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Original Article

Reducing vascular access morbidity: a comparative trial of two vascular access monitoring strategies

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Abstract

Background. Thrombosis is the primary cause of access failure in polytetrafluoroethylene grafts and arteriovenous fistulas. It can lead to significant patient and access morbidity and mortality, and is difficult to prevent medically. Intervention is largely limited to maximizing access patency by detecting culprit lesions early and intervening with angioplasty or surgical revision. The most efficacious monitoring strategy is undetermined.

Methods. This 3 year prospective study took advantage of a change in monitoring strategy used in a large dialysis centre to compare the efficacy of two methods used to monitor grafts and fistulas in order to prevent access thrombosis. Accesses were monitored using Duplex ultrasonography in year 1, while the saline ultrasound dilution technique (Transonic) became the primary monitoring strategy in year 3 (year 2 was a transition year). Risk factors for thrombosis were determined using multivariate survival analysis, and the performance of Duplex ultrasonography and Transonic monitoring was assessed.

Results. A total of 303 656 access days at risk were assessed, with 344, 385 and 425 accesses in years 1, 2 and 3, respectively. The total thrombosis rate was 1.01/1000 access days in year 1 compared with 0.66/1000 access days in year 3. This was accomplished despite a reduction in procedure rates of 55% for angiograms, 13% for angioplasties and 31% for thrombolysis.

Conclusion. Low flow rates detected using Transonic monitoring were associated with increased thrombosis, while stenosis detected using Duplex ultrasonography was not a strong predictor of incipient thrombosis; however, these different access characteristics were compared using monitoring techniques that may be ideal in different clinical situations.

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Introduction

Vascular access remains the Achilles heel of haemodialysis (HD). Vascular access complications are the leading cause of morbidity in the HD population, accounting for up to 25% of all hospital stays and up to 50% of the first year HD costs. The cost of access morbidity has been estimated to be ~US$8000 per patient year at risk [1]. Thrombosis is the primary cause of failure in both polytetrafluorethylene grafts (AVG) and arteriovenous fistulas (AVF) [2].

The high cost of access failure demands a closer look at strategies that may prevent vascular access thrombosis. Comparisons of a variety of prospective monitoring tools indicate that measurement of access blood flow (Qa) may provide the best prediction of future thrombosis [3,4]. Recommendations [5,6] have supported such monitoring on the premise that the natural history of the access will be altered by radiological or surgical intervention once access dysfunction is detected. However, there is little clear evidence that such a strategy of prospective monitoring of Qa followed by radiological or surgical intervention significantly improves patency [7–9].

The primary goal of this study was to compare the efficacy of two established monitoring strategies within our institution in detecting access malfunction and preventing vascular access thrombosis. The first strategy used routine access monitoring by Duplex ultrasonography (Duplex US) followed by radiological or surgical intervention; the second strategy involved routine monitoring of Qa by the saline ultrasound dilution technique (Transonic) followed by radiological or surgical intervention. The secondary goal was to determine patient and access characteristics that predict access thrombosis.

Subjects and methods

Study design

This was a prospective study of an inception cohort within the University Health Network (UHN) HD programme, and was approved by the UHN Ethics Review Board. The programme manages between 350 and 400 HD patients and has incorporated a multidisciplinary approach to access management since January 1996 [10]. The programme is staffed by a full-time vascular access coordinator, a part-time nurse whose responsibilities include Transonic monitoring, nephrologists, interventional radiologists and vascular access surgeons. Weekly vascular access clinics and monthly interdisciplinary meetings are held to review and discuss new or complicated cases. All individuals were dialysed with biocompatible membranes (Fresenius polysulfone dialysers) for an average of 4 h three times a week, using heparin anticoagulation.

All chronic HD patients with a permanent AVG or AVF within this programme were included in the study. Baseline demographic information was collected, including access characteristics such as dates of creation and loss, reason for loss, access type and anatomy (Table 1). The access coordinator prospectively tracked the number of angiograms, angioplasties, surgical revisions, declottings, hospitalizations related to vascular access complications, and the length of stay for such hospitalizations throughout the study. Duplex US and Transonic results were documented at the time of measurement. All information was entered into a centralized vascular access database, specifically created for the study.

Three study periods were defined: year 1 (November 1, 1997–October 31, 1998) was designed to assess the strategy of Duplex US monitoring, which at that time had been an established part of the UHN HD access monitoring programme for >5 years. Year 2 (November 1, 1998–October 31, 1999) was a transition year, designed to determine the effect of initiating a new access monitoring strategy involving Transonic surveillance. Year 3 (November 1, 1999–October 31, 2000) was designed to estimate the 'true effect' of a fully established Transonic surveillance strategy. In year 1, all AVG underwent routine monitoring by Duplex US every 6 months; those accesses that appeared at risk for further stenosis or thrombosis were monitored more frequently. An access at risk was defined as one that had a thrombotic episode within the first 3 months from its creation date or one that had a thrombosis/thrombolyis or required angioplasty within 3 months from the last time it was monitored. There was no routine surveillance of AVF: nursing staff assessed AVF at each dialysis session, and those that demonstrated evidence of stenosis by two of three criteria (abnormal physical exam, elevated venous pressures or abnormal monthly recirculation studies) were referred for a Duplex US exam [5,6]. If the Duplex US study of either an AVG or AVF found a severe stenosis, indicating a lesion of $>50\%$, a referral for an angiogram was made. If a lesion was found, and assessed by the interventional radiologist to be amenable to angioplasty, this was performed at the same visit. Otherwise, a booking for a surgical revision was made. Our radiology department followed Duplex US methodology as outlined by the radiology literature [11].

During year 2, Qa monitoring using the ultrasound dilution technique (Transonic Systems, Ithaca, NY, USA) was introduced. The study protocol involved a single trained operator who obtained Transonic measurements monthly for AVG and bimonthly for AVFs as per published guidelines [5,6]. During each Transonic session, a minimum of two flow measurements were obtained in the first hour of dialysis, when the patient was haemodynamically stable with a systolic blood pressure >110 mmHg at a blood flow rate of 300 ml/min. If the measurements were discrepant by $\geqslant 10\%$, the patients' blood pressure was assessed and another measurement was made if the patient was stable. If the patient was unstable, the attending physician was asked to

Table 1. Patient characteristics[a]

Characteristic	AVG $n=149$ (37.2%)	AVF $n=252$ (62.8%)
Age mean (range)	57.6 (19–85)	57.5 (17–90)
Male	43.0%	70.6%
Race		
Black	18.8%	7.5%
Caucasian	54.4%	62.3%
Other	26.9%	30.2%
Reason for dialysis		
Diabetes	29.5%	22.2%
Glomerulonephritis	19.5%	21.4%
Interstitial nephritis	2.7%	2.4%
Hypertension	21.5%	19.8%
Other	26.9%	34.1%
BMI[b] mean (SD)	26.5 (6.5)	24.9 (5.1)
No. co-morbidities: mean (SD)	3.0 (1.7)	2.7 (1.7)
Smoker	28.2%	33.7%
Time on dialysis at time of access creation: mean (SD)	254 days (566)	35 days (229)
Access subtype	58.4% straight 41.6% loop	70.0% radial 30.0% brachial
No. of previous accesses		
0	64.4%	96.0%
1	27.5%	3.2%
$\geqslant 2$	8.1%	0.8%

[a]Patients are described at the time of the creation of the earliest access included in the study.
[b]Body mass index.

assess the patient, and the Transonic measurement was delayed until the next time the patient was haemodynamically stable during dialysis. Qa measurements were documented, and the average of that session's measurements was included in the study. If a low or declining flow [defined as <650 ml/min (grafts) or <500 ml/min (AVF) or a drop of $>15\%$ compared with the previous measurement] was detected, referral for an angiogram was made. If the interventional radiologist assessed a stenotic lesion as severe ($>50\%$ stenosis) and amenable to angioplasty, it was done during the same visit; otherwise, a booking for a surgical revision was made. If the lesion was not severe, routine Transonic monitoring was resumed.

The study protocol for year 3 called for a continuation of the strategy incorporated in year 2. In both years, Doppler monitoring was continued longitudinally, as previously described, to allow for comparison with Transonic monitoring.

The primary end point of this study was the cumulative thrombosis rate at 14 and 30 days after access monitoring. Secondary end points were the cumulative procedure rates for angiograms, angioplasties and thrombolysis. Exploratory end points of interest included risk factors for thrombosis, the rate of access-related hospitalizations and the average length of stay of these hospitalizations.

Statistical analysis

The primary and secondary end points of this study were expressed as events/1000 access days. For several reasons, the rates for the three periods were not directly comparable. First, the population consisted of both prevalent and incident dialysis patients; therefore, some patients occurred in the tabulations for all 3 years, resulting in lack of independence in the observations and, secondly, within the study period, a patient could have had more than one access such that an 'old' access would appear earlier in the study and a 'new' one later.

To overcome these analytical problems, a subset of the patients who had the same access in place for the entire 3 year period (1095 days) was identified ($n=150$ patients). Year 1 and year 3 thrombosis rates were compared in two ways: patients were assigned a binary (yes/no) variable for each year, depending on whether the event of interest did or did not occur, the resulting 2×2 tables were analysed using McNemar's tests and the difference in the number of events was analysed using Wilcoxon sign rank tests. Sensitivity and specificity were calculated to estimate the value of Duplex US and Transonic monitoring in predicting thrombosis. Cox proportional hazard regression analysis was used to identify risk factors for thrombosis. All tests of significance were two-sided with a P-value <0.05. The statistical software used was SAS (version 8.0) (SAS Institute Inc., Cary, NC, USA).

Results

Five hundred and forty-eight accesses in 401 patients were analysed (Table 1). Over 60% of the accesses (334 accesses in 248 patients) were created on or after November 1, 1997. For 149 of the 401 patients, the first access in the study was AVG. Eighty (53.7%) of these AVG experienced at least one access thrombosis. The first access for the remaining 252 patients was AVF; 49 (19.4%) of these AVF had at least one access thrombosis.

Overall rates of thrombosis and interventions

A total of 333 016 access days at risk were assessed over three 1 year periods. During this time, the thrombosis rate in AVGs fell from 1.66/1000 access days in year 1 to 1.08/1000 in year 3 (Table 2A). Thrombosis rates in AVFs also fell, but less dramatically, from 0.44/1000 access days in year 1 to 0.33/1000 access days in year 3 (Table 2B). In the subset of patients who had retained the same access for the entire 3 year period, AVGs had significantly more episodes of thrombosis in year 1 compared with year 3: of 64 AVGs, 13 had at least one thrombosis in year 1 but none in year 3, compared with four who had at least one thrombosis in year 1 but none in year 3 ($P=0.029$, McNemar's test). Of 86 AVFs, only one had at least one thrombosis in year 1 but none in year 3, while none of them had a thrombosis in year 3 but not in year 1 ($P=0.317$, McNemar's test).

Overall, the thrombosis rate fell between year 1 and year 3, despite a decrease in the rate of angiographic procedures (angiograms, angioplasties and thrombolysis) (Table 2). The total rate of angiographic procedures decreased from 2.74/1000 access days in year 1 to 1.96/1000 access days in year 3.

An alternative to dichotomizing accesses on the basis of thrombosis or intervention is to count the actual number of events in each 1 year period and calculate the paired differences. The results confirm the previous conclusions. Patients with AVG had significantly more thromboses in year 1 than in year 3 ($P=0.034$) and received more thrombolysis in year 1 ($P=0.048$), despite more angioplasties in year 1 ($P=0.045$). Comparisons between years 1 and 2, and between years 2 and 3 were consistent with the year 1–year 3 comparison. On a per access basis, procedure rates declined each year. A similar analysis of patients with AVF accesses showed no significant trend over time. These patients were unlikely to experience any thrombosis, and received fewer interventions.

Finally, there was a total reduction in both vascular access-related hospitalizations and thrombosis-related hospitalizations in year 3 compared with year 1 (Figure 1).

Sensitivity and specificity

A total of 605 Duplex US measurements were made: in year 1, with the strategy of Duplex US monitoring, 184 studies were performed. These were continued in years 2 (226 studies) and 3 (195 studies). When the strategy of Transonic monitoring was introduced in year 2, 1216 individual Transonic measurements were made. Once established in year 3, 1516 Transonic flow studies were completed.

In order to examine the predictive value of both types of monitoring, we examined the accesses' thrombosis history following monitoring. The findings of the Duplex US studies were categorized as no stenosis

Table 2. Rates of thrombosis and procedures[a]

Year	Accesses	Patients	Access days	Angiograms	Angioplasty	Thrombolysis	Thrombosis
A. Polytetrafluoroethylene grafts							
1	155	136	42 770	0.72 (0.49, 1.03)	2.03 (1.64, 2.50)	1.22 (0.91, 1.59)	1.66 (1.29, 2.10)
2	175	158	48 755	0.59 (0.39, 0.86)	2.22 (1.83, 2.67)	1.42 (1.11, 1.78)	1.74 (1.39, 2.15)
3	184	170	55 424	0.41 (0.23, 0.63)	1.84 (1.52, 2.26)	0.96 (0.72, 1.24)	1.08 (0.83, 1.39)
B. Arteriovenous fistulas							
1	189	174	48 188	0.71 (0.50, 1.00)	0.73 (0.50, 1.02)	0.21 (0.10, 0.37)	0.44 (0.27, 0.66)
2	210	201	62 978	0.65 (0.46, 0.89)	0.95 (0.73, 1.22)	0.14 (0.06, 0.27)	0.24 (0.13, 0.40)
3	241	231	71 901	0.25 (0.15, 0.39)	0.65 (0.49, 0.88)	0.10 (0.04, 0.21)	0.33 (0.21, 0.50)

[a]Rates are per 1000 access days with exact (Poisson) 95% CIs; to covert to thrombosis/patient/year, determine the total number of thromboses/total number of patients for the year. For example, using Table 2A year 1: $1.66 \times 42\ 770/1000 = 71 \rightarrow 71/136 = 0.52$ thrombosis/patient/year1 or $71/155 = 0.46$/access/year1.

(0–24% lumen reduction), stenosis (25–49% lumen reduction) or severe stenosis ($\geqslant$50% lumen reduction). Transonic measurements were categorized as a flow rate of <500, 500–650 or $\geqslant 650$, and were also dichotomized depending on whether or not they showed a decrease of $\geqslant$15% relative to the previous measurement. The outcomes were a thrombotic episode or thrombosis-related access loss within 14 days of the measurement. For AVG, loop and straight subtypes were examined separately. It was not possible to analyse radial and brachial AVF separately due to the small number of events in these accesses. Thrombosis that occurred following 30 days was not included in determining the predictive value of Duplex US or Transonic monitoring. The total thrombosis rate in each study year is presented in Table 2.

Of the Duplex US results for AVG, 148 showed no stenosis, 252 showed stenosis and 205 showed severe stenosis. When appropriate and possible, an intervention was performed following the monitoring (angioplasty, thrombolysis or surgical revision). However, despite a finding of no stenosis, 58 accesses (40%) developed thrombosis. When severe stenosis was detected, 35% of the accesses thrombosed within 14 days. Although AVF were seldom monitored using Duplex US, the only thromboses in these accesses were associated with a finding of severe stenosis (Table 3A).

Estimates of the sensitivity and specificity of Duplex US measurements can be made in various ways. For example, the 'stenosis' column can be combined with either the 'no stenosis' or the 'severe stenosis' column. The best case scenario assumes that all patients with stenosis who received an intervention would otherwise have thrombosed, whereas none of the patients with no stenosis would have gone on to thrombose. This best case interpretation provided a sensitivity of 0.78, specificity of 0.26 and the positive predictive value of 0.44. For AVG, 40% of loop grafts had a thrombosis *vs* 29% of straight grafts if a stenosis was detected.

Transonic measurements were examined similarly (Table 3B). In AVG, there was a clear gradient: thrombosis occurred within 14 days in 45% of the accesses with a low reading, in 33% of those with an intermediate reading and in 30% of those with a high flow. The gradient appeared to be stronger in AVG straight grafts, where the thrombosis rates within 14 days were 42, 31 and 27%, while in AVG loop grafts, the thrombosis rate was 52% in grafts with low flow, but was similar (35%) in grafts with intermediate and high flow rates. There were few thrombotic episodes within 14 days in AVF, regardless of the flow rate (5, 3 and 8% of the accesses with low, intermediate and high flow rates). Change from the previous reading, dichotomized into a decrease of at least 15% or not, was not predictive of thrombosis. The conclusion did not change with dichotomization using a 20% change. In AVG, 33% of those with a large drop and 31% of those without a large drop developed thrombosis within 14 days. In AVF, 7 and 8% thrombosed, respectively.

For robustness, the analysis was repeated using a cut-off of 30 days. The results (Table 3) show that few thromboses formed and few interventions occurred after day 14.

Additional risk factors

Cox proportional hazards regression using stepwise selection identified the type of access, a diagnosis of diabetes and race to be significant predictors of risk of thrombosis. Adjusted for the other variables, AVG had an estimated hazard ratio of 2.8 [$P < 0.0001$, 95% confidence interval (CI) 2.0–4.0], while a diagnosis of diabetes as the aetiology of end-stage renal disease conferred a hazard ratio of 1.7 ($P = 0.006$, 95% CI 1.2–2.5). The risk of thrombosis was found to be highest for blacks, followed by Caucasians. The overall *P*-value for race was 0.003, and individual estimates of risk ratio were: black *vs* other, risk ratio 2.4 ($P = 0.002$, 95% CI 1.4–4.2); black *vs* Caucasian, risk ratio 1.7 ($P = 0.028$, 95% CI 1.1–2.6); and Caucasian *vs* other, risk ratio 1.4 ($P = 0.117$, 95% CI 0.9–2.3). Figure 2 depicts the risk of first thrombosis, by type of access, for accesses created on or after 1 November, 1997. The estimated time until 25% of AVF experienced their first thrombosis was 2.4 years (95% CI 1.5–4.2 years), whereas for AVG it was estimated that 25% would experience a first thrombosis within 0.6 years (95% CI

Table 3. Sensitivity and specificity of monitoring results

A. Duplex US results for AVG and AVF at 14 and 30 days	No stenosis	Stenosis	Severe stenosis
14 day outcome			
AVG No thrombosis	81 (9)	125 (39)	128 (6)
AVG Thrombosis	58	85 (3)	71
AVF No thrombosis	6 (1)	5 (0)	9 (1)
AVF Thrombosis	0	0	3
30 day outcome			
AVG No Thrombosis	73 (13)	106 (58)	124 (10)
AVG Thrombosis	62	88	71
AVF No thrombosis	5 (2)	5 (0)	9 (1)
AVF Thrombosis	0	0	3

B. Transonic results for AVG and AVF at 14 and 30 days	<500	500–650	$\geqslant 650$
14 day outcome			
AVG No thrombosis	94 (19)	100 (11)	959 (25)
AVG Thrombosis	94	54	431
AVF No thrombosis	172 (12)	108 (3)	1039 (7)
AVF Thrombosis	10	3	89
30 day outcome			
AVG No thrombosis	75 (35)	85 (23)	923 (55)
AVG Thrombosis	97	57	437
AVF No thrombosis	159 (23)	102 (8)	1025 (19)
AVF Thrombosis	12	4	91

Values in parenthess indicate the number of interventions (angioplasty or thrombolysis) that occurred.

0.5–0.9 years), and 50% would experience a first thrombosis by 1.9 years (95% CI 1.3–2.8 years). When analysed further according to subtype of accesses, there was no difference between loop and straight AVG ($P=0.157$), nor a difference between radial *vs* brachial AVF accesses ($P=0.507$).

Discussion

In Canada, approximately half of all individuals on HD have an AVF, and a quarter have an AVG [12]. In the USA, $>200\,000$ individuals are on HD, and AVG account for $\sim 75\%$ of permanent accesses [13]. Access patency is required for a well functioning access in order to provide adequate dialysis.

A variety of assessment tools [14,15] have been used in the attempts to detect vascular stenosis and to intervene before thrombosis develops. Access thrombosis is a result of a process involving progressive

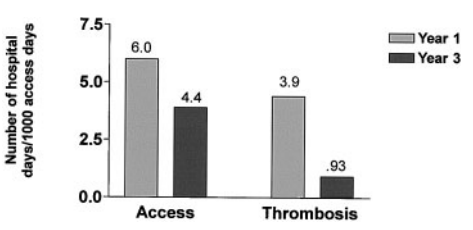

Fig. 1. Access- and thrombosis-related hospitalizations.

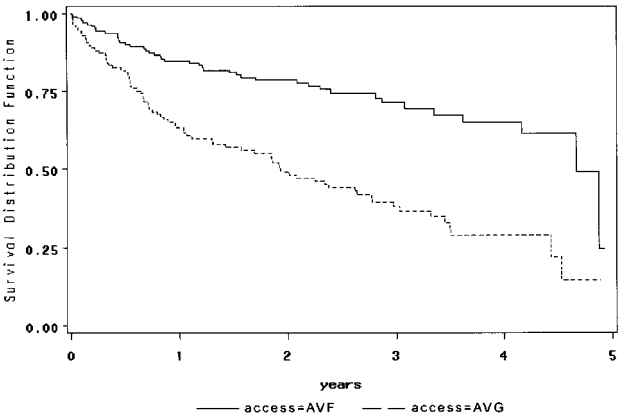

Fig. 2. Access survival for AVG and AVF, $P=0.0001$.

vascular stenosis due to intimal hyperplasia, myointimal proliferation and matrix deposition. Unfortunately, there are few proven medical therapies to inhibit this process. For this reason, the nephrologist must maximize access patency by detecting lesions early and intervening with angioplasty or surgical revision. Previous studies comparing different access monitoring techniques have concluded that access flow [4,8] and, in particular, Transonic monitoring [8,16] appeared to be superior in detecting access malfunction. The results of this study are consistent with this view and demonstrate a reduction by 35% in the total thrombosis rate associated with the use of Transonic monitoring as the primary strategy, compared with a strategy which used only Duplex US monitoring. In AVG, the results of the Duplex US monitoring correlated very poorly with the prognosis of thrombosis formation within 14 or 30 days, whereas lower flow rates detected by Transonic monitoring were associated with a greater probability of thrombosis. This is consistent with previous studies demonstrating the Transonic device's ability to predict thrombosis based on a declining Qa [4,17]. Neither strategy appeared to be useful in predicting the small number of thromboses in AVF accesses.

Our study supports the results of a recent pilot study [8] of 42 HD patients that demonstrated that intervention with angioplasty or surgical revision improved flows and reduced thrombosis rates. However, that study compared Transonic monitoring with venous pressure monitoring instead of Duplex US.

Also consistent with the literature was an increase in total angioplasty rates (9%) in the first year of Transonic monitoring in order to achieve a reduction in total thrombosis rate. This increase in intervention rate was small compared with previous studies that had up to a 13-fold increase in intervention rate [15]. However, the intervention rate and, in particular, the angioplasty rate fell below baseline by the end of the second year of Transonic monitoring, while maintaining a lower thrombosis rate. Possible explanations for the rise and fall in procedure rates, and the accompanying decrease in thrombosis rate, include the

possibility that once 'old', previously unidentified lesions were corrected, fewer subsequent stenoses would require intervention. Within the first year of Transonic monitoring, as more confidence was gained in performing and interpreting the results of the technique, more interventions occurred. Finally, the single trained operator may have later become more familiar with the patients' accesses and their flow readings, providing a more reliable estimation of the urgency for intervention of the remaining fewer and/or possibly newer stenoses, leading to more appropriate and timely referrals. Thus, the long-term benefit was mediated through fixed stenosis and became apparent when improved information from routine Transonic monitoring allowed those who needed intervention to receive it.

Although previous studies have shown that Duplex US may be useful in detecting stenosis, studies on the efficacy of intervention-based Duplex US monitoring are conflicting [7,9]. This study provides further support for exploring alternative monitoring techniques. Although Duplex US assessments provide anatomical details of the access, it is operator-dependent and expensive, inconvenient for the patient, with variable waiting times from bookings to appointments, a situation that may leave the patient at a higher risk of thrombosis. In contrast, Transonic surveillance is much more convenient for the patient and can be done more frequently and regularly, and may improve compliance with the monitoring strategy. It is because of these practical differences and difficulties that we were unable to compare US Duplex and Transonic monitoring methods directly. The disparity in the frequency of the two monitoring methods reflects our institution's practices and may account for some of the differences observed in the outcomes of this study. Also, the effect of increasing experience of the dialysis staff in access surveillance could not be controlled in this study. In the absence of a randomized controlled trial design, we could not eliminate all bias. However, our study is the first prospective study comparing these two monitoring strategies—one of intermittent off-site surveillance of access patency and the other of more frequent evaluation of intradialytic access function.

To our knowledge, this is the largest prospective study with the longest follow-up of both AVG and AVF that describes the efficacy of intervention based on Transonic monitoring in preventing thrombosis. This study supports published guidelines [5,6] for investigation and intervention based on a cut-off Qa determined by Transonic monitoring to prevent thrombosis for AVG (<650 ml/min) but not for AVF (<500 ml/min). Using a change in Qa of 15 or 20% as an indicator to investigate cannot be supported based on this study.

Recognizing the impracticality of solely depending on monitoring strategies to predict thrombosis, we analysed patient and access characteristics for risk factors for thrombosis. Our study confirms the longevity and superior thrombosis risk profile of AVF compared with AVG [18]. Of the first 25% of accesses that had a thrombosis, AVF had a 4.0 times longer thrombosis-free survival compared with AVG, with the average time from access creation to first thrombosis being 2.4 years in AVF compared with 0.6 years in AVG. Our finding of increased thrombosis in loop grafts compared with straight grafts is consistent with another report [19]. In loop grafts, the risk of thrombosis increases when Qa is <650 ml/min, while a more graded relationship exists between flow and risk of thrombosis in straight grafts. Also consistent with the literature is our finding that race and the presence of diabetes are risk factors for thrombosis. In contrast to the literature, age and gender were not statistically significant risk factors [10,19,20].

Finally, the economic benefits of this strategy have not been formally assessed but, based on a reduction in the rate of procedures, thrombosis-related hospitalizations and length of stays, it seems likely that Transonic monitoring has the potential to reduce overall costs.

Conclusion

Intervention following a finding of reduced flows (<650 ml/min) on Transonic monitoring reduced thrombosis rates and improved access patency in AVG. Duplex US was useful in predicting thrombosis in AVF that had severe stenosis. Regular Transonic monitoring should be advocated, particularly in those patients with a high thrombosis risk profile: black, diabetic patients with AVG.

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Conflict of interest statement. None declared.

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