Clinical Outcomes and Economic Impact of Starting Hemodialysis with a Catheter after Predialysis Arteriovenous Fistula Creation

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Keywords

Arteriovenous fistula · Vascular access

Abstract

Background: Patients with advanced chronic kidney disease frequently undergo arteriovenous fistula creation prior to reaching end-stage renal disease (ESRD), but some initiate hemodialysis with a central vein catheter, if their fistula is not yet usable. The clinical consequences of the delay in fistula use have not been quantified in such patients. We compared patients with pre-ESRD fistula surgery who initiated dialysis with a catheter versus a fistula in terms of the frequency of post-dialysis vascular access procedures and complications and their economic impact. **Methods:** We identified 205 patients with predialysis fistula creation from 2006 to 2012 at a large dialysis center who started hemodialysis within the ensuing 2 years. Of these, 91 (44%) initiated dialysis with a catheter and 114 (56%) with a fistula. We compared these 2 groups in terms of their annual frequency of percutaneous vascular access procedures, surgical access procedures, total access procedures, hospitalizations due to catheter-related bacteremia, and overall cost of vascular access management. **Results:** The 2 groups were similar in demographics, comorbidities, and fistula type. As compared to patients initiating dialysis with a fistula, those initiating with a catheter

had a significantly greater annual frequency of percutaneous access procedures (1.29 [1.19–1.40] vs. 0.75 [0.68–0.82]), surgical access procedures (0.69 [0.61–0.76] vs. 0.59 [0.53–0.66]), total access procedures (1.98 [1.86–2.11] vs. 1.34 [1.26–1.44]), and hospitalizations due to catheter-related bacteremia (0.09 [0.07–0.12] vs. 0.02 [0.01–0.03]). Patients initiating dialysis with a catheter incurred a median overall annual cost of access management that was USD 2,669 higher (USD 6,372 [3,121–12,242] vs. USD 3,703 [1,867–6,953], $p = 0.0001$). **Conclusion:** Among patients with predialysis fistula creation, those initiating dialysis with a catheter versus a fistula had substantially more frequent percutaneous, surgical, and total vascular access procedures, as well as hospitalizations due to catheter-related bacteremia. The annual cost of access management was substantially higher in those initiating dialysis with a catheter.

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Introduction

Current vascular access guidelines recommend pre-emptive placement of an arteriovenous fistula (AVF) in patients with advanced chronic kidney disease (CKD stages 4, 5), with the goal of achieving a mature AVF by the time dialysis is initiated [1]. Despite such advance

planning, about 50% of US patients with pre-end-stage renal disease (ESRD) AVF creation initiate dialysis with a central vein catheter (CVC), because the AVF is not yet usable [2, 3]. Similarly, we recently observed that at our medical center, only 47% of patients with pre-ESRD AVF creation who initiated dialysis were able to do so with an AVF [4]. The remaining patients initiated dialysis with a CVC, and frequently required percutaneous or surgical interventions to promote AVF maturation [5]. Once AVF maturity has been established, subsequent interventions (angioplasty, thrombectomy or surgical revision) were often required to maintain long-term AVF patency for dialysis [6]. If the initial AVF failed to mature despite salvage procedures, these patients required placement of another vascular access (AVF or AVG). The use of a CVC is associated with a high frequency of catheter-related bloodstream infections (CRBSI), many of which require expensive hospitalizations for treatment [7–10].

There is limited published literature quantifying the burden of vascular access procedures and their complications associated with starting dialysis with a CVC despite pre-ESRD AVF surgery. The goal of the present retrospective cohort study was to quantify the frequency of vascular access procedures and their complications in patients with pre-ESRD AVF surgery who initiated dialysis with a CVC versus a permanent access. Additionally, we assessed the economic impact of starting HD with a CVC.

Methods

Vascular Access Management

The University of Alabama at Birmingham (UAB) provides comprehensive medical care to over 500 hemodialysis patients in greater Birmingham. UAB nephrologists serve as the medical directors of the in-center dialysis centers, and are responsible for vascular access management, in conjunction with the surgeons and radiologists. The nephrologists refer these patients to transplant surgeons for placement of new AVFs and AVGs, and any subsequent surgical interventions. The patients are referred to interventional radiologists and nephrologists for percutaneous access interventions, such as angioplasties, thrombectomies, and CVC exchanges. All vascular access procedures are scheduled by the access coordinators, who maintain a prospective, computerized database of all access procedures and complications [11].

The surgeons plan the access type and location, taking into account their clinical evaluation and the results of preoperative vessel mapping [11–13]. Specifically, creation of an AVF requires a minimal arterial diameter of 2 mm and minimal venous diameter of 2.5 mm. Following AVF creation, patients are scheduled for a 4–6 week postoperative ultrasound to quantify the AVF diameter, blood flow, and depth [13]. If the sonographic or clinical evaluation suggests AVF immaturity, the patient is referred for a percutaneous or surgical intervention to correct an identified anatomical

problem [14]. These interventions may include angioplasty or surgical revision of an anastomotic stenosis, ligation of large accessory veins, or transposition of an AVF that is too deep for safe cannulation. If an AVF clots before it has matured, it is abandoned, and a new vascular access placed.

Once the vascular access has matured, it is monitored regularly by the nephrologists and dialysis nurses for evidence of dysfunction. If a hemodynamically significant access stenosis is suspected, the patient is referred for a diagnostic fistulogram with possible angioplasty [15, 16]. Thrombosed AVFs or AVGs are referred for mechanical thrombectomy, along with angioplasty of the underlying stenosis. Surgical revision is considered in patients with frequent access stenosis or thrombosis. If the vascular access cannot be salvaged, it is abandoned, and a CVC placed for vascular access. The patient is then referred to surgery for consideration of new access surgery.

CVCs that are unable to deliver adequate dialysis blood flow are instilled with tissue plasminogen activator, and referred for CVC exchange if the dysfunction is not restored by the thrombolytic agent [17]. CRBSI are treated with systemic antibiotics, along with an antibiotic lock instillation [18]. If the patient has severe sepsis, metastatic infection, or the bacteremia persists, the CVC is replaced. This management strategy is consistent with the Infectious Diseases Society of America guidelines [19]. Patients with severe sepsis related to CRBSI are hospitalized, whereas those with milder CRBSI are treated as outpatients. The CVC is removed after the AVF or AVG has been used successfully for hemodialysis.

Data Collection

In a previous study from our medical center, we evaluated the clinical outcomes of 308 patients with advanced CKD who underwent pre-ESRD AVF placement between January 1, 2006 and December 31, 2012 [4]. Of this patient cohort, 211 patients initiated dialysis within 2 years of AVF creation. Six of them transferred to an outside dialysis unit immediately following initiation of dialysis. The remaining 205 patients, who initiated dialysis at a UAB-affiliated unit, formed the cohort for the present study, which quantified access procedures and complications after pre-ESRD AVF creation. Of this cohort, 91 patients initiated dialysis with a CVC and 114 with an AVF. Institutional Review Board approval was obtained prior to review of the patients' medical records for research purposes.

Patient follow-up started with the date of pre-ESRD AVF creation and ended with patient death, kidney transplant, transfer to an outside dialysis unit, switch to peritoneal dialysis, or end of follow-up period (June 30, 2017). We utilized the outpatient prospective payment schedule to quantify the cost of each vascular access procedure (<https://www.cms.gov/apps/physician-fee-schedule/search/search-criteria.aspx>), and diagnosis-related groups codes to estimate the cost of hospitalizations due to CRBSI. If the patient's CRBSI was treated as an outpatient, the cost was limited to antibiotic infusion with dialysis (included in the dialysis bundle) [20], as well as the cost of the catheter replacement (when indicated). Tissue plasminogen activator instillation into the catheter lumen was not included in the cost calculations, as it is also included in the dialysis bundle. The 2015 CMS reimbursements for access-related procedures and hospitalization for CRBSI are summarized in Table 1. We calculated for each patient the overall access-related cost by multiplying the frequency of a given vascular access procedure or CRBSI hospitalization with its respective cost.

Table 1. 2015 CMS reimbursement for access procedures and complications

Procedure	Procedure or DRG code	Reimbursement*, USD
Surgical procedures		
New AVF	36821	3,923
New AVG	36825	4,067
Surgical access revision	36832	4,025
Percutaneous procedures		
Thrombectomy	36870; 36147; 36148	2,996
PTA	36147; 35476; 75978	2,451
Catheter exchange	36581	786
Hospitalization secondary to catheter related sepsis	999.32	13,528

* Includes professional and facility fees.

DRG, diagnosis-related groups; AVF, arteriovenous fistula; PTA, percutaneous transluminal angioplasty.

Table 2. Baseline demographics and clinical characteristics of patients starting hemodialysis with an AVF versus a catheter

Parameter	AVF	Catheter	<i>p</i> value
Number of patients	114	91	
Age, years, mean $\pm$ SD	57 $\pm$ 14	54 $\pm$ 13	0.17
Gender, male, <i>n</i> (%)	65 (57)	45 (49)	0.28
Black race, <i>n</i> (%)	81 (71)	70 (77)	0.34
Diabetes, <i>n</i> (%)	71 (62)	60 (66)	0.59
Hypertension, <i>n</i> (%)	113 (99)	88 (97)	0.21
Coronary artery disease, <i>n</i> (%)	35 (31)	21 (23)	0.22
Heart failure, <i>n</i> (%)	37 (32)	28 (31)	0.45
Cerebrovascular disease, <i>n</i> (%)	13 (11)	11 (12)	0.88
Peripheral vascular disease, <i>n</i> (%)	18 (16)	11 (12)	0.45
Days from AVF surgery to ESRD, median (IQR)	170 (102–340)	101 (33–205)	<0.0001
AVF type			0.68
Radiocephalic	61 (54)	51 (56)	
Brachiocephalic	48 (42)	38 (42)	
Brachiobasilic	5 (4)	2 (2)	

AVF, arteriovenous fistula; ESRD, end-stage renal disease; IQR, interquartile range.

Statistical Analysis

The exposure of interest was the type of vascular access used at hemodialysis initiation (CVC or permanent access). Outcomes of interest included the frequency of percutaneous access interventions, surgical access interventions, overall access procedures, hospitalization for CRBSI, and costs associated with each of these access events or complications. Baseline patient characteristics were compared using χ^2 test for categorical variables. For continuous variables, Student *t* tests were used to compare normally distributed values and nonparametric statistics to analyze values with skewed distributions. The frequency of access events or procedures between subgroups was assessed using Poisson regression with relative rates. *P* < 0.05 was considered statistically significant.

Results

The study cohort included 205 patients who (1) received an AVF pre-ESRD, (2) started hemodialysis within 2 years of AVF creation, and (3) initiated dialysis in the UAB system. Patients were followed from pre-ESRD AVF placement to patient death, kidney transplant, transfer to an outside dialysis unit, switch to peritoneal dialysis, or end of follow-up period (June 30, 2017). The 2 groups initiating HD with a CVC versus an AVF were similar in terms of age, sex, race, diabetes, vascular disease, and heart failure (Table 2). Both groups had a similar proportion of patients receiving a

Table 3. Frequency of access procedures after pre-ESRD AVF creation in patients starting hemodialysis with an AVF versus a catheter

Parameter	AVF	Catheter	<i>p</i> value
Number of patients	114	91	
Patient-years of follow-up	619.3	486.9	
Years of follow-up, median (IQR)	5.4 (3.0–7.4)	5.7 (2.5–7.8)	0.84
CVC exchange, <i>n</i> per patients-years (95% CI)	0.18 (0.14–0.21)	0.47 (0.41–0.54)	<0.0001
Angioplasty, <i>n</i> per patients-year (95% CI)	0.37 (0.33–0.42)	0.60 (0.54–0.68)	<0.0001
Thrombectomy, <i>n</i> patients-year (95% CI)	0.20 (0.17–0.24)	0.22 (0.18–0.26)	0.66
All percutaneous procedures per patients-year (95% CI)	0.75 (0.68–0.82)	1.29 (1.19–1.40)	<0.0001
Surgical access revisions, per patients-year	0.24 (0.21–0.29)	0.30 (0.25–0.35)	0.08
New access creations <i>n</i> per patients-year	0.35 (0.30–0.40)	0.39 (0.33–0.44)	0.29
All surgical procedures per patients-year	0.59 (0.53–0.66)	0.69 (0.61–0.76)	0.05
All access procedures per patients-year	1.34 (1.26–1.44)	1.98 (1.86–2.11)	<0.0001
CRBSI per 100 patients-year (95% CI)	5.33 (3.67–7.48)	22.8 (18.8–27.4)	<0.0001
CRBSI hosp per 100 patients-year (95% CI)	1.94 (1.00–3.38)	9.24 (6.74–12.37)	<0.0001

ESRD, end-stage renal disease; AVF, arteriovenous fistula; IQR, interquartile range; CVC, central vein catheter; CRBSI, catheter-related bloodstream infections.

Table 4. Median annual vascular access-related costs (in USD) in patients starting hemodialysis with an AVF versus a catheter

	AVF, median (IQR)	Catheter, median (IQR)	<i>p</i> value
Number of patients	114	91	
Percutaneous procedures, USD/year	912 (0–2,779)	2,423 (868–4,943)	<0.0001
Surgical access procedures, USD/year	2,106 (1,172–3,928)	3,170 (1,465–5,232)	0.02
Hospitalization for catheter-related bacteremia, USD/year	0 (0–0)	0 (0–1,167)	<0.0001
Total access-related cost, USD/year	3,703 (1,867–6,953)	6,372 (3,121–12,242)	0.0001

AVF, arteriovenous fistula; IQR, interquartile range.

radiocephalic, brachiocephalic, and brachiobasilic AVF. However, the median interval from pre-ESRD AVF surgery to dialysis initiation was approximately 10 weeks shorter in the group initiating dialysis with a CVC. Among the 91 patients starting HD with a CVC, 60 (or 66%) ultimately used the AVF for dialysis. Overall, 31 of the AVFs in this study were not used successfully for dialysis.

Frequency of Access Procedures and Complications

The median duration of patient follow-up after AVF creation was similar in the 2 groups (5.4 vs. 5.7 years; Table 3). As compared to patients starting hemodialysis with a permanent access, those starting with CVC had a 72% higher frequency of percutaneous access procedures, a 17% higher frequency of surgical access procedures, 48% higher frequency of total access procedures, and a nearly 5-fold higher rate of CRBSI (Table 3).

Cost of Access Procedures and Complications

We calculated the cost of all percutaneous and surgical access procedures, as well as the cost of hospitalization for CRBSI. As compared to patients who started hemodialysis with a permanent access, those starting with a CVC incurred a median annual access management cost that was USD 2,669 higher than those starting with an AVF (USD 6,372 [3,121–12,242] vs. 3,703 [1,867–6,953], *p* = 0.0001; Table 4). Due to the variability of patient follow-up in this study, we also used an alternative calculation of “cost to the payer,” in which we divided the total costs by the total patient-years of follow-up for each group (Table 5). Although the precise costs using this calculation varied somewhat from those calculated in Table 4, the trends were similar. Specifically, the group starting dialysis with a CVC incurred an annual cost of access management that was USD 2,198 higher than the group starting with an AVF (USD 6,497 vs. 2,198).

Table 5. Annual vascular access-related costs (in USD) per patient-year in patients starting hemodialysis with an AVF versus a catheter

	AVF	Catheter
Patients-years	619.3	486.9
Percutaneous procedures, USD/patient-years	1,662	2,497
Surgical access procedures, USD/patient-years	2,375	2,749
Hospitalization for catheter-related bacteremia, USD/patient-years	262	1,250
Total access-related cost, median USD/patient-years	4,299	6,497

AVF, arteriovenous fistula.

Table 6. Median annual vascular access-related costs (in USD) in patients starting hemodialysis with a catheter, according to whether the AVF was successfully used

	AVF success, median (IQR)	AVF failure, median (IQR)	<i>p</i> value
Number of patients	60	31	
Percutaneous procedures, USD/year	2,069 (694–4,506)	3,295 (1,670–5,823)	0.10
Surgical access procedures, USD/year	2,326 (1,311–4,698)	4,172 (2,666–5,696)	0.008
Hospitalization for catheter-related bacteremia, USD/year	0 (0–0)	0 (0–2,320)	0.08
Total access-related cost, USD/year	5,065 (2,404–10,523)	10,112 (5,549–13,290)	0.01

AVF, arteriovenous fistula; IQR, interquartile range.

Finally, for the patient group starting dialysis with a CVC, we compared the median annual cost of access management in those who had delayed successful use of the AVF for dialysis versus those in whom the AVF failed (Table 6). The median annual access-related cost was more than double in the group with the failed AVF (USD 10,112 [5,549–13,290] vs. 5,065 [2,404–10,523]).

Discussion

Despite concerted efforts to place AVFs in a timely fashion in patients with advanced CKD, nearly half of the patients in the current cohort initiated dialysis with a CVC. This finding is in agreement with 2 recent publications addressing this question in a national cohort [2, 3]. At a minimum, patients whose AVF had not yet matured prior to ESRD had a period of catheter dependence, exposing them to the need for CVC exchange due to dysfunction, as well as the risk of CRBSI hospitalization. Additionally, some patients required percutaneous or surgical interventions to promote AVF maturation, or even the occasional placement of a second

access, if the initial AVF could not be salvaged. As a consequence, the patients initiating dialysis with a CVC had a significantly higher annual frequency of percutaneous and surgical access procedures, as well as a 5-fold greater frequency of hospitalization due to CRBSI. The overall economic impact was substantial, resulting in a nearly USD 2,700 greater median annual cost for overall vascular access management. The economic analysis in the current study is qualitatively similar to that reported recently in another paper, which also observed higher overall access-related costs in patients who initiated dialysis with a CVC and a maturing AVF, as compared to those who initiated dialysis with a mature AVF [21].

The groups starting dialysis with a CVC versus an AVF had similar baseline demographics and comorbidities. The observed differences between the 2 patient cohorts in the present study may reflect unmeasured patient factors leading to delays in AVF creation or revision. For example, the quality of vessels used to create the AVF may have been inferior in the group starting HD with a CVC. Alternatively, differences in vascular access processes of care may have contributed

to the delay in AVF maturation in the group starting dialysis with a CVC. In support of the second explanation, two-thirds of the patients initiating HD with a CVC were eventually able to use the maturing AVF for dialysis. The median time interval from pre-ESRD AVF creation to dialysis initiation was about 6 months in the group initiating dialysis with a permanent access, but only 3 months in those initiating with a CVC. Hod et al. [2] reported that the odds of starting dialysis with a mature AVF was approximately twice as high if the AVF was placed 3–6 vs. 1–3 months prior to ESRD. Due to the observational nature of this study, it is not possible to determine whether these delays were related to nephrologist, surgeon, or patient factors. A recent analysis of the Hemodialysis Fistula Maturation Study found that the time to first attempted AVF cannulation was associated with differences in surgical processes of care, and unassisted (without a prior intervention) AVF maturation was associated with the presence of a dedicated vascular access coordinator [22].

Even among the subset of patients with pre-ESRD AVF creation who started dialysis with a CVC in the present study, the frequency of access procedures and complications and the cost of vascular access management were substantially lower than those observed in a previous group of patients from our center who underwent AVF creation after initiation of dialysis with a CVC [10]. Thus, the annual frequency of all access procedures in pre- vs. post-ESRD AVF creation was 1.98 vs. 2.48, and the median annual cost of vascular access management was USD 6,372 vs. 10,642, respectively.

The current study has several strengths: (1) All patients were managed by uniform vascular access protocols; (2) all vascular access procedures and complications were recorded prospectively in an electronic access database, ensuring completeness of the data; and (3) we calculated the overall costs of vascular access management, a measure that is seldom addressed in vascular access publications. The study weaknesses are as follows: (1) they reflect the practice patterns at a single large center and may not generalize to some dialysis

centers and (2) the access-related costs reflect reimbursements in the United States and may differ in other countries.

Conclusion

Among patients with pre-ESRD AVF creation, a substantial proportion initiates hemodialysis with a CVC. As compared with the patients starting dialysis with an AVF, those who initiate hemodialysis with a CVC require more frequent percutaneous, surgical, and total access procedures, as well as CRBSI hospitalizations. These procedures and complications substantially increase the overall annual cost of access management. The excess cost in the patients initiation with a CVC was driven primarily by the subset of patients (about one-third) whose AVF failed to be used successfully for dialysis. Improvements in pre-ESRD vascular access management, if they can successfully increase AVF use at dialysis initiation, could translate into substantial cost savings.

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Disclosures Statement

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