Continuous renal replacement therapy: current practice in Australian and New Zealand intensive care units

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ABSTRACT

Background: Large multicentre studies of continuous renal replacement therapy (CRRT) in critically ill patients may influence its bedside prescription and practical application. Despite this, many aspects of CRRT may not be informed by evidence but remain a product of clinician preference. Little was known about current CRRT practice in Australia and New Zealand and it is not known if the evidence from recent studies has been integrated into practice.

Design and setting: A prospective online survey of CRRT practice was sent to intensive care unit medical and nursing clinicians via three national databases in Australian and New Zealand ICUs in December 2013 to March 2014.

Results: There were 194 respondents from 106 ICUs; 49 ICUs (47%) were in tertiary metropolitan hospitals. One hundred and two respondents (54%) reported continuous venovenous haemodiafiltration as the most common CRRT technique, with a combination of predilution and postdilution of CRRT solutions. The prescription for CRRT was variable, with respondents indicating preferences for therapy based on L/hour (53%) or a weight-adjusted treatment in mL/kg/hour (47%). For all modes of CRRT, the common blood flow rates applied were 151–200 mL/minute and 201–250 mL/minute. Few respondents reported preferring flow rates < 150 mL/minute or > 300 mL/minute. Unfractionated heparin was the most commonly used anticoagulant (83%), followed by regional citrate. Femoral vein vascular access was preferred and, typically, a 20 cm length catheter was used. Bard Niagara and Arrow catheters were most frequently used. The Gambro Prismaflex was the dominant machine used (71%).

Conclusions: Our results provide insight into existing clinical management of CRRT. There is considerable variation in the prescription of CRRT in Australian and New Zealand ICUs.

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Acute kidney injury (AKI) is a significant and recognised complication of critical illness that affects 2%–7% of hospitalised patients[1-3] and up to 34% of critically ill patients.[4-6] AKI can result in severe derangements in fluid, electrolyte and acid–base balance requiring the intervention of supportive strategies. The use of renal replacement therapy (RRT) forms a key component in the treatment for severe AKI and its use is required in up to 5%–6% of all critically ill patients in intensive care units.[7]

The technical application of RRT has been highlighted in recent years with several large, multicentre, randomised controlled trials[8-9] investigating RRT technique and "dose", and its association with mortality as the primary outcome. In the Randomized Evaluation of Normal Versus Augmented Level (RENAL) study, 1464 patients receiving continuous renal replacement therapy (CRRT) (specifically, continuous venovenous haemodiafiltration [CVVHDF]) were explored at different dose intensities, and the results indicated no difference in the 90-day mortality.[8] Similarly, in the Acute Renal Failure Trial Network (ATN) study, 1124 patients receiving intermittent haemodialysis (IHD), slow low-efficiency daily dialysis (SLEDD) and CVVHDF, at different dose intensities, also showed no difference in the 60-day mortality.[9] Technical information on the application of RRT for the treatment of AKI was illustrated in several prestudy practice surveys.[10-11] Technical aspects such as modality, dose, dose prescription, replacement or dialysate fluid type, blood flow rate, predilution and postdilution for replacement fluid and machine types were explored in detail. More recently, two international groups have investigated the current management, practices and practitioner beliefs after the dissemination of results from the RENAL and ATN trials.[12-13] Of particular importance is whether CRRT practices have changed in response to these studies. These later surveys have concentrated on dose, modality and timing of RRT with limited information about practical or technical aspects of the application of therapy.

To date there have been no data published describing alteration in practice for Australian and New Zealand ICU clinicians following outcomes of the RENAL or ATN studies. In addition to practice changes following the results of these studies, there have been significant enhancements to capacity and flexibility in functionality of CRRT machines since the practice survey conducted in 2004 before the RENAL study. This improvement in machine design and functionality may have prompted changes to prescribing practices of CRRT in many Australian and New Zealand ICUs.

The aim of our survey was to establish the current practical prescription of CRRT in ICUs caring for adult and paediatric patients in Australia and New Zealand.

Table 1. Profile of survey respondents (*n* = 194)

Variable	*n* (%)
State, territory or New Zealand island	
Australian Capital Territory	3 (1.5%)
New South Wales	51 (26.3%)
Northern Territory	5 (2.6%)
Queensland	36 (18.6%)
South Australia	18 (9.3%)
Tasmania	5 (2.6%)
Victoria	53 (27.3%)
Western Australia	14 (7.2%)
North Island of New Zealand	8 (4.1%)
South Island of New Zealand	1 (0.5%)
Professional role	
Consultant intensivist	36 (18.6%)
Nurse unit manager (charge nurse)	11 (5.7%)
ICU-based educator	37 (19.1%)
Clinical nurse consultant	9 (4.6%)
Associate nurse unit manager (team leader)	12 (6.2%)
Clinical nurse specialist	47 (24.2%)
Registered nurse	42 (21.6%)
Hospital type	
Regional	53 (27.3%)
Metropolitan private	19 (9.8%)
Metropolitan public level 2	30 (15.5%)
Metropolitan public level 3	92 (47.4%)
ICU type	
Adult	134 (69.1%)
Paediatric	7 (3.6%)
Combined adult and paediatric	53 (27.3%)
Number of ICU beds	
0–5	8 (4.1%)
6–10	70 (36.1%)
11–15	47 (24.2%)
16–20	22 (11.3%)
>20	47 (24.2%)
Annual CRRT treatments	
< 10	22 (11.3%)
11–25	32 (16.5%)
26–50	44 (22.7%)
51–75	18 (9.3%)
76–100	15 (7.7%)
>100	49 (25.3%)
Don't know	14 (7.2%)

ICU = intensive care unit. CRRT = continuous renal replacement therapy.

Methods

Survey method

A descriptive online survey was distributed from December 2013 to March 2014 requesting information from clinicians about their current practical application of CRRT. A sample of ICU medical and nursing staff was accessed via three separate databases. The Australian and New Zealand Intensive Care Society (ANZICS) Clinical Trials Group (CTG), the Intensive Care Coordination and Monitoring Unit (ICCMU) ICU Connect list server and the Australian College of Critical Care Nurses (ACCCN) databases were used to seek participants for the survey. Ethics approval was granted by the Austin Health Human Research Ethics Committee (project 04918) before study commencement. Consent to participate was implied by submission or return of the questionnaire.

Survey design

The survey was devised from the practice questionnaire used in the study of 34 Australian and New Zealand ICUs in 2004 and published in 2008, before the RENAL study.[10] The tool used for this survey was a modification of the 11-point questionnaire and consisted of 20 questions (see Appendix online at cicm.org.au/Resources/Publications/Journal). Questions on demographics included the practitioner's state or territory, study site (hospital), professional role (eg, intensivist, nurse unit manager) and type of ICU (adult or paediatric). Respondents were also asked to identify the number of beds and type of ICU (eg, metropolitan tertiary or private) and the number of patients they treated with CRRT each year. Twelve questions focused on the prescription of CRRT, including the modalities of CRRT used (ie, continuous venovenous haemofiltration [CVVH], continuous venovenous haemodialysis [CVVHD] and CVVHDF), prescribed blood flow rate, if CRRT was prescribed on the basis of patient weight or litres per hour, and if prescription was for replacement or combined with dialysate flow rates. Respondents were also asked to identify the preferred anatomical site for vascular access, the catheter type and usual length of catheter, the anticoagulation regimen used and type of machine used for CRRT.

Statistical analysis

Descriptive statistics were used for all demographic and clinical data and for all items in the survey. Data were cleaned and checked for missing values and invalid responses. The prime reporting statistics were expressed as frequencies and percentages. Statistical analyses were performed using Stata version 11 (Statacorp).

Table 2. Continuous renal replacement therapy regimens

Prescription variable	Frequency of use, *n* (%)			
	Never	Occasionally	Frequently	Always
Continuous venovenous haemodiafiltration				
Dose prescription, L/h (*n* = 156)				
1 (D) + 1 (R)	60 (38.4%)	35 (22.5%)	51 (32.7%)	10 (6.4%)
1.5 (D) + 1.5 (R)	52 (33.3%)	45 (28.9%)	56 (35.9%)	3 (1.9%)
2 (D) + 2 (R)	61 (39.1%)	55 (35.3%)	30 (19.2%)	10 (6.4%)
> 2 (D) + > 2 (R)	110 (70.5%)	34 (21.8%)	7 (4.5%)	5 (3.2%)
Dose prescription, mL/kg/h (*n* = 117)				
0–15	90 (77%)	18 (15.4%)	6 (5.1%)	3 (2.5%)
16–25	27 (23%)	23 (19.7%)	44 (37.6%)	23 (19.7%)
> 25	41 (35%)	30 (25.6%)	31 (26.6%)	15 (12.8%)
Blood flow rate, mL/min (*n* = 177)				
0–50	168 (94.9%)	6 (3.4%)	3 (1.7%)	0 (0)
51–100	152 (85.8%)	15 (8.5%)	10 (5.7%)	0 (0)
101–150	85 (48%)	62 (35%)	25 (14.1%)	5 (2.9%)
151–200	24 (13.6%)	48 (27.1%)	80 (45.2%)	25 (14.1%)
201–250	57 (32.2%)	39 (22.1%)	68 (38.4%)	13 (7.3%)
251–300	92 (52%)	44 (24.9%)	35 (19.8%)	6 (3.3%)
> 300	155 (87.6%)	17 (9.6%)	2 (1.1%)	3 (1.7%)
Continuous venovenous haemofiltration				
Dose prescription, L/h (*n* = 156)				
⩽ 2	116 (74.4%)	29 (18.5%)	4 (2.6%)	7 (4.5%)
2–3	105 (67.3%)	20 (12.8%)	27 (17.3%)	4 (2.6%)
> 3	120 (76.9%)	22 (14.1%)	12 (7.7%)	2 (1.3%)
Dose prescription, mL/kg/h (*n* = 117)				
0–15	108 (92.3%)	8 (6.8%)	1 (0.9%)	0 (0)
16–25	89 (76%)	17 (14.5%)	9 (7.7%)	2 (1.7%)
> 25	86 (73.5%)	12 (10.3%)	16 (13.7%)	3 (2.5%)
Blood flow rate, mL/min (*n* = 89)				
0–50	82 (92%)	5 (5.6%)	2 (2.4%)	0 (0)
51–100	76 (85.4%)	11 (12.3%)	2 (2.3%)	0 (0)
101–150	53 (59.6%)	31 (34.8%)	5 (5.6%)	0 (0)
151–200	17 (19.1%)	19 (21.3%)	38 (42.7%)	15 (16.9%)
201–250	25 (28%)	20 (22.5%)	35 (39.3%)	9 (10.2%)
251–300	40 (45%)	25 (28%)	21 (23.6%)	3 (3.4%)
> 300	74 (83%)	11 (12.4%)	2 (2.3%)	2 (2.3%)

(D) = dialysis. (R) = replacement.

Results

Characteristics of the cohort

Survey invitations were emailed to 4105 potential participants via ACCCN (1853 participants), ICCMU (1652) and the ANZICS CTG (600) membership databases. There is likely to have been duplication between these databases, with an unknown number of people appearing on two or all three databases, so it was not possible to know the precise number of invitees. Respondents totalled 194, and 106 intensive or critical care units from Australia and New Zealand were represented. Most respondents came from New South Wales (26.3%) and Victoria (27.3%), and most worked in metropolitan ICUs (72.7%), with the largest group working in

Table 3. Preferred vascular access sites and catheter brands and lengths for continuous renal replacement therapy

	Frequency of use, *n* (%)			
Vascular access variable (*n*)	Never	Occasionally	Frequently	Always
Vein (194)				
Left internal jugular	15 (7.7%)	108 (55.7%)	69 (35.6%)	2 (1%)
Right internal jugular	7 (3.6%)	65 (33.5%)	121 (62.4%)	1 (0.5%)
Left femoral	2 (1%)	57 (29.4%)	132 (68%)	3 (1.5%)
Right femoral	3 (1.5%)	51 (26.3%)	137 (70.6%)	3 (1.5%)
Left subclavian	69 (35.6%)	98 (50.5%)	26 (13.4%)	1 (0.5%)
Right subclavian	66 (34%)	103 (53.1%)	24 (12.4%)	1 (0.5%)
Catheter brand				
Bard Niagara (133)	66 (49.6%)	16 (12%)	34 (25.5%)	17 (12.8%)
Gambro Dolphin (136)	85 (62.5%)	9 (6.6%)	18 (13.2%)	24 (17.7%)
Quinton Mahurkar (119)	114 (95.8%)	4 (3.4%)	1 (0.8%)	0 (0)
Medcomp (119)	110 (92.4%)	0 (0)	8 (6.7%)	1 (0.8%)
Arrow (137)	49 (35.8%)	30 (21.9%)	32 (23.4%)	26 (19%)
Cook (128)	84 (65.6%)	17 (13.3%)	19 (14.8%)	8 (6.3%)
Don't know (63)	–	–	–	–
Catheter access length	15 cm	20 cm	24/25 cm	
Internal jugular (150)	94 (62.7%)	55 (36.7%)	1 (0.6%)	–
Femoral (150)	4 (2.6%)	76 (50.7%)	70 (46.7%)	–
Subclavian (150)	85 (56.7%)	60 (40%)	5 (3.3%)	–
Don't know (44)	–	–	–	–

metropolitan level three tertiary institutions (47.4%), caring for adult patients only (69.1%) (Table 1). Consultant intensivists represented 18.6% of the total responses, 19.1% were ICU-based clinical educators, 24.2% were clinical nurse specialists, and 21.6% were registered nurses filling the larger part of nursing roles. About one-third (36.1%) of respondents worked in units of 6–10 beds with 24.2% working in ICUs of over 20 beds. About one-quarter of respondents (25.3%) indicated that their ICU treated over 100 patients per year with some form of CRRT.

CRRT mode and dose

There was obvious clinical variation in the dose prescription for CRRT. Fifty-three per cent of respondents indicated that the standard treatment dose of CRRT was prescribed in their ICUs in L/hour, and 47% indicated that prescriptions used a weight-based dosing strategy of mL/kg/hour. The most common CRRT technique was CVVHDF, with 54% of respondents indicating that they always used this mode of therapy. In contrast, 9% of respondents indicated that they always used CVVH, and 2% always used CVVHD in their ICUs.

CVVHDF, in combination with before-and-after fluid replacement (before-and-after dilution) was indicated by respondents as always prescribed in 29% of treatments, with predilution CVVHDF (13%) and postdilution CVVHDF (12%) the next most-used practices. If CVVHDF was prescribed in a standardised dose of L/hour, respondents reported a dose of 1 L/hour for dialysis (D) + 1 L/hour as replacement (R) fluid as being frequently or always used in 39.1% of treatments. A dose of 2 L/hour (D) + 2 L/hour (R) was nominated as frequently or always used in 25.6% of cases. CVVHDF set at 16–25 mL/kg/hour was the most common weight-based regimen, with 57.3% frequently or always prescribing this dose. A dose of > 25 mL/kg/hour (39.4%) was the next most-used dosing regimen (Table 2).

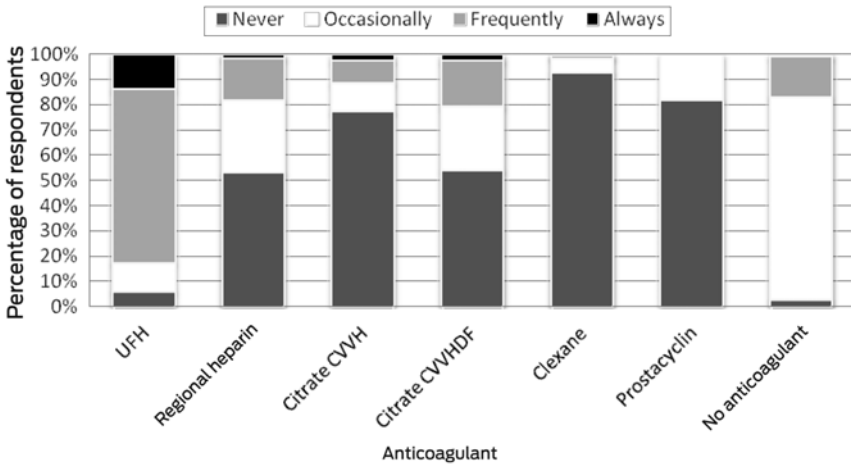
If CVVH was prescribed in a standardised dose of L/hour, respondents reported a dose of 2–3 L/hour as frequently or always used in 19.9% of treatments and a dose > 3 L/hour in only 9.0% of cases. CVVH set at > 25 mL/kg/hour was the most common weight-based regimen with 16.2% frequently or always prescribing this dose (Table 2).

Blood flow rate

A blood pump speed (set blood flow rate) of 151–200 mL/minute was frequently or always used in 59.3% of CVVHDF and 59.6% of CVVH treatments, respectively. A prescribed rate of 201–250 mL/minute was the next most-used range, with 45.7% of respondents frequently or always using it for CVVHDF, and 49.5% of respondents frequently or always using it for CVVH (Table 2). Fifty-one per cent of respondents suggested that the blood flow rate for CRRT was prescribed by unit policy or protocol, with 29% prescribed by medical staff and 20% set by the allocated bedside nurse.

The management of frequent CRRT machine alarms included the manipulation of blood flow rate in an attempt to decrease alarm conditions such as elevated transmembrane pressure and high return or venous pressures. Thirty-four per cent of respondents indicated that they frequently alter the pump speed to alleviate alarm conditions in an attempt to continue therapy.

Figure 1. Anticoagulant choices for continuous renal replacement therapy



UFH = unfractionated heparin. CVVH = continuous venovenous haemofiltration. CVVHDF = continuous venovenous haemodiafiltration.

Vascular access

The right and left femoral veins were most nominated as the access sites of choice for CRRT (Table 3). The next most common site was the right internal jugular vein, with few respondents indicating the use of subclavian veins. Bard Niagara and Arrow catheters were the most frequently used access devices, with a length of 20 cm preferred for all access sites.

Anticoagulation

Unfractionated heparin was the anticoagulant of choice, with 83% of respondents frequently or always using it to extend circuit life in CRRT. Regional techniques were less likely to be used; regional heparin (18%) and regional citrate in combination with CVVHDF (21%) were frequently or always used. Eighty per cent of respondents indicated that they occasionally used a no-anticoagulant strategy in place of drug-based anticoagulant treatment for CRRT (Figure 1).

Machines

The most commonly used CRRT machine was the Prismaflex (Gambro) (71%), followed by the Aquarius (Nikkiso) (27%), Prisma (Baxter Gambro) (8%) and the HF440 (Infomed) (5%).

Discussion

Summary of major findings

We assessed clinical practice prescriptions for the management of CRRT in Australian and New Zealand ICUs, and made five key findings. First, CVVHDF was the mode of CRRT most commonly used, typically using a combination of before-and-after filter fluid replacement. Second, about half the respondents indicated that their practice was to adjust the dose of therapy according to body weight (mL/kg/hour), while half used a standardised dose (L/hour). Third, the prescribed blood flow rate was highly variable, with 150–200 mL/minute being the most common rate for CVVH and CVVHDF. Fourth, a femoral vein was the most frequently nominated site for vascular access. Finally, unfractionated heparin is the most commonly used anticoagulant in CRRT.

Contrast with previous studies

The ANZICS Centre for Outcome and Resource Evaluation assumes that by ANZICS definitions for patient acuity managed,[14] all Australian and New Zealand level 2 and level 3 ICUs (public and private hospitals) are capable of performing RRT. If we continue this assumption, the cohort of RRT-capable ICUs would number 145. About three-quarters of these ICUs (73% [$n = 106$]) completed our survey, suggesting a strong representation of units capable of performing RRT in Australia and New Zealand. In 2001, Silvester and colleagues investigated aspects of RRT practice in 81 Australian ICUs and reported on the management and epidemiology of acute renal failure.[15] The technical aspects of their

study were limited to vascular access site, anticoagulant and mode of therapy. The only other reported study into local CRRT practices was before the RENAL study, which investigated 34 ICUs in Australia and New Zealand.[10] This study, conducted in 2004, investigated the technical and practical application of the therapy and provided important information for the conduct of our survey.

The Beginning and Ending Supportive Therapy for the Kidney study[1] investigated worldwide CRRT practice in 54 centres and 23 countries after the introduction of consensus guidelines and recommendations from the Acute Dialysis Quality Initiative (ADQI) in 2002. This multinational, multicentre study investigated technical aspects of CRRT including modality, dose, dilution method, membrane type and blood flow. The Department of Veterans' Affairs/National Institutes of Health ATN prestudy practice survey[11] reported the findings from 130 practitioners in 27 medical centres in the United States. Nine of the 26 questions specifically related to CRRT prescription, including estimation of frequency of use, vascular access (arterial or venous), mode, blood flow rates, type of fluids and dose prescription. Perhaps the largest survey investigating RRT practice involved 560 European critical care nephrology conference participants.[16] Most respondents were nephrologists (52%) with CRRT-prescribing doctors accounting for 25% of the responses. The technical aspects surveyed were limited to dose, modality and anticoagulant; technical prescription was not investigated.

Since the RENAL (2009)[8] and ATN (2008)[9] studies, there has been limited investigation of alteration in practice and prescription of CRRT, despite the publication of the respective findings from these two large and potentially influential studies. In 2010, the European Society of Intensive Care Medicine (ESICM) investigated the current practices associated with RRT from 272 doctors.[12] Despite a high number of respondents, the survey had limited technical descriptions of technique and prescription, but did provide insight into practices relating to dose, modality and intensivists' beliefs about optimal management of RRT. A survey of 167 intensivists in 2009 and 2010 investigated the management of AKI and RRT in the United Kingdom.[13] Modality and dose were addressed, with little information on specific technical prescription. Our survey, with a large representative sample from Australian and New Zealand ICUs, is the largest examination of the technical prescription of CRRT since publication of, and recommendations from, the RENAL and ATN studies.

Mode of therapy

The dominant mode of CRRT in Australia and New Zealand is CVVHDF, with 54% of respondents indicating that they always use it, and CVVH (9%) and CVVHD (2%) being less frequently favoured. Before the RENAL study, 62% of ICUs (21 of 34) indicated CVVHDF as their preferred mode.[10] ICUs had previously reported a higher use of CVVH, at 35% of ICUs (12 of 34), compared with our findings.[10] Internationally there remains great variation in practice in relation to modality of choice. The ESICM survey reported only a slight favour towards CVVHDF (50.9%) compared with CVVH (40.6%).[12] In the UK, CVVH is the dominant mode (56%) compared with CVVHDF (37%).[13] In the US, the pre-ATN practice survey conducted in 2003 indicated that 112 practitioners (86.2%) prescribed some form of CRRT in the 27 sites investigated.[11] Of these responders, most used CVVHD (78 of 112), followed by CVVHDF (67 of 112), with CVVH used in fewer than one-third of patients requiring continuous artificial renal support. It appears from these data that when nephrologists are prescribing and/or closely advising intensivists in the US, dialysate or diffusion is a mainstay for prescription by mode.

The use of CVVHDF and CVVH requires the administration of replacement solution. Our data suggest for both these modes that a combination of before-and-after dilution replacement is favoured by one-third of respondents. Historically, there is variability, with some ICUs exclusively using before-only (predilution) or after-only (postdilution) sites for substitution fluid administration. In contrast to our current findings, the Australian and New Zealand pre-RENAL practice survey conducted in 2004 reported 94% of ICUs using a predilution approach in CVVH and CVVHDF,[10] suggesting a change in practice over the past 10 years. The BEST Kidney study reported a slight favour for predilution (58%) compared with postdilution only (41%).[1] The recent ESICM and UK surveys[12,13] showed similar findings to our own: a combination of predilution and postdilution was most commonly used, with typically 30%–50% of replacement fluid delivered before dilution. It is likely, given the technological advancement of the machines used for CRRT, that this change in practice may be common. RRT machines now have the capacity to deliver replacement fluid before and after filtration, with new software and added roller pumps to achieve this dual pathway simultaneously. Therefore, the change may simply be because this is possible, or because when clotting occurs commonly in the filter or membrane and the postfilter bubble trap within the circuit, dilution into the blood path targets these two points to prevent clotting.[17]

Dose

In the pre-RENAL practice survey, no Australian or New Zealand ICU reported prescribing CRRT according to patient weight. During a similar period there was minimal prescribing of CRRT according to weight in other practice surveys.

In the US, fewer than 20% of practitioners based the dose on patient weight, with most (80%) prescribing at least 35 mL/kg/hour.[11] Ricci and colleagues described uncertainty, particularly among intensivists, about treatment prescription, but indicated a target dose of 35 mL/kg/hour or 2–3 L/hour.[16] The BEST Kidney study reported treatment doses in mL/hour with a median standardised CRRT dose of 2 L/hour and a calculated weight-adjusted dose of 20.4 mL/kg/hour.[1]

A decade on, we report that half the ICUs in Australia and New Zealand describe a weight-based dosing prescription of mL/kg/hour. Further, a CVVHDF dose of 16–25 mL/kg/hour was the most common dose, followed by > 25 mL/kg/hour. If CVVH was the mode of choice, a dose of > 25 mL/kg/hour was the most frequently used. For Australian and New Zealand ICUs prescribing in L/hour, a dose of 1 L/hour (R) and 1 L/hour (D) is the most common in CVVHDF, and 2–3 L/hour in CVVH mode. In contrast, the ESICM survey described a median CRRT dose of 35 mL/kg/hour, with < 15% of respondents prescribing a standard, fixed ultrafiltrate dose, irrespective of body weight.[12] As with the European survey, 73% of UK ICUs use a protocol for CRRT dose with a CVVH dose of 35 mL/kg/hour being the most frequent prescription.[13]

Blood flow rate

One aspect of practice with ongoing variation is the speed of blood flow in the extracorporeal circuit. Before more advanced CRRT technology, blood flow rates of 150–200 mL/minute were common. Certainly the Australian and New Zealand data from 2004 indicated a median blood flow rate of 200 mL/minute,[10] with the BEST Kidney study[1] and prepractice ATN study[11] reporting a median rate of 150 mL/minute. Interestingly, in the country breakdown, the median blood flow rate in Japan was 80 mL/minute, but in Australia, the Netherlands, Portugal and the UK, the median blood flow rate was 200 mL/minute. Our study showed that although 150–200 mL/minute was still the dominant setting for all CRRT modes, a faster rate of 200–250 mL/minute is now commonplace in Australian and New Zealand ICUs. We do not have any data on blood flow rates from more recent practice surveys, but observational studies report practices of using between 100 mL/minute and > 300 mL/minute, indicating great variability and limited evidence for best practice for this therapy.[18,19]

Vascular access

The site for vascular access for CRRT may be the most important variable for circuit life success.[20-22] There is much literature devoted to access site, type, design and catheter-related complications.[23-30] The internal jugular vein is the site traditionally considered preferable to femoral venous access,[20,31] and this choice is supported by the ADQI and Kidney Disease Improving Global Outcomes (KDIGO) consensus guidelines.[32,33] Despite this, femoral access catheters are frequently used in the delivery of CRRT[19,26] and may have a lower incidence of dysfunction and bacterial colonisation compared with jugular sites in patients with a lower body mass index.[26,27] Access sites in relation to right and left venous positions have also been investigated, with some studies suggesting that longer circuit lifespans may occur with use of the right femoral and right internal jugular veins, compared with a left-sided approach.[25,28] To our knowledge, there are no data to clarify clinician preference in relation to site, length or type. No previous or current RRT practice surveys have included vascular access as an item of interest. Our data from Australia and New Zealand indicate that the right and left femoral veins are the sites of choice, followed closely by the right internal jugular vein. A catheter length of 20 cm was the most commonly used, for all sites, with just under half the respondents indicating that 24–25 cm catheters were used in femoral veins. This may indicate that a longer catheter is not considered necessary by some, and that the 20 cm version can be used in both the femoral and internal jugular vein sites, making ordering and stocking of the device simpler. Others using the longer 24–25 cm catheter for femoral access in adults may use this to place the catheter tip closer to the right atrium and would need to order and stock both lengths.

Anticoagulants

Respondents indicated that CRRT is often performed without the aid of an anticoagulant. When patients received an anticoagulant, unfractionated heparin (UFH) was the most commonly used, with over 80% of ICUs using it to extend circuit life. This finding is consistent with previous practice surveys from a decade earlier which also indicated UFH as the anticoagulant of choice.[1,16] This approach is likely to be due to historical reasons, the predictability of outcomes and clinician familiarity with heparin use. Despite recent studies showing a better circuit life, and literature guiding the choice of CRRT anticoagulant towards use of regional techniques with citrate,[34-38] this has not translated into current practice patterns. Only a small proportion of respondents indicated that they frequently used the technique. Factors affecting citrate use may include less historical use, unfamiliarity with citrate compared with heparin, and cost.

Strengths and limitations

A strength of our study is the generalisability of the findings. Despite an unknown response rate, we gathered information from 106 hospitals in Australia and New Zealand, potentially representing 73% of all ICUs capable of performing RRT. This study therefore is the largest

investigation of Australian and New Zealand CRRT practice ever conducted.

Our study has several limitations. The accuracy of the responses could not be independently verified, as the prescription of CRRT practice was self-reported rather than by observation or collection of treatment data. The pre-RENAL,[10] ATN[11] and recent practice surveys have used a self-reporting approach. We did not obtain information about the use of, or prescribing practices associated with, alternative renal support therapies, such as IHD or SLEDD. Despite some increasing interest in prolonged intermittent therapies such as SLEDD, it has been previously reported that patients in Australian and New Zealand ICUs spend < 5% of their renal support time receiving a therapy other than CRRT.[11] We received 194 responses from 106 ICUs, indicating multiple respondents from a single ICU and the potential for reporting disagreement. When multiple responses from one site were received, individual surveys from the site were checked for consistency of practice patterns. Five ICUs with multiple responses and some inconsistencies in self-reported practice were contacted for clarification of usual CRRT prescription.

Recommendations for research

We chose to determine current practices rather than explore clinicians' perceptions of the optimal approaches to CRRT prescription, or if they prescribe according to any published evidence. It would be useful to explore the opinions of individual clinicians about their practice of CRRT, with specific themes of initiation or optimal timing, dose prescription and modality choice for specific patient groups, as well as how technical or practical prescription settings are decided in ICUs. A cross-sectional study or point prevalence study would also provide more objective and reliable data for the prescription and delivery of RRT for Australian and New Zealand ICU inpatients, further highlight consistent or inconsistent current practices, and provide useful data that may help with the design of control groups for future trials. There is also a need to continue developing a data and evidence base for the most effective aspects of CRRT. There appears to be a need to examine effective strategies for implementing results of past studies into daily practice. Data from large published trials have not changed many aspects of practice in Australia and New Zealand.

Conclusion

Our prospective survey of 194 clinicians from 106 ICUs in Australia and New Zealand on technical and practical aspects of CRRT suggests that, a decade on from the last practice survey and the dissemination of dose findings from Australia and New Zealand, there remains a high variability in the practical prescription of CRRT. This lack of uniformity, particularly in blood flow rates, access catheter length and replacement fluid site, highlights the lack of adequate randomised controlled trials (RCTs) to provide evidence for CRRT guidelines. The variability in dose and dose prescription emphasises an inconsistent approach to therapy, despite large RCTs and recommendations on the management of CRRT from recently published KDIGO guidelines. Our study shows the lack of standardisation in the application of CRRT in the critically ill.

Competing interests

None declared.

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Appendix

This appendix was part of the submitted manuscript and has been peer reviewed. It is posted as supplied by the authors.

Continuous renal replacement therapy practice survey

1. Please identify the location of your hospital

- North Island of New Zealand
- South Island of New Zealand
- Queensland
- New South Wales
- Victoria
- Australian Capital Territory
- South Australia
- Tasmania
- Western Australia
- Northern Territory

2. To ensure hospital data is not duplicated, can you please type the name AND location of your hospital

_____

3. Indicate your position in your Intensive Care Unit

- Consultant Intensivist
- Medical (other)
- Nurse Unit Manager (Charge Nurse)
- ICU based Educator
- Clinical Nurse Consultant
- Associate Nurse Unit Manager (Team leader)
- Research Nurse

- Clinical Nurse Specialist
- Registered Nurse

4. What best describes your Intensive care unit

   - Regional Hospital
   - Metropolitan Private Hospital
   - Metropolitan Public Level 2
   - Metropolitan Public Level 3

5. What best describes your Intensive care unit

   - Adult Intensive Care only
   - Paediatric Intensive Care only
   - Combined Adult Paediatric Intensive Care

6. What is the size (number of beds) of your Intensive care unit

   - 0-5 beds
   - 6-10 beds
   - 11-15 beds
   - 16-20 beds
   - > 20 beds

7. Estimate or approximate the number of patients treated with CRRT per year in your ICU
   - < 10
   - 11 – 25
   - 26 – 50
   - 51 – 75
   - 76 – 100
   - > 100
   - Don't Know

8. How often would you use the following modes of CRRT
   Please respond to all options in list below

	Never	Occasionally	Frequently	Always

CVVH (Predilution)

CVVH (Postdilution)

CVVH (Pre+Post dilution)

CVVHDF (Predilution)

CVVHDF (Postdilution)

CVVHDF (Pre+Post dilution)

CVVHD

9. The standard dose or treatment of CRRT in your ICU is measured in:

- mls/kg
- litres /hr

10. How often do you set the following prescription (Replacement and/or Dialysate) rate? Respond to all options in the list below

	Never	Occasionally	Frequently	Always
CVVH **≤ 2 Litres**				
CVVH **> 2 L but < 3 Litres**				
CVVH **≥ 3 Litres**				
CVVHDF **(1L Replacement + 1L Dialysate)**				
CVVHDF **(1.5L Replacement + 1.5L Dialysate)**				
CVVHDF **(2L Replacement + 2L Dialysate)**				
CVVHDF **(>2L Replacement + >2L Dialysate)**				

11. How often do you set the following exchange (Replacement and/or Dialysate) rate? Respond to all options in the list below

	Never	Occasionally	Frequently	Always
CVVH **0-15 mls/kg**				
CVVH **16-25 mls/kg**				
CVVH **>25 mls/kg**				
CVVHDF **0-15 mls/kg**				
CVVHDF **16-25 mls/kg**				
CVVHDF **>25 mls/kg**				

12. How often would you use the following blood pump speed (blood flow rate) in CVVH?

	Never	Occasionally	Frequently	Always
0-50 mls/min				
51-100 mls/min				
101-150 mls/min				
151-200 mls/min				
201-250 mls/min				
251-300 mls/min				
> 300 mls/min				

13. How often would you use the following blood pump speed (blood flow rate) in CVVHDF?

	Never	Occasionally	Frequently	Always
0-50 ml/min				
51-100 mls/min				
101-150 mls/min				

151-200 mls/min

201-250 mls/min

251-300 mls/min

> 300 mls/min

14. In response to frequent alarms (High TMP, Venous pressure, Low Access pressure), do you manipulate/alter the blood flow rate (pump speed) in order to continue treatment

Never Occasionally Frequently Always

15. How often would you use vascular access catheters (Vascaths) in the following locations

	Never	Occasionally	Frequently	Always
Left Internal Jugular				
Right Internal Jugular				
Left Femoral				
Right Femoral				
Left Subclavian				
Right Subclavian				
Other				

16. For the vascular access site indicated above, select the Vascath length you use (cms)

	15 cm	20 cm	24/25 cm
Internal Jugular			
Subclavian			
Femoral			

Other (please specify)

17. Please indicate your Anticoagulation choice for CRRT in your ICU
    Please respond to all options below

	Never	Occasionally	Frequently	Always
Unfractionated Heparin				
Regional Heparin (heparin + protamine)				
Citrate CVVH				
Citrate CVVHDF				
Clexane				
Prostacyclin				
No Anticoagulation				

Other (Please specify)

18. How often would you use the following vascular access types in your intensive care unit

	Never	Occasionally	Frequently	Always
Bard Niagara				
Gambro Dolphin				
Quinton Mahurkar				
Medcomp				
Arrow				
Cook				

Other

Don’t know the access
make/type

19. Which of the following best describes how blood flow rates are chosen / prescribed?

    Nurse initiated

    Medical initiated

    Protocol or unit policy (standard)

    Other

20. Which of the following machines do you use for CRRT

    - Prisma
    - Prismaflex
    - Aquarius
    - Infomed HF440
    - Other