by 55 % of the respondents for SLED and 81 %of the respondents for PD. SLED was the favourite modality of only 5 % of respondents (n = 44), although 34 % (n = 288) of respondents considered that SLED combined advantages of intermittent and continuous modalities (Supplementary Fig. S1).

When CRRT was available (n = 1017, 97 %), the most frequently used technique was CVVHDF (n = 597, 59 %), followed by CVVHD (n = 261, 26 %) and CVVH (n = 159, 16 %). 70 % of respondents reported the availability of at least two different CRRT techniques in their unit (n = 710). Among the 30 % (n = 308) of respondents who had only one CRRT technique available, 32 % (n = 100) would have liked to have access to other CRRT techniques.

Among the respondents who prescribed CVVH, 62 % (n = 418) stated that they calculated the filtration fraction. The most frequently prescribed ratio of substitution fluid was $^1/_3$ in pre-dilution and $^2/_3$ in post-dilution (n = 208, 31 %), followed by ½ in pre-dilution and ½ in post-dilution (n = 143, 22 %), and 100 % in post-dilution (n = 139, 21 %).

Among the respondents who prescribed CVVHDF, the most frequently prescribed ratio of solute removal mechanisms was ½ convection – ½ diffusion (n = 254, 39 %), followed by $^1/_3$ convection – $^2/_3$ diffusion (n = 155, 24 %) and $^2/_3$ convection – $^1/_3$ diffusion (n = 110, 17 %). 16 % (n = 104) of CVVHDF users did not know what ratio they prescribe. CVVHDF was the preferred CRRT technique of 43 % of respondents (n = 366) and 58 % of all respondents (n = 490) indicated that CVVHDF offered advantages of both mechanisms (Supplementary Fig. S1).

Regarding anticoagulation for CRRT, most respondents agreed, or totally agreed, that RCA was their preferred anticoagulation strategy (61 %, n = 479), was safer and provided better filter patency than systemic heparin anticoagulation (67 % and 62 %) (Fig. 1). Almost half of respondents reported a neutral opinion regarding the advantages of using RCA with CVVHD over CVVH (41 %, n = 325) and the other half was distributed between those agreeing or not.

We repeated our analyses according to hospital status of the respondent (Supplementary Tables S3 and S4). Respondents working in

Table 2
RRT prescriptions and implementation, by continent.

	Africa	Asia	Europe	North-America	Oceania	South-America	All
	N = 23	N = 277	N = 724	N = 45	N = 30	N = 75	N = 1174
Number of countries	8	21	32	2	1	9	73
Who prescribes RRT[a]							
The intensivist	6 (32)	150 60)	460 (71)	5 (13)	23 (77)	7 (10)	651 (62)
The nephrologist/other consultant coming from outside the ICU	8 (42)	49 (20)	76 (12)	31 (76)	0 (0)	43 (64)	207 (20)
Both (intensivist or other, depending on the modality)	4 (21)	48 (19)	128 (20)	5 (13)	10 (33)	16 (24)	211 (20)
Both (intensivist or other, depending on the time)	3 (16)	13 (5)	34 (5)	0 (0)	0 (0)	9 (13)	59 (6)
Number of IHD sessions prescribed monthly							
0 to 1	1 (5)	76 (32)	145 (27)	3 (8)	16 (64)	5 (8)	246 (27)
2 to 5	8 (42)	60 (25)	141 (27)	14 (39)	4 (16)	20 (30)	247 (27)
6 to 15	3 (16)	40 (17)	73 (14)	5 (14)	0 (0)	16 (24)	137 (15)
> 15	4 (21)	51 (21)	61 (12)	14 (39)	0 (0)	21 (32)	151 (16)
Not available	3 (16)	14 (6)	109 (21)	0 (0)	5 (20)	4 (6)	135 (15)
Number of CRRT days prescribed monthly							
0 to 1	2 (11)	30 (12)	47 (7)	2 (5)	2 (7)	4 (6)	87 (8)
2 to 5	6 (32)	79 (32)	225 (35)	8 (20)	10 (33)	26 (39)	354 (34)
6 to 15	3 (16)	49 (20)	194 (31)	11 (28)	11 (37)	13 (20)	281 (27)
> 15	3 (16)	82 (33)	157 (25)	19 (48)	7 (23)	14 (21)	282 (27)
Not available	5 (26)	9 (4)	11 (2)	0 (0)	0 (0)	9 (14)	34 (3)
Most used CRRT modality							
CRRT is not available	6 (32)	9 (4)	15 (2)	0 (0)	0 (0)	6 (9)	36 (3)
CVVH	0 (0)	51 (21)	82 (13)	15 (38)	2 (7)	9 (13)	159 (15)
CVVHD	6 (32)	35 (14)	201 (31)	5 (13)	2 (7)	12 (18)	261 (25)
CVVHDF	7 (37)	154 (62)	350 (54)	20 (50)	26 (87)	40 (60)	597 (57)
RCA is the favourite anticoagulation for CRRT							
1 (totally disagree)	2 (22)	22 (11)	32 (7)	1 (3)	0 (0)	6 (13)	63 (8)
2	0 (0)	23 (11)	35 (8)	1 (3)	1 (4)	5 (11)	65 (8)
3	4 (44)	67 (33)	70 (15)	13 (39)	5 (22)	13 (28)	172 (22)
4	1 (11)	36 (18)	51 (11)	2 (6)	10 (43)	7 (15)	107 (14)
5 (totally agree)	2 (22)	55 (27)	276 (59)	16 (48)	7 (30)	16 (34)	372 (48)

Data are presented in numbers and percentages. Percentages are calculated in columns for the number of respondents who answered the question.
ICU = intensive care unit, RRT = renal replacement therapy, CRRT = continuous renal replacement therapy, CVVH = continuous veno venous hemofiltration, CVVHD = continuous veno venous hemodialysis, CVVHDF = continuous veno venous hemodiafiltration, RCA = regional citrate anticoagulation.
[a] Several answers were possible (sum of percentages may be >100 %).

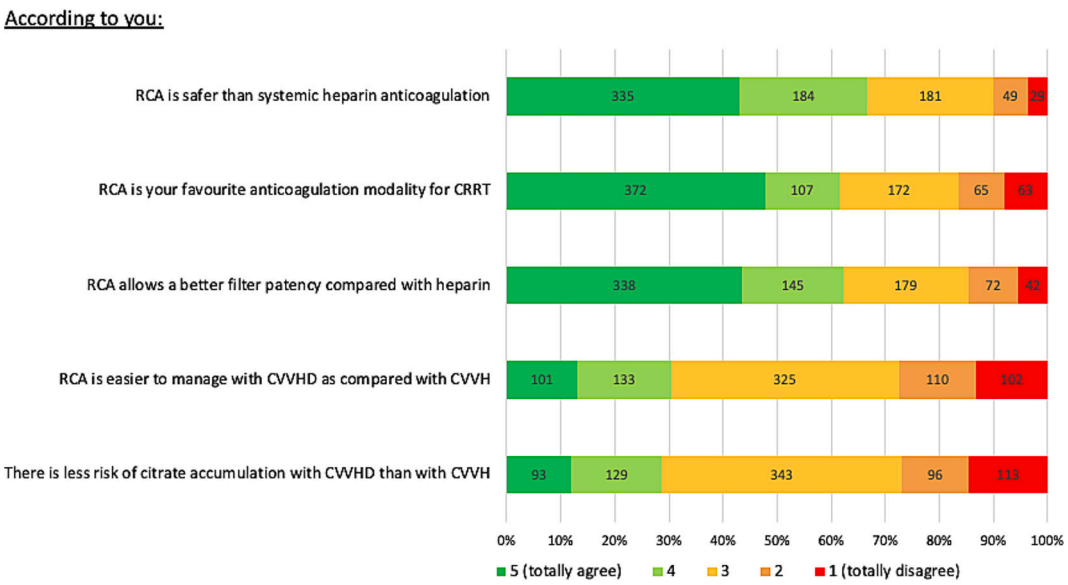

Fig. 1. Participants' opinion regarding regional citrate anticoagulation for CRRT (n = 785).
CRRT = continuous renal replacement therapy, CVVH = continuous veno venous hemofiltration, CVVHD = continuous veno venous hemodialysis.

university hospitals received additional training in RRT more frequently than those woking in non-university hospitals (42 % vs 15 % through additional academic training, 42 % vs 17 % through participation in congresses). They also had chronic dialysis center embedded within their hospital more often (89 % vs 72 %) and worked in larger units (44 % vs 23 % have more than 20 beds). IHD was more often available in university hospitals (88 % vs 80 %) and CRRT was prescribed more often (32 % vs 19 % respondents prescribed more than 15 CRRT sessions monthly).

3.3. Factors associated with the use of each modality/technique

When asked about the best modality (IHD, CRRT, SLED or PD) in different clinical situations and for different goals, most respondents indicated that one modality was better than the other. Renal recovery was the clinical goal for which equipoise was most common (44 % of respondents either stated that RRT modalities had similar impact or had no opinion); those who expressed a preference chose CRRT to facilitate renal recovery (Fig. 2). CRRT was widely preferred over IHD for septic shock (91 % vs 1 % of respondents), acute brain injury (74 % vs 4 %) and fluid overload (52 % vs 28 %). In contrast, reasons to use IHD included

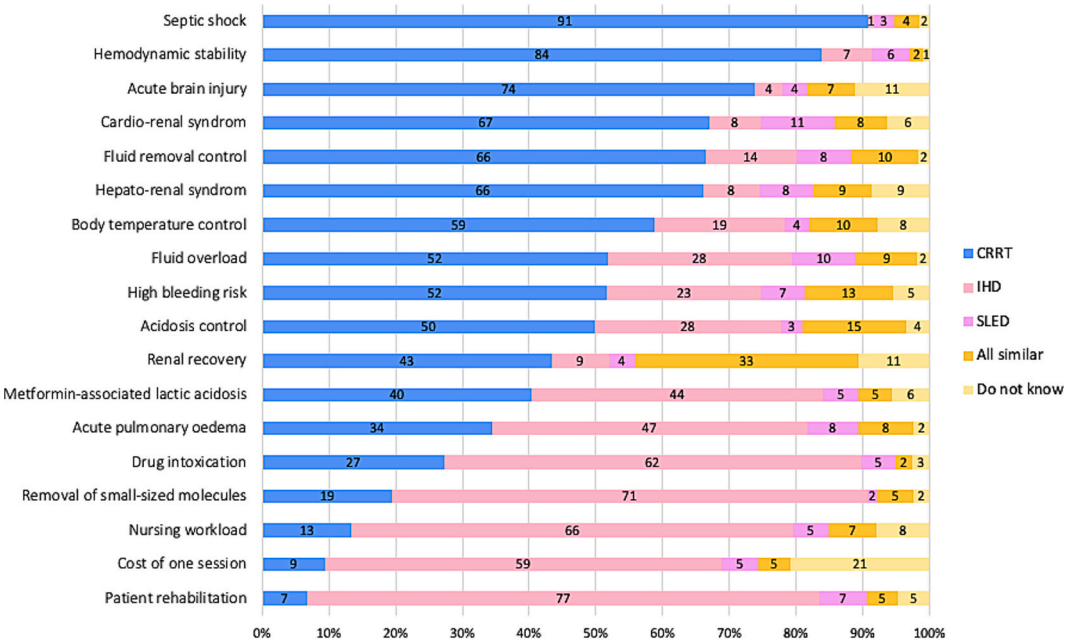

Fig. 2. Preferred RRT modality for various clinical situations and scenarios.
Intensivists' preferences between different RRT modalities in various clinical situations and objectives. The length of each colored bar and the number within bar represent the percentage of respondents endorsing the corresponding modality as the best choice for the specific clinical situation or goal.
771 respondents answered at least to one of the clinical situations and scenarios. The 78 respondents to the Chinese survey were not included in this analysis due to a modification in the propositions' list.
IHD = intermittent hemodialysis, CRRT = continuous renal replacement therapy, SLED = sustained low efficiency dialysis.

rehabilitation (77 % vs 7 %), cost (59 % vs 9 %), nursing workload (66 % vs 13 %) and intoxication (62 % vs 27 %).

Considering the choice of a CRRT technique (CVVHD, CVVHDF, CVVH), more respondents expressed equipoise. Thus, depending on the clinical situation, 18 % to 77 % of respondents were not able to identify a technique as being superior to the others (Fig. 3). For the vast majority of clinical situations, the preferred technique was CVVHDF. CVVHD was deemed better than the other techniques for removal of small-sized molecules, optimizing hemofilter lifespan and reducing nursing workload. CVVH was never the preferred technique but its preferential applications appeared to be septic shock, middle-sized molecule removal and the treatment of fluid overload. When we analyzed respondents' preferences taking into account which CRRT technique they used the most, we observed different patterns, suggesting that opinions about a given modality were related to its use (Supplementary Figs. S2 to S4). Thus, CVVH users largely preferred CVVH for most situations with the exception of small-sized molecules removal, drug intoxication and to improve hemofilter lifespan. Similarly, CVVHD users preferred this technique in most situations except for middle-sized molecule epuration and in case of septic shock, where they preferred hemofiltration. Interestingly, CVVHD users displayed a high degree of uncertainty regarding their preferred technique for fluid removal and control of fluid overload.

The vast majority of respondents felt comfortable with the indication and timing of RRT and with the settings of the IHD and CRRT techniques (Supplementary Fig. S5). However, 85 % ($n = 660$) indicated that they would like to receive more education regarding RRT in ICU. Moreover, the need for additional data to inform decision making was most commonly related to comparing the different CRRT techniques (73 %, $n = 512$), and comparing different RRT modalities in a particular context or for a specific aim (77 %, $n = 529$ and 62 %, $n = 436$). Just over half of respondents had a protocol available in their unit regarding timing and indications for RRT ($n = 431$, 51 %) and for the settings of each available modality or technique ($n = 444$, 52 %).

4. Discussion

This survey, encompassing 1174 intensivists from 73 countries, offers a comprehensive overview of current RRT practices in ICUs worldwide. A notable finding is the predominant availability (97 % vs. 85 %) and use of CRRT over IHD. This preference underscores a global trend towards continuous modalities, particularly in settings requiring meticulous management of hemodynamics and fluid balance such as septic shock, acute brain injury, cardiorenal and hepatrorenal syndrome. Among CRRT techniques, CVVHDF was the most used technique (59 %) but its application was highly heterogeneous regarding the proportion of diffusion and convection. Similarly, an important heterogeneity was observed regarding the proportion of pre- and post-dilution ratios in CVVH. Depending on the clinical situation, there was a strong agreement or, on the contrary, considerable uncertainty or heterogeneity about the best modality/technique to use. This suggests clinicians not only consider modalities/techniques to be non-equivalent, but they also believe that the best modality/technique in one indication is not necessarily the best for another indication.

Compared with previous literature, our findings show an increase in diffusion-based CRRT techniques over the recent years. A decade ago, convection-based treatments dominated CRRT prescriptions, with CVVHDF being the most prescribed technique (51 %), followed by CVVH (40 %) and then CVVHD (9 %) [11]. The persistence of CVVHDF as the most commonly used technique may be explained by its perceived versatility, allowing the combination of diffusion and convection advantages. However, although patients with end-stage renal disease may benefit from the combination of both mechanisms to reduce inflammation and potentially improve long-term outcomes [23], this has not been demonstrated in critically ill patients. The new notable preference for CVVHD over CVVH may also be explained by its perceived ease-of-use, reduced nursing workload and longer haemofilter life, especially when used with RCA. This preference is consistent with previous studies

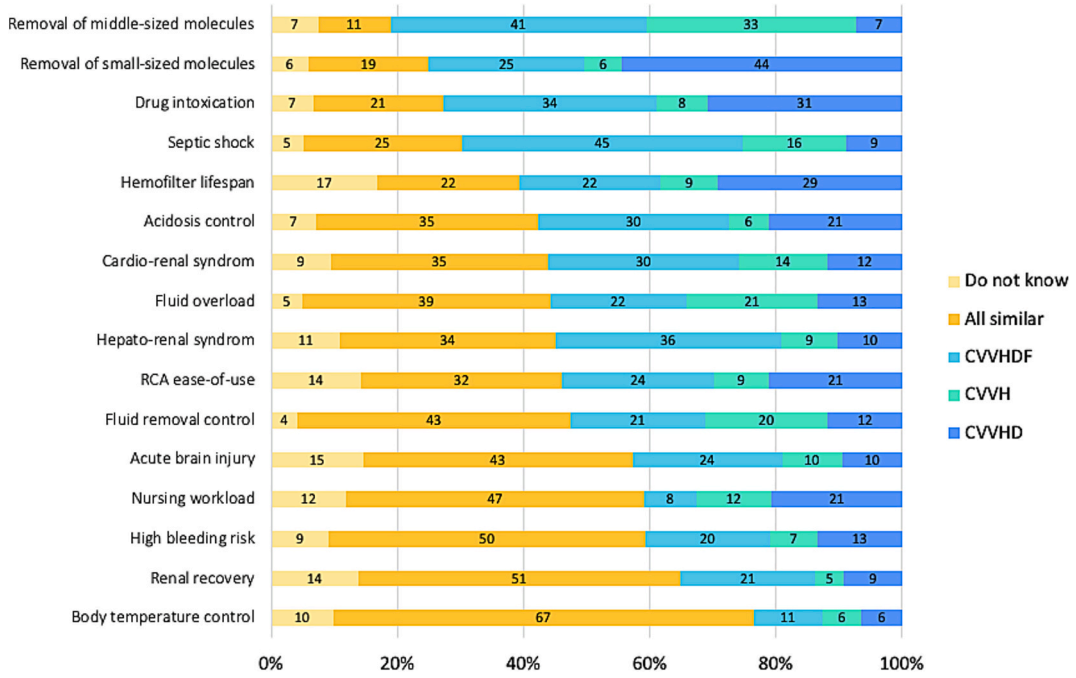

Fig. 3. Preferred CRRT technique for various clinical situations and scenarios.
Intensivists' preferences between different CRRT modalities in various clinical situations and objectives. The length of each colored bar and the number within bars represent the percentage of respondents endorsing the corresponding CRRT modality as the best choice for the specific clinical situation or goal.
771 respondents answered at least to one of the clinical situations and scenarios. The 78 respondents to the Chinese survey were not included in this analysis due to a modification in the propositions' list.
CRRT = continuous renal replacement therapy, RCA = regional citrate anticoagulation, CVVHDF = continuous veno venous hemodiafiltration, CVVH = continuous veno venous hemofiltration, CVVHD = continuous veno venous hemodialysis.

highlighting the advantages of CVVHD with RCA [19]. In this survey, RCA was indeed the preferred anticoagulation strategy for CRRT (61 %), demonstrating the widespread and rapid adoption of this anticoagulation method, compared to 2007 when it accounted for only 10 % of treatments [24]. However, we could not find a direct association between the increase in use of CVVHD and RCA. Respondents preferred CVVH over CVVHD for septic shock, clearance of middle-sized molecules and fluid removal, probably based on the hypothesis that removal of middle-sized molecules (e.g., cytokines) is higher with convection as compared to diffusion and may improve outcomes in sepsis. Neither of these hypotheses is actually supported by high quality data in the literature. Only one prospective cross-over study in 15 patients and one randomised pilot trial in 78 patients compared CVVH and CVVHD and they failed to reject the hypothesis of equivalence between techniques, in terms of solute removal and patient outcomes, respectively [16,18]. Overall, our results suggest that the choice of a RRT modality or technique is influenced by local practice and familiarity, rather than high-quality evidence. This implies a potential bias towards familiar techniques over potentially more effective ones. It also highlights the need for continuous education and the implementation of prospective randomised trials to further elucidate the optimal RRT modality or technique in different clinical scenarios that not only improve patient outcomes, but also integrate smoothly into the ICU environment. As our results underlined a great heterogeneity in CRRT settings (e.g., in the distribution of substitution fluids and the convection/diffusion ratio), future trials would probably require the standardization of RRT settings ahead, to take full advantage of each modality or technique.

A major strength of this study lies in its broad geographic coverage, capturing a wide array of practices and perspectives on RRT across diverse healthcare systems. The international scope and the substantial number of respondents with diverse educational and clinical backgrounds enhance its relevance and add robustness to the findings. The 60 % completion rate observed in our survey suggests good respondents' engagement, despite the length of the survey and the complexity of some of the questions. Indeed, the survey explored not only technical aspects of RRT such as availability and settings but also clinicians' beliefs regarding the advantages of each modality and technique. Also, it is the first survey to describe the use of PD in ICU. We believe that PD is worth to describe as it may be an alternative to conventional RRT modalities, particularly in low-resource settings or during periods of high healthcare demand when conventional RRT resources may be limited [10].

This study has also some limitations. The self-reported nature of the survey data might introduce response bias, and the voluntary participation could result in sampling bias, over-representing views from more engaged and experienced intensivists, or resource-rich settings. The electronic format of the survey may also have introduced a technological bias by favoring participation from physicians with reliable internet access, potentially underrepresenting respondents from regions with limited digital connectivity. Also, it was not possible to prevent participation of more than one doctor working in the same unit. We grouped countries by continent; however variability is likely to exist also at national level. For several countries, only few respondents participated, which may not be representative of the country practice patterns. To limit the time required to complete the survey, we chose not to explore in detail the reasons for regional variations in RRT preferences, highlighting the need for qualitative research to better understand these issues. Additionally, the survey does not capture patient outcomes, preventing us from associating RRT practices with clinical endpoints. Future studies should aim to address this limitation, possibly through randomised controlled trials. Finally, we could not explore all aspects of RRT. Thus, we did not survey the use and beliefs regarding different types of dialysis catheters and hemofilters, nor did we explore IHD settings, which may largely affect the efficacy and tolerance of the technique [10].

5. Conclusion

This survey revealed an evolving landscape of RRT practices worldwide, with an increase in CVVHD and regional citrate anticoagulation use. There remain considerable heterogeneity regarding technical settings. Depending on the clinical situation, there was a strong agreement or, on the contrary, considerable uncertainty or heterogeneity about the best modality/technique to use, highligthing that clinicians do not consider all modalities/techniques to be equivalent. These findings call for future research aimed at comparing different RRT modalities and CRRT techniques and settings.

Ethics approval and consent to participate

According to French law, ethics approval was not required for this study.

Survey completion implied consent to participate as specified in the survey's cover letter.

Consent for publication

Not Applicable.

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Authors contribution

CM, AM and TR participated in survey development, data analysis and interpretation, and drafted the manuscript.

MJ, MO and AS participated in survey development and dissemination, and critically revised the manuscript and approved the final version.

All authors contributed to the survey dissemination, critically revised the manuscript and approved the final version.

CRediT authorship contribution statement

Céline Monard: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Arnaud Marel:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael Joannidis:** Writing – review & editing, Investigation, Conceptualization. **Marlies Ostermann:** Writing – review & editing, Investigation, Conceptualization. **Zhiyong Peng:** Writing – review & editing, Investigation. **Kent Doi:** Writing – review & editing, Investigation. **Silvia De Rosa:** Writing – review & editing, Investigation. **Ilona Bobek:** Writing – review & editing, Investigation. **Dmitry Sokolov:** Writing – review & editing, Investigation. **Vin-Cent Wu:** Writing – review & editing, Investigation. **Vedran Premuzic:** Writing – review & editing, Investigation. **Ravindra Mehta:** Writing – review & editing, Investigation. **Rinaldo Bellomo:** Writing – review & editing, Investigation. **Xaime Garcia:** Writing – review & editing, Investigation. **Camilo Pizarro:** Writing – review & editing, Investigation, Conceptualization. **Alexander Zarbock:** Writing – review & editing, Investigation. **Igor Milet:** Writing – review & editing, Investigation. **Thiago Reis:** Writing – review & editing, Investigation. **Marc Romain:** Writing – review & editing, Investigation. **Bairbre Mc Nicholas:** Writing – review & editing, Investigation. **Antoine Schneider:** Writing – review & editing, Investigation, Conceptualization. **Thomas Rimmelé:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

CM received speaker honoraria from Baxter, Fresenius Medical Care and bioMerieux.

AM does not report any conflicts of interest.

MJ has received honoraria or research support from Baxter Healthcare Corp, AM-Pharma, CLS Behring, Fresenius, Takeda and Novartis outside the submitted work.

MO's institution received research support from Baxter and BioMerieux.

ZP does not report any conflicts of interest.

KD received lecture and consultancy fees from Toray, Nipro, and AM Pharma.

SDR received speaker honoraria from Baxter, Fresenius Medical Care, Biotest, Estor, Jafron, Toray.

DS received speaker honoraria from Baxter, Fresenius Medical Care, Bbraun and Efferon.

VCW does not report any conflicts of interest.

VP received speaker honoraria from Baxter, Fresenius Medical Care, Cytosorbents and Astellas.

RM has received consulting fees from Am Pharma, Baxter, Fresenius, Sphingotec, Alexion, Mallinckrodt, Rensym, Abiomed, SeaStar, Biomerieux, and served on Data Safety and Advisory Boards for Novartis, Guard therapeutics and Unicycive.

RB has received consulting fees from Baxter and Jafron and speker honoraria from Jafron, Baxter, Viatris.

XG does not report any conflicts of interest.

CP does not report any conflicts of interest.

AZ has received consulting fees from Astute-Biomerieux, Baxter, Bayer, Novartis, Guard Therapeutics, AM Pharma, Paion, Fresenius, research funding from Astute-Biomerieux, Fresenius, Baxter, and speakers fees from Astute-Biomerieux, Fresenius, Baxter.

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MR received speaker honoraria from Baxter.

BMcNs' institution received consulting fees from Teleflex and she is Deputy Chair of the Irish Critical Trials research Group.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcrc.2025.155076.

Data availability

The dataset supporting the conclusions of this article is available from the corresponding author upon reasonable request.

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