

Vascular access site influences circuit life in continuous renal replacement therapy

Ashley Crosswell, Matthew J Brain and Owen Roodenburg

Acute kidney injury (AKI) requiring continuous renal replacement therapy (CRRT) is common in intensive care unit patients, with a prevalence of about 4%.¹ CRRT is the preferred mode of renal support² in Australian ICUs. Effectiveness of this mode requires maintaining patency of an extracorporeal circuit over extended periods. A major impediment to achieving adequate support is premature circuit failure. This may depend as much on the adequacy of vascular access as on other factors, such as circuit anticoagulation.

The site of vascular access has previously been investigated in relation to catheter performance in achieving adequate catheter blood-flow rates.³ Achieving target blood flow is particularly important in intermittent haemodialysis (commonly using flows in excess of 250 mL/min); however, this parameter may not be as useful in assessing CRRT with lower blood-flow rates. In this retrospective audit of ICU patients receiving CRRT, we assessed whether different vascular access sites influenced the total time for which blood flowed through each extracorporeal circuit.

Methods

The Alfred Health Human Ethics Committee and the Monash University Human Research Ethics Committee approved the study. We identified the unique record (UR) numbers of patients who received CRRT between June 2011 and May 2012 in the Alfred ICU computer database. UR numbers were then used to identify the CRRT vascular access device used for each patient, including site and side; the dates of insertion and removal (from the ICU procedures database); and clinical history. We cross-checked the site location with radiological studies.

Over this study interval, vascular access was via 12 Fr dual-lumen temporary dialysis catheters 15 cm or 24 cm in length (Dolphin Protect, Gambro Lundia AB); tunnelled 14.5 Fr internal jugular vein semipermanent catheters (Palindrome, Covidien AG; or Hemosplit, Bard Access Systems); or directly via an extracorporeal membrane oxygenation (ECMO) circuit.

The UR numbers we identified were used to link vascular access site to data extracted and processed from the Prismaflex CRRT platform (Gambro). Linkage was performed by UR number and date range. The response variable was cumulative run time of each circuit, a novel

ABSTRACT

Objective: To determine the influence of vascular access site on continuous renal replacement therapy (CRRT) filter survival.

Design, setting and patients: Retrospective study of the records of patients who received CRRT in The Alfred intensive care unit from June 2011 to May 2012.

Main outcome measure: Filter run time.

Methods: We matched filter run time to site and type of vascular access. Mean run times were compared using a linear mixed-effects model between: temporary femoral, internal jugular (IJ) and subclavian catheters, tunnelled semipermanent IJ catheters, and extracorporeal membrane oxygenation (ECMO) circuit access. The Markov chain Monte Carlo method was used to construct 95% confidence intervals, and the Wilcoxon rank sum test was used for post hoc testing of significance.

Results: Filter run-time data were available for 131 patients (191 occasions of vascular access) with a total of 870 individual filters analysed. Mean run times were subclavian, 14.4 h; IJ, 17.1 h; femoral, 20.2 h; tunnelled IJ, 25.2 h; and ECMO, 29.0 h. Differences were significant for all combinations except between subclavian and IJ, and between tunnelled access and ECMO. Sites in order of best-performing to worst-performing were ECMO circuit, tunnelled IJ, femoral vein, direct IJ vein, and subclavian vein.

Conclusion: Vascular access for CRRT plays a significant role in determining filter life. Our study suggests that for temporary dialysis catheters the femoral site should be favoured in ICU patients, and if CRRT is likely to continue for an extended period, a tunnelled IJ line should be considered.

Crit Care Resusc 2014; 16: 127–130

parameter describing the length of time for which blood flowed in the extracorporeal circuit, and, hence, duration of therapy delivery.

Circuit anticoagulation was protocolised according to The Alfred ICU CRRT anticoagulation guidelines with deviations permitted at the clinician's discretion. Options included no anticoagulation, regional heparin, regional heparin with

Table 1. Number of access lines and filters, by site

Site	No. of access lines	No. of access lines left/right	No. of filters	No. of filters left/right
Subclavian	13	6/7	80	22/58
Internal jugular	53	22/31	234	108/126
Femoral	94	39/55	393	148/245
Tunnelled internal jugular	15	8/7	60	38/22
ECMO circuit	16	na	103	na

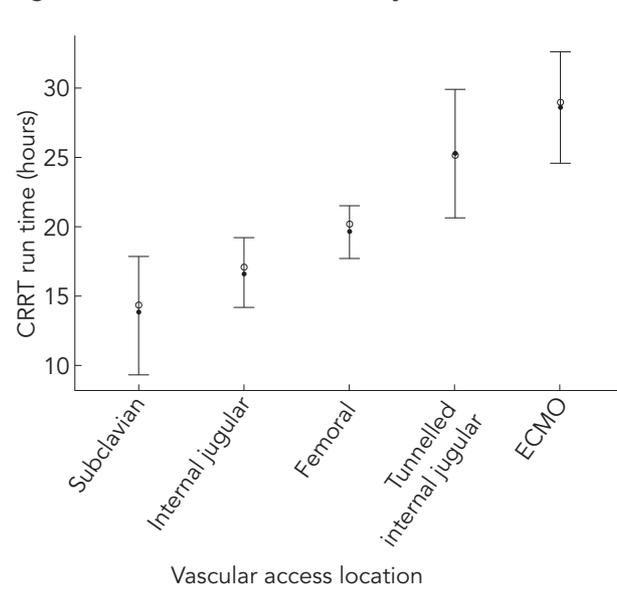
ECMO = extracorporeal membrane oxygenation. na = not applicable.

Table 2. Mean run time, by site

Site	Model estimate of mean run time, h	MCMC estimate of mean run time, h (95% CI)
Subclavian	14.38	13.84 (9.54–18.04)
Internal jugular	17.09	16.62 (14.19–19.18)
Femoral	20.20	19.67 (17.81–21.60)
Tunnelled internal jugular	25.15	25.29 (20.66–29.85)
ECMO circuit	28.97	28.57 (24.56–32.53)

MCMC = Markov chain Monte Carlo. ECMO = extracorporeal membrane oxygenation.

Figure 1. Mean filter run time, by site*



* Open circles represent the linear mixed-effects model estimates of the mean. Closed circles and 95% confidence intervals are Markov chain Monte Carlo sampling estimates from the mixed-effects model.

protamine reversal, systemic heparinisation, and regional citrate.

Vascular access devices were classified as being left or right temporary internal jugular vein, subclavian vein, or common femoral vein dialysis catheters; left or right tunnelled internal jugular vein semipermanent catheters; or connected to an ECMO circuit.

Statistical analysis and figure creation was performed in R (R version 3.0.1 with dependent packages) using a linear mixed-effects model fitted by restricted maximum likelihood estimation for repeated measures of run time with vascular access site (fixed effect) nested within patient as a random effect. Confidence intervals were constructed using Markov chain Monte Carlo (MCMC) analysis with 10 000 iterations. Both model estimates and MCMC means are reported. Wilcoxon rank sum tests corrected for multiple comparisons by the Holm method were used for post hoc testing of significance between access sites.

Results

Our initial search identified 284 vascular access sites from 160 patients. Linkage to recorded data for filter run time was achieved for 191 vascular access sites from 131 patients with a total of 870 individual filters available for analysis. The number of filters analysed from each vascular access site is shown in Table 1.

The model estimate of mean run time differed between vascular access sites and type. The estimate of mean run time and the run time from MCMC analysis for each site are presented in Table 2 and Figure 1.

Post hoc comparisons of groups reached significance for all combinations except between subclavian and internal jugular sites and between tunnelled access and ECMO (Table 3).

Comparison was also made between left- or right-sided placement of devices at each site. This revealed a similar trend to analysis by site alone, though differences did not reach statistical significance (Table 4 and Figure 2).

Discussion

Vascular access is a major determinant of circuit survival,⁴ with access insufficiency leading to intermittent reductions in circuit blood flow, which in turn decreases circuit life.⁵ The mechanisms of dialysis catheter dysfunction involve increased resistance to flow secondary to tip occlusion (venous suck down), kinking, strictures and later thrombotic complications with intraluminal or extrinsic thrombosis.⁶ Importantly, premature circuit loss leads to increased patient blood loss (and increased blood transfusion), decreased effective RRT delivery and increased cost. However, much of

Table 3. Post hoc comparisons of run time between sites with *P* values corrected by the Holm method

	Internal jugular	Femoral	Subclavian	Tunnelled internal jugular
Femoral	0.013			
Subclavian	0.521	0.005		
Tunnelled internal jugular	<0.001	0.016	<0.001	
ECMO	<0.001	<0.005	<0.001	0.778

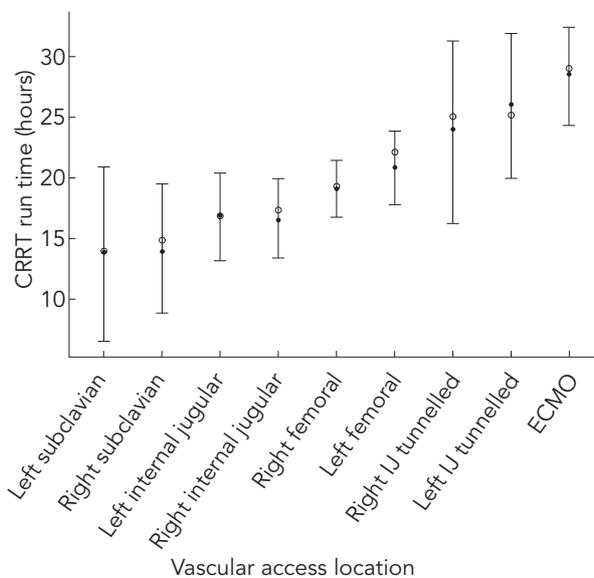
ECMO = extracorporeal membrane oxygenation.

Table 4. Mean run time, by site and side of vascular access

Site	Side	No. of access lines	Model estimate of mean run time, h	MCMC estimate of mean run time, h (95% CI)
Subclavian	L	6	13.97	13.87 (6.31–20.48)
	R	7	14.86	13.92 (8.66–19.34)
Internal jugular	L	22	16.84	16.84 (13.25–20.48)
	R	31	17.36	16.50 (13.20–19.81)
Femoral	L	39	22.12	20.87 (17.91–23.95)
	R	55	19.29	19.08 (16.77–21.50)

L = left. R = right. MCMC = Markov chain Monte Carlo.

Figure 2. Mean filter run time, by site and side*



* Open circles represent linear mixed-effects model estimates of the mean. Closed circles and 95% confidence intervals are Markov chain Monte Carlo sampling estimates from the mixed-effects model.

the evidence regarding optimal vascular access site relates to ambulatory intermittent haemodialysis patients, and not to immobile ICU patients undergoing CRRT at lower blood-flow rates.

This study suggests that site of vascular access for CRRT plays a significant role in determining filter life. The ECMO circuit allows direct access and is not limited by dialysis catheter function. Therefore, ECMO provides a control with which to compare the hierarchy of routinely available CRRT access sites. Our results show that positive pressure access from the ECMO circuit (which is always under closely monitored therapeutic anticoagulation) provides the longest filter run time, and hence, survival of the filter. This was significantly better than any of the temporary dialysis catheters placed in subclavian, internal jugular or femoral veins.

In our institution, fluoroscopically placed internal jugular vein tunnelled semipermanent catheters are used when it is

predicted that a patient will require longer-term CRRT, or as a step towards chronic intermittent haemodialysis in the dialysis unit after ICU discharge. Our data suggest that when tunnelled semipermanent internal jugular catheters are used for CRRT, run times comparable to those with ECMO circuit access can be achieved. Tunnelled lines provide significantly better run times than temporary dialysis catheters in the femoral, internal jugular or subclavian sites. Possible reasons for improved run time with these catheters include larger internal lumen diameter, more accurate catheter tip placement at the junction of the superior vena cava and right atrium, and less propensity to kink at the insertion site. This raises the question of when semipermanent tunnelled internal jugular insertion should be contemplated for CRRT access in ICU patients. It may be a reasonable approach to pursue tunnelled internal jugular access if a patient is judged to be likely to require renal support for more than a week.

Comparison of the temporary dialysis catheter sites showed significantly better filter life with femoral vein access compared with internal jugular vein and subclavian vein catheterisation. A significant difference could not be detected between internal jugular and subclavian vein catheterisation. These findings are different to the secondary analysis of the Cathedia randomised controlled trial, which found there was no difference in rates of catheter dysfunction or dialysis performance between the femoral and internal jugular sites.³ However, that study included a

large proportion of critically ill patients undergoing intermittent haemodialysis, and for the patients undergoing CRRT the test parameter was median downtime per 24 hours, not filter run time, which was our main outcome measure.

Our study did not detect any difference in filter run time between temporary dialysis catheters placed in the right femoral compared with the left femoral positions, and does not support the previous finding that right-sided placement significantly improved filter life in CRRT.⁷ Our result is unlikely to be due to a lack of power, given that filters from 94 temporary femoral dialysis catheters were analysed, compared with 50 in the previous study.⁷ Likewise, no significant difference was detected between the filter run times of left internal jugular and right internal jugular temporary dialysis catheters in the 53 such catheters studied.

The limitations of this study relate to it being retrospective and non-randomised. Although initially 160 patients were identified as having undergone CRRT, we were only able to match extracted filter run-time data for 131 patients. This was a consequence of failure to enter patient UR numbers at the time of filter set-up, and resulted in only being able to analyse 191 occasions of access from a possible 284. The allocation of vascular access site was not random, with femoral access being preferred in our institution for the first temporary dialysis catheter. This temporal preference may influence the outcome, as coagulopathy and deeper sedation earlier in the ICU course might favour function of earlier catheters. Another limitation is that anticoagulation, although protocolised, was not standardised across groups. Most notably, the ECMO patients are routinely maintained on therapeutic systemic heparinisation and this might have positively influenced CRRT filter run times. A randomised controlled trial by group would alleviate many of these confounders.

The run-time parameter used in our study gives an indication of both filter performance and circuit survival. The findings of our audit suggest that tunnelled internal jugular access is the most effective and best prolongs filter life compared with temporary dialysis catheters for CRRT. This warrants further investigation with regard to the cost, benefits and risks of tunnelled catheters in ICU patients on prolonged CRRT. Of the non-tunnelled temporary dialysis catheters, femoral vein access appears to be the most effective at prolonging filter life. Within the limits of this retrospective audit, these findings should be taken into

account when determining unit preference for the location of temporary dialysis catheters.

Acknowledgements

We thank John McNeil, Head of the School of Public Health and Preventive Medicine, Monash University, Australia, for reviewing the manuscript, and Eldho Paul, School of Public Health and Preventive Medicine, Monash University, Australia, for statistics advice.

Competing interests

None declared.

Author details

Ashley Crosswell, Registrar¹

Matthew J Brain, Intensivist,^{2,3} and Clinical Lecturer⁴

Owen Roodenburg, Intensivist, Deputy Director of Intensive Care and Head of Trauma Intensive Care Unit¹

1 Department of Intensive Care, The Alfred, Melbourne, VIC, Australia.

2 Launceston General Hospital, Launceston, TAS, Australia.

3 School of Public Health and Preventive Medicine, Monash University, Melbourne, VIC, Australia.

4 University of Tasmania, Launceston, TAS, Australia.

Correspondence: Ashley.Crosswell@mh.org.au

References

- 1 Uchino S, Kellum JA, Bellomo R, et al. Acute renal failure in critically ill patients: a multinational, multicenter study. *JAMA* 2005; 294: 813-8.
- 2 RENAL Study Investigators. Renal replacement therapy for acute kidney injury in Australian and New Zealand intensive care units: a practice survey. *Crit Care Resusc* 2008; 10: 225-30.
- 3 Parienti J, Megarbane B, Fischer M, et al; Cathedia Study Group. Catheter dysfunction and dialysis performance according to vascular access among 736 critically ill adults requiring renal replacement therapy: a randomized controlled study. *Crit Care Med* 2010; 38: 1118.
- 4 Joannidis M, Oudemans-van Straaten. Clinical review: patency of the circuit in continuous renal replacement therapy. *Crit Care* 2007; 11: 218.
- 5 Baldwin I, Bellomo R, Koch B. Blood flow reductions during continuous renal replacement therapy and circuit life. *Intensive Care Med* 2004; 30: 2074-9.
- 6 Canaud B, Desmeules S, Klouche K, et al. Vascular access for dialysis in the intensive care unit. *Best Pract Res Clin Anaesthesiol* 2004; 18: 159-74.
- 7 Kim IB, Fealy N, Baldwin I, et al. Insertion side, body position and circuit life during continuous renal replacement therapy with femoral vein access. *Blood Purif* 2011; 31: 42-6. □