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Original Article

Access

Safety of arteriovenous fistulae and grafts for continuous renal replacement therapy: The Michigan experience

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Abstract

Introduction: Arteriovenous fistula or graft (AVF/AVG) use is widely considered contraindicated for continuous renal replacement therapy (CRRT), yet insertion of hemodialysis (HD) catheters can carry high complication risk in critically ill end-stage renal disease (ESRD) patients.

Methods: Single-center analysis of 48 consecutive hospitalized ESRD patients on maintenance HD who underwent CRRT using AVF/AVG from 2012 to 2013. Primary outcome was access-related complications.

Findings: Mean age was 60 years, 48% were male, and 88% required vasopressor support. Median duration of AVF/AVG use for CRRT was 4 days (range 1–34). Ten (21%) patients had access complications (5 bleeding, 5 infiltration, 1 thrombosis); 5 (10.4%) required catheter placement. Overall 31 (65%) patients survived to hospital discharge and AVF/AVG access was functional at the time of discharge in 29 (94%) patients.

Discussion: In our experience, use of AVF/AVG for CRRT can be performed with a low serious complication rate and low risk of access loss, potentially avoiding catheter-related complications.

Key words: CRRT, patient safety, arteriovenous fistula, arteriovenous graft

INTRODUCTION

Patients with end-stage renal disease (ESRD) undergoing maintenance hemodialysis (HD) are hospitalized an average of 1.7 times per patient per year.[1] During hospitalization, ESRD patients are typically managed using a similar prescription to their outpatient regimen. An exception, however, is in critically ill patients admitted to the intensive care unit (ICU) who may require continuous renal replacement therapy (CRRT). In these situations, dialysis catheters are considered the preferred access for CRRT and the use of an arteriovenous fistula (AVF) or arteriovenous graft (AVG) is widely considered contraindicated due to concerns about patient safety and access longevity.[2–4]

As such, most centers place temporary dialysis catheters in ESRD patients who require CRRT, even in the presence of a functional AVF or AVG. Yet insertion of catheters may be complicated due to a significant history of prior vascular catheterizations in many ESRD patients, and exposes patients to the risk of mechanical complications.[5] Presence of an indwelling dialysis catheter also increases the risk for infectious complications in this high-risk population.[6,7]

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In our tertiary care center, we routinely use functional AVF/AVG for access when CRRT is prescribed in ESRD patients. Here we describe our experience over a 2-year period, focusing on safety and efficacy outcomes.

METHODS

Subjects and setting

This single-center, retrospective study was performed at the University of Michigan Health System (UMHS) in Ann Arbor, Michigan. Inclusion criteria consisted of:

1. Age $\geq$ 18 years;
2. Diagnosis of ESRD on maintenance HD;
3. Functional AVF or AVG as their dialysis access;
4. Underwent CRRT during the two-year period of 2012 through 2013.

Patients were excluded if they were on maintenance peritoneal dialysis (PD) or if they were catheter-dependent prior to initiation of CRRT. The protocol was approved by the University of Michigan Institutional Review Board with a waiver for informed consent.

CRRT vascular access protocol

The decision to utilize an AVF/AVG for CRRT access (vs. placing a new dialysis catheter) is at the discretion of the nephrology dialysis consult team. General considerations include expected duration of CRRT, patient cognitive status, presence of coagulopathy, and baseline functionality of the access. CRRT is performed at UMHS using a regional citrate anticoagulation protocol in hemodiafiltration (CVVHDF) mode, with blood flow rates of 150 to 200 mL/min and target prescribed effluent dose of 25 to 30 mL/kg/h.

CRRT is performed on a cooperative basis between the dialysis team and ICU nursing. In the ICU, nursing staff with at least one year of ICU experience are eligible to undergo CRRT-specific training. This consists of eight hours of didactic class with a hands-on component, followed by 12 hours of bedside orientation with direct supervision and checklist requirement. Training specific to AVF/AVG use encompasses anatomical description of flow patterns, dressing integrity including use of arm boards for stability as needed, and needle discontinuation in the case of infiltration or other complication.

CRRT access needles (steel, 15 gauge) are placed and exchanged by dialysis nursing staff following similar procedures to standard intermittent HD. While dialysis nurses take primary responsibility for needle placement/adjustment/removal, ICU nurses are trained to identify complications (such as infiltration) and to remove needles in emergent situations. The access is to be available for direct visualization at all times, and integrity of the access is checked on an hourly basis by the bedside ICU nurse and examined daily by a dialysis nurse. By policy, access needles are routinely replaced at least every 96 hours or after any down time exceeding 12 consecutive hours. For procedures with expected short duration, CRRT needles are kept in place and capped after disconnection from the CRRT machine. Once CRRT is initiated via AVF/AVG, the dialysis nurse hands off care to the bedside ICU nurse, but remains available for troubleshooting.

Data collection

Data were collected through review of the medical chart, nursing notes, as well as incident reports. In addition to basic demographics, information on comorbidities and primary diagnosis for ICU admission was collected. Pre-existing access problems, defined as prolonged bleeding, any access intervention within the past year (e.g., fistulogram with angioplasty), or aneurysm, were also recorded. Additional data included length of ICU stay and duration of vasopressor and CRRT requirements. We collected data on complications that developed during use of the CRRT access, defined as bleeding around needles, infiltration/hematoma, or thrombosis. The number of patients requiring catheter placement, viability of original vascular access at discharge, and patient survival to hospital discharge were also captured.

Outcome measures

The primary outcomes were the type of dialysis access at the time of hospital discharge, as well as the rate of complications of using AVF/AVG for CRRT access. Secondary outcomes included in-hospital mortality and complications associated with the placement of new dialysis access.

Statistical analyses

For this descriptive study, categorical variables were presented as percentages, while continuous variables were presented as means with standard deviations when normally distributed, or as medians with interquartile range when nonnormally distributed.

RESULTS

Subjects

There was a total of 95 ESRD patients who required CRRT during the study period. Forty-seven (49%)

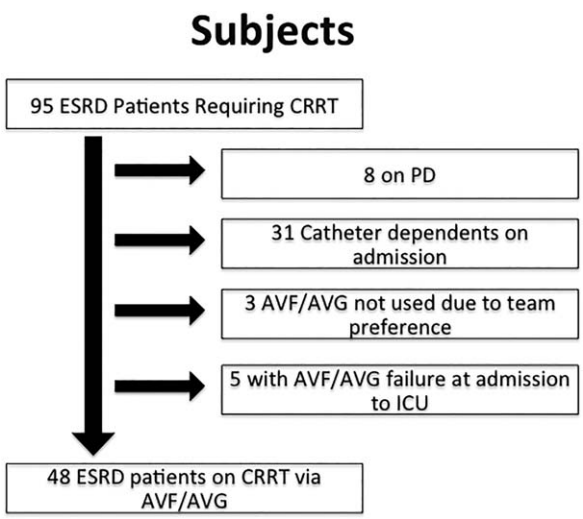

Figure 1 Patient flow diagram. A description of the initial study cohort with application of exclusion criteria. Hemodialysis (HD); peritoneal dialysis (PD); acute kidney injury (AKI); arteriovenous fistula (AVF); arteriovenous graft (AVG); continuous renal replacement therapy (CRRT).

patients were excluded from further analysis because they did not undergo CRRT using an AVF or AVG (Figure 1). A clinical decision was made to not use the AVF/AVG in 3 of these patients (1 dysfunctional, 1 aneurysmal, 1 "save for intermittent HD"). The final cohort consisted of 48 patients. A summary of patient characteristics is presented in Table 1. Approximately half of the patients were male, with mean age 59.6 years and a mean dialysis vintage 66.3 months. The majority (37/48, 77%) had an AVF as their dialysis access, and 25% of all patients had documented pre-existing access problems. Most patients (42/48, 87.5%) required vasopressors. The majority of the patients were either sedated (64.6%) or awake and following commands (27.1%) when treatment was started; four patients were confused and not sedated at the time of the CRRT initiation. The median duration of CRRT was 4 days, with a range from 1 to 34 days (Table 2).

Vascular access complications

Ten patients (20.8%) had a CRRT-related access complication (Table 3), and eight of these patients had an AVF as their dialysis access. Five of these 10 patients (10.4% of the total cohort) required catheter placement, 4 of whom had pre-existing access issues documented before admission. Of patients who required catheter insertion, 1 required blood products for line placement and 1 subsequently had a catheter-related bloodstream infection.

Patient outcomes

At discharge, the original dialysis access was viable in 45 of the initial 48 patients (93.8%) and in 29 of the 31 patients (93.5%) who survived to hospital discharge (Table 3). Seven of the ten patients with access complications survived, and five had their original access usable at discharge.

Following discharge, 5 of the 31 surviving patients were documented to have interventions on their access within the subsequent 6-month period. All five accesses were salvaged and usable post-intervention.

Table 1 Characteristics of study patients at initiation of continuous renal replacement therapy

Variable	Patient characteristic (n = 48)
Age in years, mean (SD)	59.6 (11.5), range 33 to 85
Gender (male)	23 (47.9%)
Dialysis vintage in months, median (IQR)	36.0 [17.5, 82.5], range 1 to 300
Dialysis access	
AVF	37 (77.1%)
AVG	11 (22.9%)
Pre-existing access problem: Any	12 (25.0%)
Prolonged bleeding	3 (6.3%)
Access intervention (within past year)	6 (12.5%)
Aneurysm	5 (10.4%)
Diagnosis:	
Septic shock	17 (35.4%)
Cardiogenic shock	23 (47.9%)
Hemorrhagic shock	3 (6.3%)
Other	5 (10.4%)
Comorbidities	
Diabetes mellitus	21 (43.8%)
Hypertension	39 (81.3%)
Congestive heart failure	26 (54.2%)
Coronary artery disease	21 (43.8%)
Peripheral veno-occlusive disease	7 (14.6%)
Mental status	
Awake and alert	13 (27.1%)
Awake and confused	4 (8.3%)
Sedated	31 (64.6%)
Requiring vasopressors	42 (87.5%)

SD = standard deviation; IQR = interquartile range; AVF = arteriovenous fistula; AVG = arteriovenous graft.

Table 2 Treatment characteristics of study patients

Variable	Result (n = 48)
Duration of ICU stay in days, mean (SD)	10.6 (7.0)
Duration of CRRT in days, median (IQR)	4 [3, 6], range 1 to 34
Duration of CRRT using AVF in days, median (IQR)	4 [3, 6], range 1 to 34

ICU = intensive care unit; SD = standard deviation; CRRT = continuous renal replacement therapy; IQR = interquartile range; AVF = arteriovenous fistula.

DISCUSSION

Use of AVF/AVG for CRRT is widely considered to be contraindicated due to concerns for patients' safety and access longevity,[2] yet there are no studies to describe the potential harm resulting from this approach or how it compares to routine use of temporary dialysis catheters. At the University of Michigan, we have employed a protocol to routinely utilize AVF/AVG access in ESRD patients requiring CRRT. During our study period of two years, we did not observe any adverse outcomes that directly affected patient hospital mortality. While access-related complications were not infrequent, these were generally minor and only 10% required dialysis catheter placement. The vast majority of patients (94%) had a viable vascular access at discharge. These findings suggest that AVF/AVG can be used safely and effectively for CRRT care in patients with ESRD, although the long-term safety of this practice requires further evaluation.

Vascular access infiltration or hematoma were the most common adverse effects observed. Indeed, these are relatively common complications even in the general ESRD population; Lee et al. reported an annual major (requiring temporary catheter placement) fistula infiltration rate of 5.2% in a cohort of nonhospitalized ESRD patients.[8] In our population of critically ill patients with hypotension and pressor requirements, it would be reasonable to expect a higher rate of complications. Indeed, both intradialytic hypotension and lower predialysis blood pressure have been identified as independent risk factors for AVF thrombosis.[9] Among the 5 patients who required dialysis catheter placement for access complications, two had their AVF/AVG in use again by the time of hospital discharge. Of the 3 patients who lost their access by the time of discharge, only in 1 patient was this thought to be potentially related to the use of the access for CRRT. One of the other two patients had experienced multiple recent thrombosis episodes prior to ICU admission (and actually already had a new AVF placed awaiting maturation), and the other patient had severe central venous stenosis complicated by thrombosis following a pacemaker insertion during the hospitalization. Therefore, pre-existing access issues may be an important factor in risk stratifying which patients may be suitable candidates for use of AVF/AVG for CRRT.

Use of dialysis catheters for CRRT is the current standard of care, but this may not be a benign procedure. First, there can be a significant delay in initiation of CRRT while awaiting coordination and placement of a new temporary catheter. Second, catheter placement in ESRD patients may be particularly challenging due to many patients having prior vascular cannulations, as underlined by the fact that approximately 80% of incident U.S. ESRD patients have a dialysis catheter as their first access.[1] Although catheter insertion complication rates are not well-described in the ESRD population, studies in other populations support a cautious approach. Denys et al. described 34 cardiac transplant patients in which the internal jugular vein was not visualized, presumably due to occlusion or thrombosis from multiple prior cannulations for right heart catheterization procedures.[10] Similarly, Mansfield et al. found prior catheterization to be a risk factor for failure of central venous catheter insertion.[11] Mechanical complications are another risk that is associated with catheter insertion and they occur despite the use of dynamic "real-time" ultrasound guidance. Arterial puncture has been described at variable rates of 1.39% to 14% of insertions, potentially affected by operator experience.[10,12,13] Additionally, arterial cannulation with large-bore catheters continues to occur with, in many cases, catastrophic outcomes.[5] Last, dialysis catheters, both nontunneled and tunneled, add significant risk for infectious morbidity and mortality.[2,6,7] By using an existing AVF/AVG access, we were able to avoid temporary

Table 3 Outcomes of study patients

Variable	Result (n = 48)
Documented CRRT-related access complication	
Any	10 (20.8%)
Bleeding around needles	5 (10.4%)
Infiltration/hematoma	5 (10.4%)
Thrombosis	1 (2.1%)
CRRT-related access complication, requiring line placement	5 (10.4%)
Access viable at discharge	
All (n = 48)	45 (93.8%)
Among survivors (n = 31)	29 (93.5%)
Survive to hospital discharge	31 (64.6%)

CRRT = continuous renal replacement therapy.

dialysis catheter placement (and any associated risks) in 90% of our ESRD patients requiring CRRT.

One potential risk from using an AVF/AVG for CRRT is unrecognized extravasation due to needle dislodgement. Dislodgment of the arterial needle will invariably lead to a machine alarm for pressure differential or air entering the circuit. However, the return pressure created by the relatively small lumen of the venous cannulation needle may be sufficient to prevent pressure alarms from being triggered even if the needle is dislodged. This risk also exists when an AVF/AVG is used for standard intermittent hemodialysis, and thus vascular access is required to be visible at all times. We employ the same policy to avoid this complication while using AVF/AVG for CRRT; the arm is always exposed and visible to the nurse. During our 2-year study period, there were no instances of unrecognized extravasation related to needle dislodgement.

A critical aspect to the success of using AVF/AVG in our CRRT program is the cooperation between dialysis and critical care nursing. To achieve appropriate buy-in from ICU nurses, who are generally not familiar or comfortable with dialysis vascular access, we maintain an ongoing focus on nursing CRRT education. Understanding that this is a potentially high-risk practice, we promote a safety culture by encouraging routine reporting of all potential adverse events. The institutional CRRT committee, which includes nursing members from each ICU, reviews all CRRT-related safety incidents and disseminates informational updates as needed. In addition, dialysis nurses provide support for any access-related issues.

Our study has some limitations worth noting. First, as a retrospective study, we relied on adequate documentation to identify complications. It is possible that not all complications were appropriately recorded in the medical chart; however, we believe that all serious complications (i.e., affecting patient care, including need for catheter placement) were recorded, either in the medical notes or the patient safety reporting system. Second, very limited data about long-term consequences was available to us as many patients were not longitudinally followed in our center after hospital discharge. However, the primary outcome of the dialysis access at the time of discharge is accurately and completely documented on all the study subjects. Thirdly, because we routinely use AVF/AVG for CRRT whenever feasible, we did not have a comparison group of ESRD patients managed with the alternate strategy of dialysis catheter placement. Importantly, only 1 of our patients lost use of their vascular access potentially related to CRRT, and any benefit from using catheters would need to be weighed against the potential mechanical and infectious risks.

In conclusion, our study suggests that the use of AVF/AVG for CRRT can be both safe and feasible, and this remains the first-line approach at our medical center. Further research to compare this approach to the routine use of catheters for CRRT in the ESRD population, and to evaluate long-term access outcomes, should be conducted to better describe the comparative effects on patient outcome and safety.

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