Comparison between Surgical and Endovascular Hemodialysis Arteriovenous Fistula Interventions and Associated Costs

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ABSTRACT

Purpose: To compare: (*i*) rate of arteriovenous fistula (AVF) interventions in both incident and prevalent end-stage kidney disease patients; (*ii*) their associated costs; and (*iii*) intervention-free survival between patients with surgical hemodialysis arteriovenous fistula (SAVF) versus those with an endovascularly created fistula (endoAVF).

Materials and Methods: Data from the United States Renal Data System (USRDS) were abstracted to determine the rate of AVF interventions performed in the first year and associated costs (based on Medicare payment rates) for SAVFs created from 2011 to 2013 in the incident and prevalent patient cohorts. Comparative data for endoAVF were obtained from the Novel Endovascular Access Trial (NEAT). Event rates, intervention-free survival, and costs were compared between endoAVF and SAVF cohorts after 1:1 propensity score (PS) matching.

Results: In the matched incident patients, the event rate was 0.74 per patient-year (PY) for endoAVF versus 7.22/PY for SAVF ($P < .0001$), with a difference in expenditures of $16,494. Similarly, in matched prevalent patients the event rate was 0.46/PY for endoAVF vs 4.10/PY for SAVF ($P < .0001$), resulting in a cost difference of $13,389. Time-to-event analysis showed that at 1 year, 70% of endoAVF patients experienced freedom from intervention versus only 18% of SAVF patients for incident patients; these numbers were 62% and 18% for endoAVF and SAVF prevalent patients, respectively ($P < .0001$ for both).

Conclusions: Both incident and prevalent patients with endoAVF required fewer interventions and had lower costs within the first year compared with matched patients with SAVF.

ABBREVIATIONS

AVF = arteriovenous fistula, endoAVF = endovascularly created fistula, NEAT = Novel Endovascular Access Trial, PS = propensity score, SAVF = surgical hemodialysis arteriovenous fistula, USRDS = United States Renal Data System

A mature, usable surgical arteriovenous fistula (SAVF) offers longer access survival and reduced infection rate, and requires fewer maintenance interventions compared with other hemodialysis vascular access types, such as central venous catheters (CVCs) and AV grafts (AVGs) (1–5). However, studies have found that 70%–86% of SAVFs require 2–3 interventions per patient-year (PY) in the first year after fistula creation to facilitate maturation and maintain function after fistula creation (6–10). SAVFs that are not usable for dialysis or have shortened survival

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Tables E1 and E2 can be found by accessing the online version of this article on *www.jvir.org* and clicking on the Supplemental Material tab.

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leave the patient dependent on CVCs. It is well established in the literature that using CVCs for dialysis patients leads to an increased risk of infection and mortality (2,3,11).

Multiple procedures to facilitate SAVF maturation and use contribute to increased patient morbidity and are costly. However, few studies have examined costs associated with vascular access care, especially differentiating incident versus prevalent patients. One such study evaluating first-year SAVF maintenance costs observed a range from $13,819 to $19,257, depending on patient sex and SAVF location (12). Another study found that SAVFs with limited patency of <6 months had a median cumulative cost of $17,526 (13).

The Everlinq endoAVF System (TVA Medical, Austin, Texas), a potential alternative to SAVF, uses a minimally invasive endovascular method with magnetic catheters and radiofrequency energy to create an AVF (endoAVF) (14,15). Creating a fistula with the use of an endovascular approach may reduce neointimal hyperplasia and stenosis by minimizing trauma to the vessels and by the use of a side-to-side anastomosis. A recent study by Yang et al compared AVF interventions to achieve maturation and maintain vascular access and their associated costs in patients with a new endoAVF versus SAVF patients from a 5% random sample from Medicare Standard Analytical Files (SAFs) (9). However, information on incident and prevalent status and patient body mass index (BMI), which may affect the rate and type of interventions, could not be assessed with the use of Medicare SAFs. The aims of the present study were to compare the rates of interventions and associated health care costs (with the use of Medicare payment rates as a proxy for actual hospital cost data) and intervention-free survival in patients with an endoAVF to propensity score (PS)–matched cohorts in both incident and prevalent end-stage kidney disease (ESKD) patients who had traditional SAVFs (SAVF cohort) in the United States Renal Data System (USRDS).

METHODS

Study Design and Data Sources

Data for this study came from 2 sources. The SAVF data were pulled from the most current USRDS Standard Analytical Files (SAFs) at the time of this study (2010–2013), and the endoAVF data were collected during the NEAT study. NEAT, a prospective, multicenter, single-arm study conducted in Canada, Australia, and New Zealand, studied patients who received an endoAVF and were followed for 1 year. (14). The USRDS is a national registry of chronic kidney disease (CKD) and ESKD in the United States with ~115,000 incident ESKD patients entered annually (16). The USRDS core data and claims files contain deidentified patient demographic, clinical, and dialysis information, as well as health care utilization and cost data from Medicare claim records. In the present study, the 2 SAVF cohorts—incident SAVF cohort and prevalent SAVF cohort—were developed by combining the USRDS data with the USRDS Standard Information Management System (SIMS) and CROWNWeb data by means of their unique USRDS identifiers. CROWNWeb is a web-based data collection system that enables Medicare-certified dialysis facilities to securely submit administrative and clinical data to the Centers for Medicare and Medicaid Services (CMS) in real time. SIMS was used to access CMS Medical Evidence, Death Notification, and Facility Survey forms, and included information to track patient transitions from one treatment modality to another. CROWNWeb was used specifically to access data on patient BMI. The 2 endoAVF cohorts (incident endoAVF cohort and prevalent endoAVF cohort) were derived from NEAT. Incident and prevalent patients in the endoAVF cohort were determined based on dialysis use at the time the endoAVF was created. Thus, patients not on hemodialysis or peritoneal dialysis at the time of endoAVF creation were considered to be incident patients, even if they did not start dialysis by the end of the study. The USRDS database specified if patients were incident or prevalent dialysis patients; patients were defined as incident if they were not on hemodialysis or peritoneal dialysis at the time of AVF creation; all USRDS incident patients received dialysis.

Patient Inclusion and Exclusion Criteria

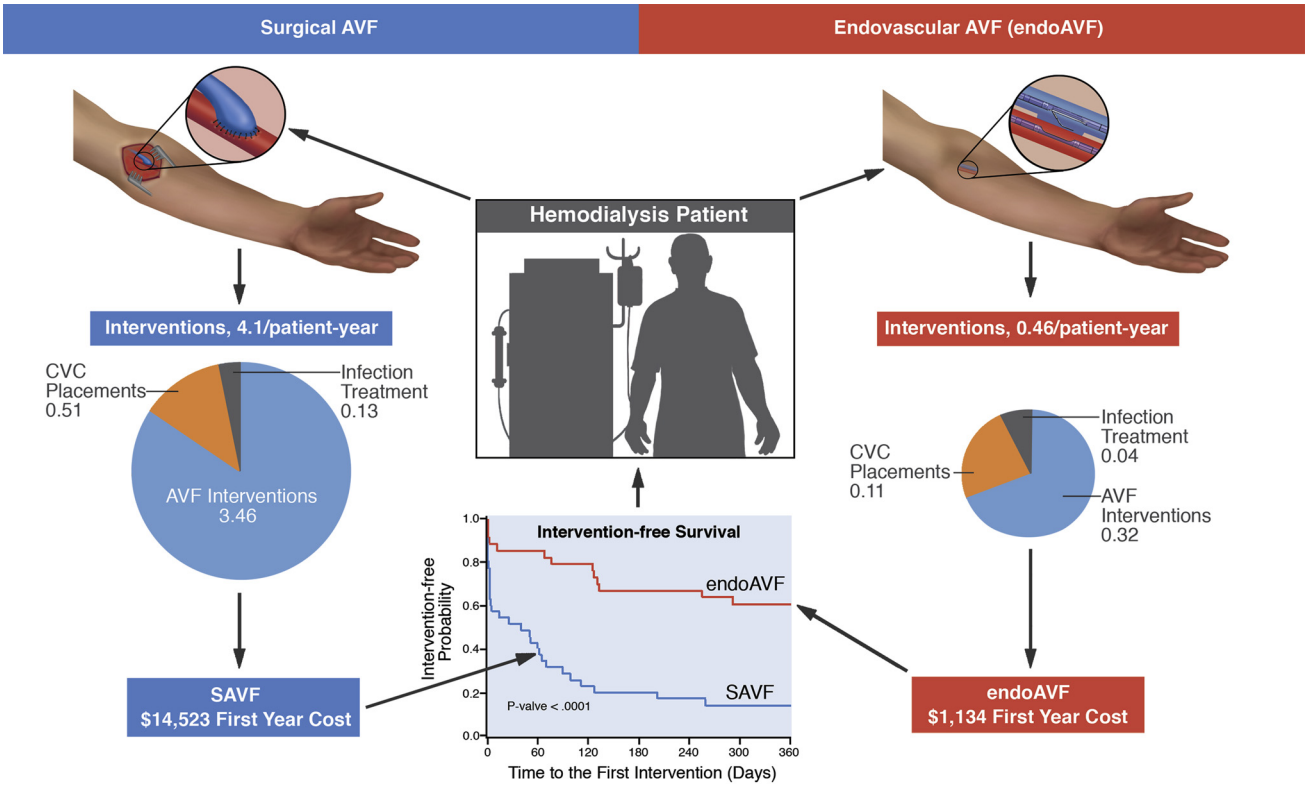
SAVF Cohort.—Patients in the USRDS database were eligible for inclusion in the SAVF cohort if they met the following criteria: (*i*) traditional SAVF creation during 2011–2013 (Current Procedural Terminology [CPT] codes 36818, 36819, 36820, and 36821); (*ii*) $\geq$ 18 years of age on the date of AVF creation; and (*iii*) continuously enrolled in Medicare Parts A and B during the 6-month baseline period before the AVF creation date and the 6-month follow-up period after the AVF creation date.

Endo AVF Cohort.—The endoAVF cohort included all evaluable NEAT participants (n = 60). The endoAVF cohort had deidentified demographic and clinical data collected during the prospective study, including the type, frequency, and complications associated with procedures that occurred during NEAT.

Patient Demographics and Clinical Characteristics

Demographic and clinical information for the SAVF cohort was obtained from the CMS ESKD SAFs. Baseline information included age, BMI, sex, race/ethnicity, select medical conditions (hypertension, cerebrovascular disease [CVD], chronic pulmonary disease, congestive heart failure [CHF], myocardial infarction [MI], diabetes, peptic ulcer disease, connective tissue/rheumatic disease, malignancy, peripheral vascular disease [PVD], and having ever received dialysis). Corresponding International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes were also used to determine baseline clinical information from the USRDS

Visual Synopsis



inpatient, outpatient, and physician Part B files for both incident and prevalent patients.

Demographic and baseline clinical data for the endoAVF cohort was extracted from NEAT (14).

AVF Interventions and Associated Costs

Interventions in the SAVF cohort were identified from Medicare outpatient and Part B claims with the use of CPT codes (**Table E1** [available online on the article's Supplemental Material page at *www.jvir.org*]). Percutaneous and surgical interventions included angioplasty, stent placement, embolization/ligation, thrombolysis, thrombectomy, thrombin injection, revision, distal revascularization and interval ligation (DRIL, for Steal syndrome), CVC placement, AVG creation, and new SAVF creation. Vascular access–related infections were also examined for all patients in Medicare inpatient, outpatient, and part B files with the use of ICD-9-CM codes (996.62, 999.31, 999.32, 999.33). For the endoAVF cohort, intervention data were obtained from NEAT.

Cost data were not collected as part of the NEAT study, so for both endoAVF and SAVF cohorts we used Medicare payment rates for the interventions as a proxy for costs. Costs associated with AVF interventions were estimated with the use of Medicare fee-for-service payment schedules for physician and facility services, not adjusting for geographic differences. In keeping with the years of USRDS files accessed, the following Medicare fee schedules for years 2012 and 2013 were used: Medicare Physician Fee Schedule for physician-based services per site of service; the payment being the facility payment rate or nonfacility payment rate, including services performed in office-based laboratories; Outpatient Prospective Payment System Ambulatory Payment Classifications rate for hospital outpatient facilities; Ambulatory Surgical Center (ASC) payment rate for services performed in an ASC; and Inpatient Prospective Payment Systems Medicare Severity-Diagnosis Related Groups payment rate for hospital inpatient facilities. Costs were estimated based on the total allowed charge for a specific CPT code and did not include ancillary services.

For vascular access–related infection, cost was estimated separately for inpatient and outpatient settings, according to place of treatment as recorded in the claims, because severe infection (eg, sepsis) is typically treated in the hospital, and the cost of care is higher in the inpatient setting compared with outpatient settings.

Statistical Analysis

To compare baseline demographics, event rates, and costs, descriptive statistics with the use of *t* tests and chi-square tests for continuous and categoric variables, respectively, were conducted for the unmatched endoAVF and SAVF incident and prevalent cohorts; paired *t* test and McNemar test were

Table 1. Baseline Characteristics among Incident Patients

Variable	endoAVF (n = 27)		SAVF (n = 13,265)		*P* Value*	SAVF (n = 27)		*P* Value*†
	Mean	SD	Mean	SD		Mean	SD	
Age (y)	63.4	12.7	70.2	11.9	.003‡	64.4	14.5	.8099
BMI (kg/m^2)	28.9	5.8	29.3	8.0	.8064	32.3	10.2	.1990
	n	%	n	%		n	%	
Female	12	44.44	5823	43.9	.9544	13	48.15	.8506
White	19	70.37	9206	69.4	.913	18	66.67	.7815
Medical history								
Hypertension	25	92.59	9638	72.66	.0202‡	26	96.3	1
Cerebrovascular disease	3	11.11	2118	15.97	.7911	5	18.52	.7266
Chronic pulmonary disease	4	14.81	3399	25.62	.1986	8	29.63	.3437
Congestive heart failure	5	18.52	4925	37.13	.0455‡	5	18.52	1
Myocardial infarction	5	18.52	1179	8.89	.0868	5	18.52	1
Diabetes	22	81.48	7784	58.68	.0162‡	21	77.78	1
Peptic ulcer disease	1	3.7	281	2.12	.4399	1	3.7	1
Connective tissue disease–rheumatic disease	7	25.93	448	3.38	<.0001‡	8	29.63	1
Cancer	7	25.93	1286	9.69	.0126‡	7	25.93	1
Peripheral vascular disease	2	7.41	3133	23.62	.0475‡	2	7.41	1

endoAVF = endovascularly created arteriovenous fistula; SAVF = surgically created arteriovenous fistula.
*Chi-square and *t* tests were applied to examine differences between endoAVF and SAVF cohorts.
†McNemar test and paired *t* test were applied to examine differences between endoAVF and SAVF 1:1 matching cohorts.
‡$P < .05$.

Table 2. Baseline Characteristics among Prevalent Patients

Variable	Before Matching					1:1 Matching		
	endoAVF (n = 33)		SAVF (n = 90,105)		*P* Value*	SAVF (n = 33)		*P* Value*†
	Mean	SD	Mean	SD		Mean	SD	
Age (y)	57.0	13.9	64.8	14.7	.0024‡	65.3	13.0	.0142‡
BMI (kg/m^2)	27.1	6.3	29.9	8.4	.0538	30.4	7.9	.0843
	n	%	n	%		n	%	
Female	9	27.27	40,396	44.83	.0425‡	9	27.27	1
White	17	51.52	56,699	62.93	.1748	21	63.64	.3877
Medical history								
Hypertension	30	90.91	79,614	88.36	1	24	72.73	.1094
Cerebrovascular disease	6	18.18	20,156	22.37	.5638	6	18.18	1
Chronic pulmonary disease	7	21.21	32,966	36.59	.0668	10	30.3	.5811
Congestive heart failure	2	6.06	46,804	51.94	< .0001‡	2	6.06	1
Myocardial infarction	8	24.24	15,454	17.15	.28	8	24.24	1
Diabetes	17	51.52	62,938	69.85	.0218‡	23	69.7	.1795
Peptic ulcer disease	3	9.09	3,500	3.88	.1355	1	3.03	.6250
Connective tissue disease–rheumatic disease	6	18.18	4,200	4.66	.0038‡	6	18.18	1
Cancer	4	12.12	9,324	10.35	.7718	3	9.09	1
Peripheral vascular disease	2	6.06	31,072	34.48	.0006‡	2	6.06	1

endoAVF = endovascularly created arteriovenous fistula; SAVF = surgically created arteriovenous fistula.
*Chi-square and *t* tests were applied to examine differences between endoAVF and SAVF cohorts.
†McNemar test and paired *t* test were applied to examine differences between endoAVF and SAVF 1:1 matching cohorts.
‡$P < .05$.

Table 3. Event Rates and Estimated Costs (Medicare Fee Schedule Amount) for Incident Patients

Outcomes	Event Rate per Patient-Year			Expenditures ($US)	
	endoAVF Cohort (n = 27)	1:1 Matched SAVF Cohort (n = 27)	Difference*	Average for the Intervention†	Estimated Difference per Patient-Year
Inpatient vascular access–related infection	0.000	0.461	0.461	15,920.0	7,332.2
Outpatient vascular access–related infection	0.000	0.384	0.384	2,356.1	904.3
Thrombectomy	0.083	0.077	−0.006	2,190.0	−12.8
Revision	0.041	0.461	0.419	3,845.0	1,612.0
DRIL, for Steal syndrome	0.041	0.000	−0.041	2,898.2	−119.7
Angioplasty	0.041	0.844	0.803	3,219.7	2,585.7
Catheter placement	0.124	3.070	2.947	548.6	1,616.4
AVG creation	0.041	0.384	0.342	1,813.8	621.2
New AVF or transposition	0.083	1.382	1.299	1,264.0	1,642.1
Thrombin injection	0.083	0.000	−0.083	171.8	−14.2
Embolization/ligation	0.207	0.077	−0.130	457.8	−59.4
Thrombolysis	0.000	0.000	0.000	346.7	0.0
Stent placement	0.000	0.077	0.077	5,038.4	386.8
Total event rate	0.744	7.216	6.472		
Total cost ($US)	$814.60	$17,443.10			$16,494.50

AVF = arteriovenous fistula; AVG = arteriovenous graft; DRIL = distal revascularization and interval ligation; endoAVF = endovascularly created arteriovenous fistula; SAVF = surgically created arteriovenous fistula.
*Positive value indicates that the event rate of SAVF cohort is higher than that of the endoAVF cohort.
†Estimated based on the matched SAVF cohort (n = 27), converted to 2016 dollars with the use of the Medical Care Component of the Consumer Price Index.

used for the 1:1 matched endoAVF and SAVF incident and prevalent cohorts. PS matching was used to form the SAVF cohort for the endoAVF patients in a 1:1 ratio. Logistic regression, incorporating patient baseline demographic and clinical characteristics, was performed to estimate PSs with the use of a local optimal algorithm. After matching, baseline characteristic between the matched cohorts were compared again with the use of *t* tests and chi-square tests to ensure that the balance of matching was achieved. Any overlap between the PS-matched values was determined by the success of the PS match (calculated as mean PS score in 1:1 matched SAVF cohort/mean PS match in the endoAVF cohort), wherein a higher overlapping of the PS scores between the 2 matched groups indicates a good match. This was determined for both a 1:1 and a 1:10 match (1:10 match not presented) for both incident and prevalent cohorts.

The rates of AVF interventions for the follow-up period were annualized per their individual follow-up times, ie, estimated per PY. The event rates were then compared between the endoAVF and SAVF cohorts with the use of chi-square tests. The average cost for each type of procedure was applied to the event rates, and differences in costs associated with AVF interventions between the 2 cohorts were compared with the use of *t* tests. To determine and compare intervention-free survival of endoAVF and the 1:1 matched SAVF, Kaplan-Meier survival curves and Cox proportional hazards models that stratified on matched pairs were used. Intervention-free AVF survival was defined as the period from the AVF creation date until the date of the first intervention. Patients were censored by the date of death or 1 year after the AVF creation date.

A sensitivity analysis was conducted to account for differences in time to initiating dialysis. This sensitivity analysis excluded CVC-related infections and CVC placements from the event rates in incident patients. *P* values of $< .05$ were considered to be statistically significant. All statistical analyses were performed with the use of SAS 9.3 (Cary, North Carolina).

RESULTS

Of the 103,420 patients in the USRDS that met the inclusion criteria, 13,265 were incident patients and 90,105 were prevalent patients. Baseline characteristics among incident and prevalent endoAVF patients and their corresponding 1:1 matched SAVF cohorts are presented in Tables 1 and 2. The overlaps were 98.6% between the matched incident SAVF (n = 27) and incident endoAVF (n = 27) cohorts and 100% for the prevalent SAVF (n = 33) and prevalent endoAVF (n = 33) cohorts, indicating a very good match in both patient populations.

Total event rates and costs per PY for incident and prevalent patients are presented in Tables 3 and 4. In the matched incident patients the event rate was 0.74/PY for endoAVF versus 7.22/PY for SAVF ($P < .0001$), with a difference in expenditures of $16,494. Similarly, in matched prevalent patients the event rate was 0.46/PY for

Table 4. Event Rates and Estimated Costs (Medicare Fee Schedule Amount) for Prevalent Patients

Outcomes	Event Rate per Patient-Year			Expenditures ($US)	
	endoAVF Cohort (n = 33)	1:1 Matched SAVF Cohort (n = 33)	Difference*	Average for the Intervention†	Estimated Difference per Patient-Year
Inpatient vascular access–related infection	0.035	0.064	0.029	11,569.9	332.1
Outpatient vascular access–related infection	0.000	0.064	0.064	2,356.1	150.9
Thrombectomy	0.000	0.384	0.384	3,357.7	1,290.1
Revision	0.035	0.192	0.157	2,155.1	337.9
DRIL, for Steal Syndrome	0.000	0.000	0.000	2,898.2	0.0
Angioplasty	0.035	1.217	1.181	5,854.0	6,915.5
Catheter placement	0.106	0.512	0.406	1,165.6	473.6
AVG creation	0.000	0.640	0.640	1,763.2	1,129.1
New AVF or transposition	0.141	0.640	0.499	1,597.1	797.0
Thrombin injection	0.000	0.000	0.000	171.8	0.0
Embolization/ligation	0.071	0.192	0.121	1,146.3	139.2
Thrombolysis	0.035	0.000	−0.035	346.7	−12.2
Stent placement	0.000	0.192	0.192	9,556.5	1,835.9
Total event rate	0.459	4.098	3.639		
Total cost ($)	$1,134.24	$14,523.15			$13,388.92

AVF = arteriovenous fistula; AVG = arteriovenous graft; DRIL = distal revascularization and interval ligation; endoAVF = endovascularly created arteriovenous fistula; SAVF = surgically created arteriovenous fistula.
*Positive value indicates that the event rate of SAVF cohort is higher than that of the endoAVF cohort.
†Estimated based on the matched SAVF cohort (n = 33), converted to 2016 dollars with the use of the Medical Care Component of the Consumer Price Index.

endoAVF versus 4.10/PY for SAVF ($P < .0001$), resulting in a cost difference of $13,389. An additional sensitivity analysis that removed CVC-related infections and CVC placements from incident patients also showed a lower event rate for the endoAVF cohort compared with the SAVF cohort, 0.62/PY versus 3.84/PY, and a lower cost for the endoAVF interventions compared with the SAVF cohort: $11,290 cost difference (**Fig 1**; **Table E2** [available online on the article's Supplemental Material page at *www.jvir.org*]).

Time-to-event analysis showed that at 1 year, 70% of incident endoAVF patients experienced freedom from intervention versus only 18% of incident SAVF patients; these numbers were 62% and 18% for prevalent endoAVF and SAVF patients, respectively. All comparisons were significant at $P < .05$ (**Fig 2**).

DISCUSSION

Compared with traditional SAVF from USRDS data, both incident and prevalent patients with endoAVF had significantly lower event rates and associated costs than SAVF patients, suggesting the endoAVF may improve outcomes and reduce costs in both patient populations. Furthermore, the impact on quality of life for these patients may be a potential benefit, with fewer outpatient visits and hospitalizations following endoAVF creation.

EndoAVF creation does not involve the same surgical manipulation of vessels experienced by SAVF. This is important because surgical manipulation may contribute to vessel damage, leading to neointimal hyperplasia and stenosis, which then requires intervention for the SAVF to properly mature. In addition, it has been demonstrated that SAVFs that require intervention to facilitate maturation have reduced cumulative patency compared with SAVFs that can be cannulated without intervention (17,18). Once an SAVF requires an intervention, it is at risk of needing future interventions owing to recurrence of stenosis. Angioplasty is the mainstay treatment but associated with limited patency. Patency rates of angioplasty are ~50%–75% at 6 months for SAVFs (19,20), and failure to maintain SAVF patency results in a clotted and possibly lost SAVF. Given the poor SAVF patency associated with angioplasty, multiple newer technologies have been introduced, including, but not limited to, drug-eluting balloons and stent grafts. These technologies are costly and, although evidence suggests improved patency, cost-impact analyses has not yet been performed (21,22). Balloon-assisted maturation, a technique described for SAVFs that fail to mature enough to provide hemodialysis, has been shown to require an average of 2.6 angioplasties to achieve what is considered to be a usable AVF, with 2.8 angioplasties per year required to maintain patency of SAVF (23). Such outcomes data support the notion of "injury begets injury," so preempting the problem is a less damaging and potentially more cost-effective solution.

The results of this study are consistent with findings in Yang et al's study (9), demonstrating lower post–AVF

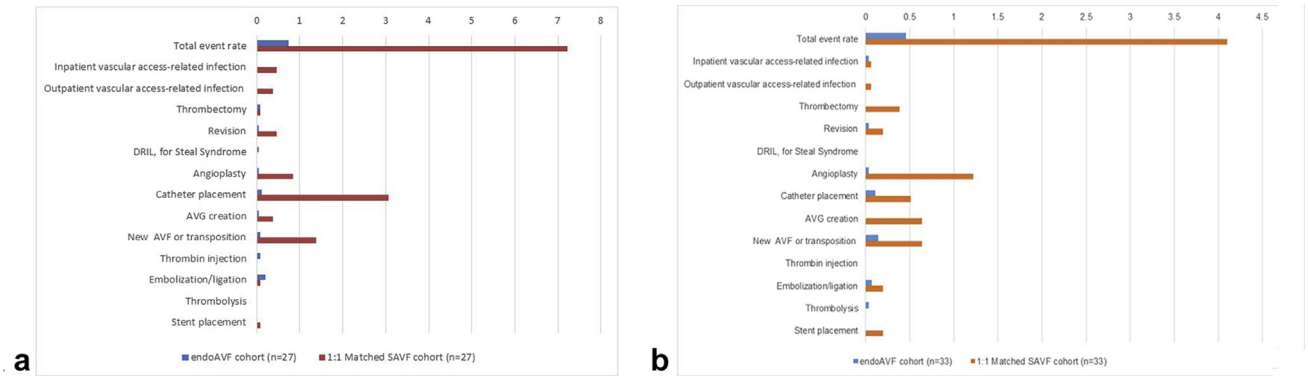


Figure 1. Post-matching comparison of interventions rates for SAVF and endoAVF cohorts for (**a**) incident and (**b**) prevalent patients.

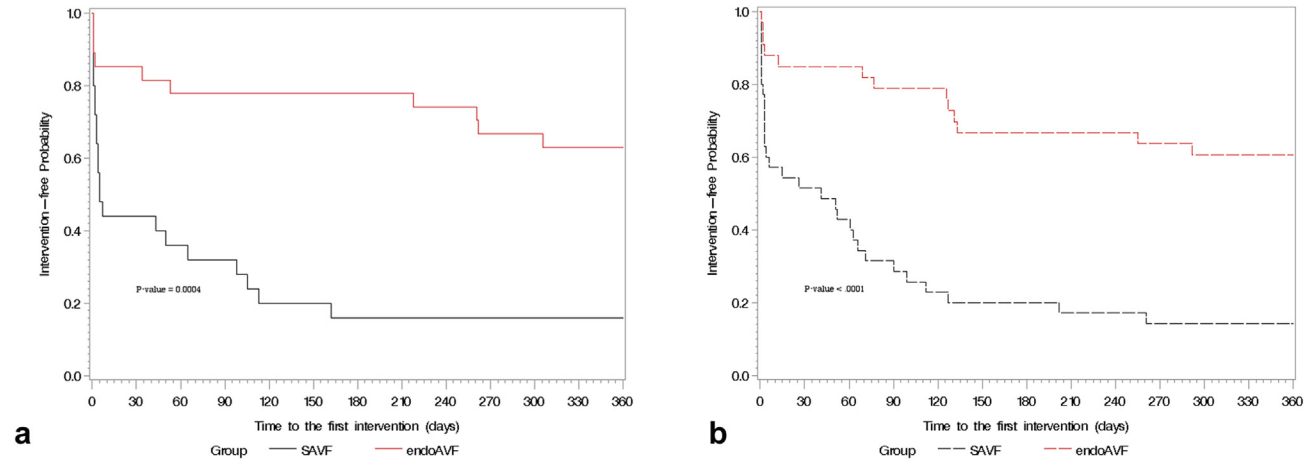


Figure 2. Time to first intervention for endoAVF patients and matched SAVF patients for (**a**) incident and (**b**) prevalent patients.

creation intervention rates and costs for the endoAVF versus the SAVF cohort. However, our results are perhaps more illuminating, owing to the more comprehensive ESKD patient sample available in the present analysis versus the 5% sample used by Yang et al, the ability to analyze incident and prevalent cohorts separately with the use of USRDS, inclusion of BMI in the PS matching, and the use of national Medicare payment rates as the basis for determining costs because the payment rates are consistent across the country and for every hospital. In Yang et al, the analysis used the total allowed charge on the claim to Medicare to identify costs to the health care system, which may inflate the costs of the fistula interventions because ancillary services and procedures are often included on the same claim. Our USRDS analysis used the Medicare national fee schedule amount for a specific CPT code based on the setting of care and year of service and were not varied by geography. This is a conservative approach because it does not take into account other services performed by the provider that may be billed on the same claim, which better enabled us to isolate the cost impact of fistula interventions in the health care system. Furthermore, the breakout between incident and prevalent patients allowed for a more accurate comparison of the matched populations, given that almost one-half of the endoAVF patients in NEAT were incident at the time of fistula creation.

Although we compared endoAVF costs with SAVF costs, there are limited studies within the SAVF literature comparing different AVF anastomotic techniques and associated cost of maintenance with SAVF (24). El-Gamil et al used USRDS to compare vascular access costs in free-standing office-based centers with the hospital outpatient department, but they combined SAVF and AVG outcomes, so the results can not be compared with the present study (25,26). Another recent study, by Al-Balas et al, quantified intervention rates and costs by access type in incident patients starting dialysis with a CVC and found 2.48 procedures per PY were needed to mature and maintain a surgical AVF with a median first year cost of $16,602 (10). Al-Balas et al's findings are consistent with the event rates and costs found in the present study in the prevalent SAVF and incident SAVF subanalysis (which excluded CVC placements) when considering that our study included additional procedures (CPT codes) not included in the Al-Balas et al study. Costs were slightly higher in the Al-Balas et al analysis because they did not adjust for site of service when using the Medicare fee schedule rates.

Regarding intervention rates for SAVFs, our analysis included CVC placements and treatment for infection in

the total intervention rates. These are not commonly included in the intervention rates reported in the SAVF literature. When excluding CVC placements and infection treatment, our analysis found intervention rates of 3.3/PY for the incident SAVF cohort and 3.5/PY for the prevalent surgical cohort. These interventions are consistent with intervention rates reported in the literature, where Falk et al reported a rate of 1.75/PY (7), Lee et al (17) a range of 0.76–3.51/PY to maintain patency after cannulation, and Al-Balas et al (10) 2.48/PY. The latter study included only selected procedures, such as thrombectomy, percutaneous transluminal angioplasty, surgical revisions, and new AVF placement (10).

Kaplan-Meier survival curves demonstrated that the SAVF patients had a significantly higher risk of receiving interventions than the endoAVF patients. The differential between endoAVF and SAVF occurred early and remained stable starting at 200 days after AVF creation. This is a significant finding, because previous studies have shown that fistulas requiring an intervention have a shorter patency (17,18).

A possible criticism of the present study is that the endoAVF cohort contained a large number of incident (before dialysis) patients (almost 50%), which may mean that fewer events would be incurred after the procedure because fewer patients were using their endoAVF. However, the study factored in incident status and found a reduction in interventions with endoAVF for incident patients as well as prevalent patients. In addition, we compared time-to-event curves between incident and prevalent patients and found no statistical difference in either the endoAVF patients or the SAVF patients, suggesting that incident patients receive just as many interventions as prevalent patients, primarily due to maturation procedures and surgical revisions/new creations from early failures.

There are limitations to this study. Interventions the SAVF cohort were not collected through a prospective study as they were in the endoAVF cohort, nor were they obtained from patients' medical charts. Instead, interventions in the SAVF cohort were identified from Medicare claims, so it is possible that procedure or diagnostic codes may have been entered incorrectly. The analysis examined only the most common procedures after the initial AVF creation and did not include diagnostic procedures. In addition, despite the use of PS matching, residual confounding, eg, by institutional processes for patient care, is possible, especially considering that the NEAT population is composed of individuals from Canada, Australia, and New Zealand. These populations may differ from the US comparison cohort in unmeasured ways that PS matching does not address (eg, process of care issues, such as use of multidisciplinary care).

In addition, the USRDS database does not distinguish between types of SAVFs placed. Given that the endoAVF is created in the distal forearm, a comparison of upper- and lower-arm SAVFs with the endoAVF was not possible.

CONCLUSION

Freedom from intervention was significantly higher in both incident and prevalent endoAVF patients. Compared with SAVF patients, endoAVF patients had a significantly lower rate of creation procedures after AVF, resulting in a significantly lower AVF maintenance cost in the first year following AVF creation in these patients.

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REFERENCES

1. Almasri J, Alsawas M, Mainou M, et al. Outcomes of vascular access for hemodialysis: a systematic review and meta-analysis. J Vasc Surg 2016; 64:236–243.
2. Ravani P, Palmer SC, Oliver MJ, et al. Associations between hemodialysis access type and clinical outcomes: a systematic review. J Am Soc Nephrol 2013; 24:465–473.
3. Ravani P, Quinn R, Oliver M, et al. Examining the association between hemodialysis access type and mortality: the role of access complications. Clin J Am Soc Nephrol 2017; 12:955–964.
4. Greenberg J, Jayarajan S, Reddy S, et al. Long-term outcomes of fistula first initiative in an urban university hospital—is it still relevant? Vasc Endovascular Surg 2017; 51:125–130.
5. Lok CE, Sontrop JM, Tomlinson G, et al. Cumulative patency of contemporary fistulas versus grafts (2000–2010). Clin J Am Soc Nephrol 2013; 8:810–818.
6. Thamer M, Lee T, Wasse H, et al. Medicare costs associated with arteriovenous fistulas among US hemodialysis patients. Am J Kidney Dis 2018; 72:10–18.
7. Falk A. Maintenance and salvage of arteriovenous fistulas. J Vasc Interv Radiol 2006; 17:807–813.
8. Kimball TA, Barz K, Dimond KR, Edwards JM, Nehler MR. Efficiency of the kidney disease outcomes quality initiative guidelines for preemptive vascular access in an academic setting. J Vasc Surg 2011; 54:760–765; discussion 765–766.
9. Yang S, Lok C, Arnold R, Rajan D, Glickman M. Comparison of post-creation procedures and costs between surgical and an endovascular approach to arteriovenous fistula creation. J Vasc Access 2017; 18(Suppl 2): 8–14.
10. Al-Balas A, Lee T, Young CJ, Kepes JA, Barker-Finkel J, Allon M. The clinical and economic effect of vascular access selection in patients initiating hemodialysis with a catheter. J Am Soc Nephrol 2017; 28: 3679–3687.
11. US Renal Data System. *USRDS annual report 2011: atlas of chronic kidney disease and end-stage renal disease in the United States, National Institutes of Health. Chapter 2: Clinical indicators and preventative care.* Bethesda, Maryland: National Institute of Diabetes and Digestive and Kidney Diseases; 2011.
12. Abramowitz SD, Kokkosis AA, Schanzer H, Faries PL, Marin MM, Teodorescu VJ. Cost discrepancies in the creation and maintenance of functional arteriovenous fistulas. J Vasc Surg 2013; 58: 1148–1149.
13. Feldman ZM, Liu LB, Abramowitz SD, et al. Hemodialysis vascular access: rising costs as a surrogate marker for patency and function of arteriovenous fistulas. Ann Vasc Surg 2017; 38:136–143.
14. Lok C, Rajan D, Clement C, et al. Endovascular proximal forearm arteriovenous fistula for hemodialysis access: results of the prospective, multicenter Novel Endovascular Access Trial (NEAT). Am J Kidney Dis 2017; 70:486–497.

15. Rajan DK, Ebner A, Desai SB, Rios JM, Cohn WE. Percutaneous creation of an arteriovenous fistula for hemodialysis access. J Vasc Interv Radiol 2015; 26:484–490.
16. US Renal Data System. *USRDS 2015 annual data report: atlas of chronic kidney disease and end-stage renal disease in the United States, National Institutes of Health. Chapter 1: Incidence, prevalence, patient characteristics, and treatment modalities*. Bethesda, Maryland: National Institute of Diabetes and Digestive and Kidney Diseases; 2015.
17. Lee T, Ullah A, Allon M, et al. Decreased cumulative access survival in arteriovenous fistulas requiring interventions to promote maturation. Clin J Am Soc Nephrol 2011; 6:575–581.
18. Harms JC, Rangarajan S, Young CJ, Barker-Finkel J, Allon M. Outcomes of arteriovenous fistulas and grafts with or without intervention before successful use. Journal of Vascular Surgery 2016; 64:155–162.
19. Clark TW, Hirsch DA, Jindal KJ, Veugelers PJ, LeBlanc J. Outcome and prognostic factors of restenosis after percutaneous treatment of native hemodialysis fistulas. J Vasc Interv Radiol 2002; 13:51–59.
20. Rajan DK, Bunston S, Misra S, Pinto R, Lok CE. Dysfunctional autogenous hemodialysis fistulas: outcomes after angioplasty—are there clinical predictors of patency? Radiology 2004; 232:508–515.
21. Bent CL, Rajan DK, Tan K, et al. Effectiveness of stent-graft placement for salvage of dysfunctional arteriovenous hemodialysis fistulas. J Vasc Interv Radiol 2010; 21:496–502.
22. Kitrou PM, Papadimatos P, Spiliopoulos S, et al. Paclitaxel-coated balloons for the treatment of symptomatic central venous stenosis in dialysis access: results from a randomized controlled trial. J Vasc Interv Radiol 2017; 28:811–817.
23. Miller GA, Hwang W, Preddie D, Khariton A, Savransky Y. Percutaneous salvage of thrombosed immature arteriovenous fistulas. Semin Dial 2011; 24:107–114.
24. Shenoy S, Woodward RS. Economic impact of the beneficial effect of changing vascular anastomotic technique in hemodialysis access. Vasc Endovascular Surg 2005; 39:437–443.
25. El-Gamil A, Dobson A, Manolov N, et al. What is the best setting for receiving dialysis vascular access repair and maintenance services? J VAsc Access 2017; 18:473–481.
26. Dobson A, El-Gamil AM, Shimer MT, et al. Clinical and economic value of performing dialysis vascular access procedures in a freestanding office-based center as compared with the hospital outpatient department among Medicare ESRD beneficiaries. Semin Dial 2013; 26:624–632.

Table E1. Coding Used to Identify Interventions from USRDS Claims Data

Creation Procedures after AVF	CPT Codes
Angioplasty	35475, 35476, 75962, 75978, 37224
Thrombolysis	36593, 37201
Thrombectomy	36831, 36870
Stent placement	37205, 37207, 37236, 37237, 37238, 37239
Embolization/ligation	37241, 37607
Thrombin injection	36002
Distal Revascularization and Interval ligation (DRIL, for Steal Syndrome)	36838
Revision	36832, 36833
Catheter placement	36556, 36558, 36565
AVG creation	36825, 36830
New surgical AVF placement	36818, 36819, 36820, 36821
	ICD-9-CM codes
Vascular access-related infection	996.62, 999.31, 999.32, 999.33

AVF = arteriovenous fistula; AVG = arteriovenous graft; CPT = Current Procedural Terminology; USDS = United States Renal Data System.

Table E2. Sensitivity Analysis of Event Rates and Estimated Costs (Medicare Fee Schedule Amount) for Incident Patients

Outcomes	Event Rate per Patient-Year			Expenditures ($US)	
	endoAVF Cohort (n = 27)	1:1 Matched SAVF Cohort (n = 27)	Difference*	Average for the Intervention†	Estimated Difference per Patient-Year
Inpatient infection	0	0.23	0.23	16823.15	3869.32
Outpatient infection	0	0.307	0.307	2522.67	774.46
Thrombectomy	0.083	0.077	-0.006	2189.97	-13.14
Revision	0.041	0.461	0.42	3844.99	1614.90
DRIL, for Steal Syndrome	0.041	0	-0.041	2898.2	-118.83
Angioplasty	0.041	0.844	0.803	3219.74	2585.45
Catheter placement	0	0	0	548.57	0.00
AVG creation	0.041	0.384	0.343	1813.77	622.12
New AVF or transposition	0.083	1.382	1.299	1264.03	1641.97
Thrombin injection	0.083	0	-0.083	171.8	-14.26
Embolization/ligation	0.207	0.077	-0.13	457.75	-59.51
Thrombolysis	0	0	0	346.7	0.00
Stent placement	0	0.077	0.077	5038.43	387.96
Total event rate	0.62	3.838	3.218		
Total cost ($)	$878.54	$12,169.00			$11,290.46

Note–Excludes CVC-related infection and CVC placements.
AVF = arteriovenous fistula; AVG = arteriovenous graft; CVC = central venous catheter; DRIL = distal revascularization and interval ligation; endoAVF = endovascularly created fistula; SAVF = surgical hemodialysis arteriovenous fistula; $USD = United States Dollar.
*Positive value indicates event rate of SAVF cohort is higher than the endoAVF cohort.
†Estimated based on the matched SAVF cohort (n = 27), and has been converted to 2016 dollars using the Medical Care Component of the Consumer Price Index.