Establishment and Maintenance of Vascular Access in Incident Hemodialysis Patients: A Prospective Cost Analysis

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Despite the importance of hemodialysis vascular access, the cost of vascular access care has not been studied in detail. A prospective cost analysis was performed among incident hemodialysis patients to determine the cost of vascular access care overall and on the basis of access type. Detailed clinical and demographic information, as well as data on access type, was collected for all local incident hemodialysis patients between July 1, 1999, and November 1, 2001. A comprehensive measure of total vascular access costs, including surgery, radiology, hospitalization for access complications, physician costs, costs for management of outpatient bacteremia, and vascular access monitoring costs, was obtained. Costs are reported in 2002 Canadian dollars (1CAN$ = 0.69US$). A total of 239 consecutive incident hemodialysis patients were identified, 49, 157, and 33 of whom were dialyzed exclusively with a catheter or had a native arteriovenous fistula or synthetic graft attempted, respectively. In year 1, 18.4% of all hospital admissions were for vascular access–related complications. The mean cost of all vascular access care in year 1 was CAN$6890 (median $4020; interquartile range [IQR] $2440 to $7540). The mean cost of access care per patient-year at risk for maintaining a catheter exclusively, attempting an arteriovenous fistula, or attempting a graft was $9180 (median $3812; IQR $2250 to $7762), $7989 (median $4641; IQR $3035 to $8832), and $11,685 (median $8152; IQR $3395 to $12,908), respectively ($P$ = 0.01). Vascular access care is responsible for a significant proportion of health care costs in the first year of hemodialysis. These results support clinical practice guidelines that recommend preferential placement of a native fistula.

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Patients who choose hemodialysis require vascular access before initiation of dialysis. The choices include a native arteriovenous fistula (AVF), a synthetic graft, and a central venous catheter (either temporary or a permanent tunneled catheter) (1). There are advantages and disadvantages of each type. Primary failure is highest for AVF, ranging from 50% failure overall to >80% in subgroups of diabetic, elderly, or female patients (2). When successful, the AVF has the highest long-term patency and the lowest infection and complication rates (1,3–6). Although primary failure rates are much lower for synthetic grafts (7), primary and secondary patency rates are also significantly lower for synthetic grafts compared with AVF, and infection rates are significantly higher (6–8). Finally, central venous catheters have the advantage of immediate use but are associated with high failure, dysfunction, and infection rates (8,9). As such, current guidelines recommend AVF as the first-line vascular access (1).

Up to 30% of hospital admissions in hemodialysis patients are related to vascular access complications, and significant outpatient resources, including vascular access monitoring and diagnostic radiology, are used to maintain access patency (10,11). As such, in addition to clinical outcomes, the resources required to establish and maintain patency could potentially influence the desirability of each vascular access type.

At present, only one study has reported in detail the cost of vascular access on the basis of access type (11), but this study considered only the cost of maintaining a functioning access among prevalent patients (11). The cost of access care was high (ranging from CAN$600 to $5000) per year for the various access types) but was significantly lower for those who began the study period with a functioning AVF. This study did not consider the cost of establishing permanent vascular access, which would include the cost of "unsuccessful" access creation attempts. Given that this cost may be very significant among certain subgroups (*e.g.*, female or elderly patients, those with diabetes), we performed a prospective cost analysis among incident hemodialysis patients to determine the cost of vascular access care during the first year of dialysis.

Materials and Methods

Patient Cohort

Between July 1, 1999, and November 1, 2001, in Calgary, Alberta, Canada, 312 patients commenced dialysis; 239 chose hemodialysis as

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their first modality and did not switch to peritoneal dialysis during the incident year. Clinical and demographic data, as well as data on modality and access type, were collected for these patients from the Southern Alberta Renal Program database (12). Data on vascular access type and surgical procedures were taken from the Southern Alberta Transplant Program Database (ALTRAbase), which captures information for all patients who receive a vascular access. Of the 239 hemodialysis patients, 49 were dialyzed exclusively with a permanent central venous catheter (and had no attempt at construction of an AVF or graft) during the first year ("catheter only"). The remaining 190 patients had a total of 274 vascular access procedures performed. The first access attempted was an AVF in 157 patients; 33 patients had primary placement of a synthetic graft. Information on initial success of the vascular access (defined as use of the access on three consecutive dialysis sessions with a blood flow >300 ml/min) was collected through review of all outpatient dialysis records. All patients were followed for 1 yr or until death; no patients were lost to follow-up.

Vascular access placement is performed locally by a group of dedicated vascular access surgeons. As of 2001, two dedicated vascular access coordinators also reviewed all patients with respect to their suitability for a vascular access. No systematic program-wide protocol is followed with respect to placement of vascular access. However, nephrologists, with the assistance of the vascular access service, generally recommend an AVF or synthetic graft unless patients refuse surgery or placement of an access is contraindicated (*e.g.*, threatened limb ischemia, central venous stenosis). Preoperative ultrasound screening of vessels is not performed. For patients in whom an access is attempted, surgical dissection is performed to access adequacy of cephalic vein and radial artery for radial-cephalic primary AVF. If a radiocephalic fistula is not feasible, then an ipsilateral brachiocephalic fistula is considered. This entails an antecubital dissection to assess adequacy of artery and vein. If vessel size and/or patency are believed to be inadequate to sustain development of a brachiocephalic AVF, then primary placement of a polytetrafluoroethylene graft is performed. With the exception of patients who are on anticoagulation for a heart valve, all surgeries are performed in day surgery without the need for hospital admission.

Resource Use

This study took the perspective of the health care purchaser and included only direct health care–related costs. Societal costs (*e.g.*, time costs, patient transport costs) were excluded. Costs are reported in 2002 Canadian dollars (1CAN$ = 0.69US$). The resources required to care for a patient's vascular access were divided into the following six categories: Access surgery, hospitalization, diagnostic imaging, outpatient infections, local catheter thrombolysis, and access monitoring for fistula and grafts.

Access Surgery. Information on all vascular access surgeries was captured from the ALTRAbase database, which collects surgical and outcome data for all patients who undergo vascular access surgery. The cost of the surgery, whether performed as an inpatient or an outpatient, was captured on the basis of surgery type and number of minutes spent in the operating suite by the Calgary Health Region. Surgeon and anesthetist fees were recorded as per the Alberta Health and Wellness Benefit list, the sole payer for physician services in Alberta.

Hospitalization. Information on hospitalization for management of a complication relating to vascular access (*e.g.*, local or metastatic infection, hemorrhage or thrombosis) was collected from the Calgary Health Region as described previously (11). The cost of physician care was recorded as per the Alberta Health and Wellness Benefit list. The cost of admissions for which the primary reason for admission (as defined by the discharge diagnosis [*International Classification of Diseases, Ninth Revision* codes] and subsequently confirmed by chart review using predefined criteria) was related to access care was costed at 100%. In cases in which hospitalizations were only partly related to vascular access care, the number of hospital days required for vascular access care was recorded; the cost for the relevant portion of these hospitalizations was determined by costing each day separately (12).

Diagnostic Imaging. The cost and the number of catheter placements, venograms, fistulograms, access-directed thrombolysis, and access-related angioplasties (*i.e.*, all radiology procedures performed as part of access-related care) were taken from a prospectively maintained radiology database (11). The costs of radiology procedures are updated yearly on the basis of supplies used and vary within procedure and patient on the basis of the number of minutes required in the radiology suite. The cost of a physician's services for these procedures was recorded as per the Alberta Health and Wellness Benefit list.

Outpatient Infections. The cost for outpatient management of access-related bacteremia that did not result in admission was captured through a link with Calgary Laboratory Services, a regional laboratory that performs all blood cultures for patients in the Calgary Health Region. Bacteremia was defined as the isolation of a pathogenic organism from at least one set of blood cultures with a blood culture set consisting of an aerobic and an anaerobic bottle pair from a single blood draw. At least two positive sets of blood cultures within a 2-d period were required to classify bacteremias with common skin contaminants, including coagulase-negative staphylococci or *Bacillus*, *Corynebacterium*, or *Propionibacterium* species. The local practice for staphylococcal infections is 3 wk of vancomycin intravenously postdialysis with thrice-weekly predialysis vancomycin levels. The local practice for managing Gram-negative infections is 1 wk of gentamycin therapy intravenously postdialysis in conjunction with 2 wk of cephalosporin therapy intravenously postdialysis.

The cost for the cephalosporin was based on therapy with 2 g of cefazolin (CAN$6), the local cephalosporin of choice. The cost of vancomycin (CAN$44.58 for 1 g) and gentamycin (CAN$3.96 for 80 mg) and for laboratory monitoring of levels three times per week was determined on the basis of local costs. This represents a conservative estimate of the cost of outpatient infections because we were unable to capture the cost of antibiotics used to treat fever presumptively in patients whose blood cultures were subsequently determined to be negative.

Local Catheter Thrombolysis. Dysfunction of catheters (defined as the complete inability to withdraw blood or the inability to withdraw blood at a sufficient rate to sustain dialysis [blood flow <200 ml/min]) has been managed routinely with local instillation of tissue plasminogen activator since 2000 (13). Data were collected from the local hospital pharmacy, which records all doses of tissue plasminogen activator dispensed to dialysis patients within the Calgary Health Region (CAN$125 per 2-mg dose) (13).

Access Monitoring for Fistula and Grafts. During this study period, it was standard practice to monitor vascular accesses, done locally on a monthly (synthetic grafts) or trimonthly (AVF) basis. Local practice on ordering fistulograms and the use of angioplasty is consistent with published guidelines (1,14). The ultrasound dilution technique is performed with a modified ultrasound machine by dedicated hemodialysis access coordinators. The cost of access monitoring per episode was based on the number of access screening procedures done per year, the useful life of the machine (7 yr), and the actual percentage of time spent by the access coordinators in screening patients on an annual basis (50% of both coordinators' time).

Table 1. Baseline characteristics of patients, overall and according to first access type attempted[a]

	Overall (n = 239)	Catheter Only (n = 49)	AVF (n = 157)	Graft (n = 33)
Mean age (yr [95% CI])	63.6 (61.6–65.6)	65.1 (60.1–70.0)	63.6 (61.2–66.0)	61.3 (55.4–67.2)
Female gender (%)[b]	86 (36.0)	21 (42.9)	44 (28.0)	21 (63.6)
Charlson comorbidity index (mean [95% CI])	5.0 (4.7–5.3)	5.1 (4.3–6.0)	5.0 (4.7–5.3)	4.7 (3.9–5.5)
low risk (≤3)	26.8%	17 (34.7%)	38 (24.2%)	9 (27.3%)
medium risk (4–5)	38.1%	12 (24.5%)	63 (40.1%)	16 (48.5%)
high risk (≥6)	35.1%	20 (40.8%)	56 (35.7%)	8 (24.2%)
Comorbid conditions (%)				
coronary heart disease	42.7%	34.7%	44.6%	45.5%
congestive heart failure	39.3%	42.9%	40.8%	27.3%
peripheral vascular disease	21.8%	22.4%	22.3%	18.2%
previous stroke	16.3%	14.3%	17.2%	15.2%
lung disease	34.3%	30.6%	35.7%	33.3%
diabetes[c]	45.2%	28.6%	47.8%	57.6%
Site of first surgery				
forearm (%)	N/A	N/A	95 (60.5%)[f]	31 (93.9%)[f]
Successful surgery on first attempt[d] (95% CI)	N/A	N/A	66.9% (58.9–74.1)	84.8% (68.1–94.9)
Risk of death in year 1[e] (%)		25 (51.0%)	25 (15.9%)	5 (15.1%)

[a]AVF, arteriovenous fistula; CI, confidence interval.
[b]$P < 0.001$ for comparison of gender between vascular access groups, using one-way ANOVA.
[c]$P = 0.02$ for comparison of diabetes between vascular access groups, using Fisher exact test.
[d]Defined as needling of the access with two needles on three consecutive runs with blood flow >300 ml/min.
[e]$P < 0.001$ for comparison of risk of death between vascular access groups, using one-way ANOVA.
[f]$P < 0.001$ for comparison of likelihood of placement of a forearm access between AVF and graft groups, using Fisher exact test.

Table 2. Access-related procedures in the first year for patients, overall and according to first access type attempted[a]

	Access Surgeries (Mean [Median, IQR])	Access-Related Hospitalization		Inpatient and Outpatient Diagnostic Imaging Procedures			Outpatient Bacteremic Episodes (Mean [Median, IQR])
		No. of Admissions (Mean [Median, IQR])	Total Length of Stay (Days; Mean [Median, IQR])	Catheters (Mean [Median, IQR])	Angiograms[b] (Mean [Median, IQR])	Angioplasties[b] (Mean [Median, IQR])	
Overall ($n = 239$)	1.45 (1, 1–2)[c]	0.243 (0, 0–0)	2.8 (0, 0–0)	1.05 (1, 0–2)	0.73 (0, 0–1)	0.43 (0, 0–1)	0.60 (0, 0–1)
Catheter only ($n = 49$)	N/A	0.204 (0, 0–0)	4.7 (0, 0–0)	2.12 (2, 1–3)	0.082 (0, 0–0)	0.082 (0, 0–0)	1.17 (1, 0–2)
AVF ($n = 157$)	1.39 (1, 1–2)	0.22 (0, 0–0)	1.9 (0, 0–0)	0.69 (0, 0–1)	0.81 (1, 0–1)	0.43 (0, 0–1)	0.51 (0, 0–1)
Graft ($n = 33$)	1.70 (1, 1–2.5)	0.39 (0, 0–1)	4.2 (0, 0–2)	1.15 (1, 0–2)	1.33 (1, 0–2)	0.94 (0, 0–1)	0.39 (0, 0–0)

[a]IQR, interquartile range.
[b]Including angiograms/angioplasties done for investigation/treatment of central vein stenosis.
[c]Based on $n = 190$, the number of patients who had access surgery.

Statistical Analyses

The primary objective of this analysis was to compare the resources required to establish and maintain patency of each type of vascular access care during the first year of treatment among incident hemodialysis patients. A secondary objective was to compare the resources required for the first year of vascular access care for prespecified subgroups of incident hemodialysis patients (>65 yr of age, female, and patients with diabetes) on the basis of access type.

The variable of interest in these analyses was access-related costs during year 1. Given that some patients had accesses created before initiation of dialysis whereas others had their access created several weeks after initiation of dialysis, it was important to define a common starting point for cost assessment (*i.e.*, day 0). To avoid bias related to the variable timing of surgical vascular access placement, we considered the first day of costing as the first day of dialysis or the day of surgical creation of the AVF or graft for patients whose first surgery was done after initiation of dialysis. In sensitivity analysis, we considered the "first day of dialysis" and the "first day of successful access use" as alternative choices for day 0 in patients who had vascular accesses placed after dialysis initiation. For all patients, costs were censored 1 yr after the first day of costing or on the date of death or transplantation.

We compared the cost of access care during year 1 for catheter-only patients and in patients in whom an AVF or a graft was attempted as the first access of choice, using an intention-to-treat approach and one-way ANOVA. Because costs were not normally distributed, they were log-transformed before statistical testing. To adjust partially for the impact of comorbidity on costs, we performed additional analyses that stratified patients on the basis of their Charlson score (≥ or < median).

As expected, given the high mortality rate among patients who exclusively used catheters (51% in year 1), exploratory analyses revealed that access costs were lower for catheter-only patients as a result of the shorter observation period. To address the impact of variable follow-up time as a result of early death on costs for the different access types, and to be consistent with U.S. Renal Data System reporting style, we recalculated the year 1 cost of access care by direct extrapolation from the truncated costing period for patients who died in year 1 to enable reporting as cost per patient-year at risk (15).

Results

Baseline Characteristics

Of the 239 incident hemodialysis patients, 49 (20.5%) were dialyzed exclusively with a catheter during year 1, whereas 157 (65.7%) and 33 (13.8%) had an attempt at fistula or synthetic graft placement, respectively, during the first year. The average age of patients (63.6; 95% CI 61.6 to 65.6) was similar among the three groups of patients (Table 1). Of the 190 primary access surgeries attempted, 120 were done after the initiation of dialysis, with the median time to access surgery for this group of patients being 93 d (interquartile range [IQR] 48 to 141).

It was more likely for a graft to be attempted in women and in people with diabetes ($P < 0.001$ and $P = 0.02$, respectively; Fisher exact test). Of the 157 AVF attempted, 105 (66.9%) were used successfully; 28 (84.8%) of the 33 synthetic grafts placed were used successfully. The mortality rate of patients in year 1 was significantly higher in catheter-only patients (51%) compared with those who underwent access surgery (15.8%; $P < 0.001$; Table 1).

Table 3. Year 1 cost of access-related care (unadjusted for early death), overall and according to first access type attempted[a]

	Surgical Costs (Mean [Median, IQR])	Hospitalization Costs[b] (Mean [Median, IQR])	Diagnostic Imaging Costs (Mean [Median, IQR])	Outpatient Infection Costs (Mean [Median, IQR])	tPA Costs (Mean [Median, IQR])	Access Monitoring Costs (Mean [Median, IQR])	Total Costs (Mean [Median, IQR])
Overall (n = 239)	$2017 ($2094, $2094–$2317)	$2339 (0, 0–0)	$2135 ($1355, $560–$3139)	$232 (0, 0–$410)	$13 (0, 0–0)	$82 (0, 0–$173)	$6818 ($4015, $2443–$7520)
Catheter only (n = 49)	N/A	$3279 (0,0–0)	$1686 ($925, $925–$2012)	$373 ($184, 0–$777)	$61 ($67, $10–$67)	N/A	$5400 ($1742, $992–$4807)[c]
AVF (n = 157)	$2454 ($2094, $2094–$2267)	$1916 (0, 0–0)	$2048 ($1450, $485–$3173)	$206 (0, 0–$410)	N/A	$65 (0, 0–$115)	$6688 ($4193, $2716–$6619)[c]
Graft (n = 33)	$2939 ($2317, $2317–$3475)	$2956 (0, 0–$2339)	$3212 ($2726, $560–$5249)	$148 (0, 0–0)	N/A	$288 ($346, 0–$519)	$9543 ($7603, $3395–$11,744)[c]

[a]tPA, tissue plasminogen activator.
[b]Includes nursing, medications, laboratory tests, diagnostic imaging, support staff, surgery, and supplies.
[c]P < 0.001 comparing the log-transformed cost of the three vascular access types using one-way ANOVA.

Resource Use

Use of surgical, diagnostic imaging and in-patient hospital services was high in incident hemodialysis patients (Table 2). The 239 patients were admitted to the hospital a total of 315 times, 18.4% of which were required to manage an access-related complication, contributing to 13.8% of total hospital length of stay. Patients in whom an AVF was attempted spent a similar number of days in the hospital during the first year for access-related complications (1.9 d), compared with patients in whom a synthetic graft was attempted (4.2 d) or in whom a catheter was used exclusively (4.7 d; P = 0.10; Table 2).

Cost of Vascular Access

The cost of vascular access care was substantial, with a mean year 1 cost of CAN$6890 (median $4020; IQR $2440 to $7540). The cost (unadjusted for follow-up time) was high for all three access groups, although they were highest for patients in whom a graft was placed (P < 0.001; one-way ANOVA; Table 3). Given that early deaths occurred more commonly in catheter-only patients, we repeated this analysis reporting the cost for each of the vascular access types as the cost per patient-year at risk (Table 4). The mean cost of access care per patient-year at risk for catheter-only patients and for patients in whom an AVF or a graft was attempted was $9180 (median $3812; IQR $2250 to $7762), $7989 (median $4641; IQR $3035 to $8832), and $11,685 (median $8152; IQR $3395 to $12,908), respectively ($P$ = 0.01, log-transformed ANOVA). As such, the lower access cost (unadjusted for follow-up time) of caring for catheter-only patients seemed to be due to their shorter observation time (which in turn was due to the higher frequency of early deaths). Table 5 demonstrates that catheter-only patients had lower access costs than graft patients, even after stratifying on death and adjusting for variable follow-up time.

In patients who were dialyzed exclusively with a catheter, the largest component of costs (unadjusted for follow-up) was related to hospitalization for access-related complications (Table 3). For patients in whom an AVF was attempted, nearly 70% of year 1 costs were spent on surgeries and diagnostic imaging (Table 3).

Given the uncertainty surrounding the appropriate selection of day 0 (*i.e.*, the first day of costing), we considered the "first day of dialysis" and the "first day of successful access use" as alternative choices for day 0 in patients who had vascular accesses placed after dialysis initiation. When the first day of dialysis was used as day 0 for all patients (thus including the cost of catheters used before access placement), results were similar to the primary analysis. Specifically, the cost of vascular access care in year 1 was $5400 (median $1740; IQR $940 to $4810), $7162 (median $4828; IQR $3126 to $7520) and $8714 (median $7329; IQR $4757 to $9993) for patients who were treated with catheters exclusively and those who had an AVF or graft attempted, respectively (P = 0.07).

Year 1 costs were also estimated from the day of first use of the access for patients in whom an AVF or a synthetic graft was successful. As expected, costs were lower for this select group of patients who did not experience primary access failure (AVF $3710; grafts $8130), compared with patients whose first access

Table 4. Year 1 cost of access-related care per patient-year at risk, overall and according to first access type attempted

	Surgical Costs (Mean [Median, IQR])	Hospitalization Costs[a] (Mean [Median, IQR])	Diagnostic Imaging Costs (Mean [Median, IQR])	Outpatient Infection Costs (Mean [Median, IQR])	TPA Costs (Mean [Median, IQR])	Access Monitoring Costs (Mean [Median, IQR])	Total Costs (Mean [Median, IQR])
Overall (n = 133)	$2728 ($2094, $2094–$3141)	$2885 (0, 0–0)	$2671 ($2012, $769–$3723)	$333 (0, 0–$410)	$41 (0, 0–0)	$86 (0, 0–$173)	$8744 ($4807, $2988–$9843)
Catheter only (n = 49)	N/A	$4749 (0, 0–0)	$3603 ($2443, $1425–$3855)	$629 ($184, 0–$979)	$199 ($68, $10–$209)	N/A	$9180 ($3812, $2250–$7762)[b]
AVF (n = 157)	$3207 ($2096, $2094–$3142)	$2188 (0, 0–0)	$2248 ($1633, $485–$3493)	$278 (0, 0–$410)	N/A	$67 (0, 0–$173)	$7989 ($4641, $3035–$8832)[b]
Graft (n = 33)	$4501 ($2317, $2317–$3475)	$3432 (0, 0–$2339)	$3296 ($2942, $560–$5374)	$156 (0, 0–0)	N/A	$301 ($346, 0–$519)	$11,685 ($8152, $3395–$12,908)[b]

[a]Includes nursing, medications, laboratory tests, diagnostic imaging, support staff, surgery, and supplies.
[b]P = 0.01 comparing the log-transformed cost per patient-year at risk of the three vascular access types using one-way ANOVA.

surgery was unsuccessful (AVF $7740 [$P$ = 0.009 *versus* successful AVF]; grafts $12,791 [$P$ = 0.30 *versus* successful grafts]).

Factors Associated with Higher Access-Related Costs

The cost of vascular access care (unadjusted for follow-up time) in the first year was significantly higher for women (mean $8850 *versus* $5720; P = 0.04 using a Kruskal-Wallis rank test) but not for patients over the age of 65 ($8180 *versus* 5300; P = 0.07) or those with diabetes ($7820 *versus* $6040; P = 0.09). Among the patients in whom an AVF was attempted, the cost of vascular access care in the first year was significantly higher for women ($9130 *versus* $5740 for men; P = 0.006) and for those over the age of 65 ($8320 *versus* $5120; P = 0.03) but not for patients with diabetes ($7310 *versus* $6120; P = 0.9). To consider more fully the impact of comorbidity on access costs, we repeated the analysis for patients with each of the access types stratified by the median Charlson score. Comparing patients with Charlson comorbidity scores <5 with those ≥5, the mean access cost (unadjusted for follow-up time) was similar for catheter-only patients ($5468 *versus* $5339; P = 0.96), patients in whom an AVF was attempted ($6537 *versus* $6793; P = 0.87), and patients in whom a graft was attempted ($11,571 *versus* $7109; P = 0.14).

Discussion

We found that vascular access costs in the first year were high for all three access types, with patients selected for graft placement incurring the highest costs. Even after considering the costs associated with primary nonfunction of AVF, patients who were selected for AVF placement incurred the lowest costs during the first year of dialysis. Previous papers that have examined access choice in hemodialysis patients have focused exclusively on clinical outcomes, and, in the absence of costing data, current guidelines have been based exclusively on clinical outcomes. This article offers a different perspective on vascular access selection and presents the resources required to treat patients in whom the various vascular accesses are selected. Dialysis outcome quality initiative (DOQI) guidelines suggest placement of an AVF as the initial vascular access and recommend accepting up to a 50% risk of primary access failure (1). Although a functioning AVF is clearly the best form of vascular access, our study shows that vascular access costs are significantly higher for patients in whom an AVF attempt is unsuccessful. As such, attempted creation of AVF in patients in whom primary success is very unlikely may significantly increase resource use. Further research is needed to permit prospective identification of patients in whom the chance of successfully creating an AVF is low (16,17).

DOQI guidelines also state that use of a graft should be considered as the second choice in patients for whom an AVF fails or is not possible. Our study suggests that access costs are significantly higher for patients in whom grafts are created, as compared with catheter-only patients, even after adjusting for comorbidity and the impact of variable patient follow-up as a result of early death. Moreover, the incidence of vascular access complications was similar between the two groups. Although observational studies demonstrate that catheters are associated

Table 5. Cost of access care, stratified by survival status, according to first access type attempted

	All Patients (Mean [Median, IQR])	Patients Alive at End of Year 1 (Mean [Median, IQR])	Patients Who Died During Year 1 (Mean [Median, IQR])
Access costs unadjusted for follow-up time			
catheter only	$5400[b] ($1742, $992–$4807)	$3810 ($2551, $1093–$5095; $n = 24$)	$6925 ($1345, $992–$3918; $n = 25$)
AVF	$6688 ($4193, $2716–$6619)	$7005 ($4364, $2826–$6839; $n = 133$)	$4934 ($3854, $2521–$5992; $n = 24$)
graft	$9543[b] ($7603, $3395–$11,744)	$7872 ($7198, $3379–$11,465; $n = 28$)	$18,999 ($11,743, $5229–$35,795; $n = 5$)
Cost per patient-year at risk[a]			
catheter only	$9180[c] ($3812, $2250–$7762)	$3810 ($2551, $1093–$5095; $n = 24$)	$14,334 ($5898, $3259–$12,729; $n = 25$)
AVF	$7989 ($4641, $3035–$8832)	$7005 ($4364, $2826–$6839; $n = 133$)	$13,444 ($11,151, $6075–$15,348; $n = 24$)
graft	$11,685[c] ($8152, $3395–$12,908)	$7872 ($7198, $3379–$11,465; $n = 28$)	$33,038 ($41,345, $12,424–$49,740; $n = 5$)

[a] Calculated by direct extrapolation from the truncated costing period for patients who died in year 1 to enable reporting as cost per patient-year at risk.
[b] $P < 0.001$ comparing the log-transformed cost of catheter-only and graft patients using a two-sample t test.
[c] $P = 0.01$ comparing the log-transformed cost per patient-year at risk of catheter-only and graft patients using a two-sample t test.

with increased mortality compared with AVF or grafts, it is possible that the adverse consequences associated with use of catheters in observational studies (8) may be partly due to unmeasured patient comorbidity or acuity of illness. Given the high costs involved and the clinical uncertainty, a randomized trial comparing permanent catheters and grafts for patients in whom an AVF cannot be created seems warranted.

The high access costs associated with use of AVF or synthetic grafts may be partially due to the diagnostic imaging costs induced by regular vascular access monitoring. In previous studies, approximately 50% of fistulograms were done on the basis of the results of a transonic screening examination (18,19). As such, we estimate that monitoring may have resulted in additional annual costs of $1020 and $1610 for AVF and grafts, respectively. This expenditure may be worthwhile if access monitoring improves clinical outcomes or reduces costs by saving vascular accesses that were otherwise going to fail (20). However, a randomized study that compared the utility of ultrasound screening with dynamic venous pressure monitoring in synthetic grafts showed no difference in graft survival but higher use of resources among patients who were randomized to ultrasound dilution monitoring (21). In AVF, a small, unblinded, and partially randomized study that examined the utility of angioplasty in well-functioning AVF with radiologic stenosis suggested that angioplasty prolonged median AVF survival (22). Given the high cost of vascular access monitoring, further randomized trials assessing the clinical and economic impact of access monitoring are warranted.

To our knowledge, only one study has measured the cost of vascular access care, on the basis of the type of access, in detail (11). This study showed that the cost of vascular access care was significantly lower for those who began the study period with a functioning AVF rather than a synthetic graft or a central venous catheter. However, this study enrolled prevalent patients who had a functioning catheter, AVF, or graft and was conducted at a time when access screening was not performed (11). The U.S. Renal Data System also estimated the cost of vascular access care for 1994 prevalent hemodialysis patients as being US$6228 per year at risk (8.4% of total Medicare ESRD spending), although the type of access used by patients was not known in this study (23).

The present study extends these findings and reports the cost of vascular access care, on the basis of the type of access attempted, in a cohort of incident hemodialysis patients. The current study also reflects contemporary practice, because ultrasound dilution studies were used to screen all patients with permanent access as recommended by current guidelines (1,14). Vascular access costs were substantial in the first year of dialysis, regardless of the access type attempted, and represented approximately 10% of the total cost of health care for a similar hemodialysis patient population (11).

Our study had several limitations. Selection of candidates for access surgery and the type of access surgery performed may differ among centers and countries, and this may have an impact on the external generalizability of our results. It is possible that patients who receive grafts in centers that favor placement of grafts rather than AVF might note lower access costs for graft patients than that observed in our study. However, in our study, the cost of access care for patients who were dialyzed with each of the access types did not differ on the basis of the comorbidity status of the patient. This suggests that access costs were more a function of the access selected than the patient. Although this lack of observed association may be due to appropriate selection by the vascular access surgeons in terms of who is selected for each of the access types, we believe that AVF placement in all eligible patients, regardless of center, will result in lower access costs compared with a strategy of preferentially placing a graft. The only way to answer this question for certain would be to randomize incident hemodialysis patients to receive one of the three access types and follow clinical outcomes and costs for at least 1 yr. However, this likely is not feasible.

Another limitation of our study is its generalizability to the United States, because the cost of certain health care procedures has been reported to be as much as 50% higher in the United States compared with Canada (24). As such, access costs may be higher in the United States (23), although the *relative* amount of resources required for each access type and the determinants of vascular access costs are likely to be similar in other centers. The finding that patients who were treated exclusively with catheters had lower costs (unadjusted for follow-up time) should be interpreted with caution because analyses that considered cost per patient-year at risk suggested that AVF are the least expensive dialysis access. This should not be taken to mean that all patients should have an attempt at an AVF in an attempt to save money, because patients who are likely to have very limited survival on hemodialysis may incur lower access-related costs during their lifetime through exclusive use of a catheter. Last, our inability to show differences in access costs between subgroups of patients (*e.g.*, patients with diabetes) may have been due to low statistical power. In our opinion, these potential limitations are offset by the accurate assessment of patient comorbidity and the detailed inclusion of all costs relating to vascular access.

Conclusion

The cost of vascular access care is high among all patients and highest among patients in whom a graft is placed. These results support DOQI guidelines that recommend initial placement of AVF. Given the high cost of vascular access care in catheter-only patients and patients who receive a graft, further research into the optimal vascular access type for patients in whom placement of an AVF is not possible is needed. Given the high costs associated with ultrasound vascular access monitoring, the economic implications of this strategy should be studied in more detail.

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