Correlation of Intragraft Blood Flow with Characteristics of Stenoses Found During Diagnostic Fistulography

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PURPOSE: To determine if intragraft blood flow measurements correlate with the anatomical characteristics of stenoses found during diagnostic fistulography.

MATERIALS AND METHODS: This investigation was a retrospective review of 40 patients with decreased intragraft blood flow (<600 mL/min) in patent polytetrafluoroethylene hemodialysis grafts who underwent diagnostic fistulography and angioplasty. Intragraft blood flow was measured with the ultrasonic dilution technique. The fistulogram images were reviewed and the anatomic characteristics of all stenoses were measured and recorded. These characteristics were correlated with the intragraft blood flow values.

RESULTS: The mean intragraft blood flow was 476 mL/min (range, 270–600 mL/min). Fistulography revealed a total of 71 stenoses and all 40 patients had at least one lesion with >50% stenosis. There was no correlation between the intragraft blood flow and the location, length, or number of stenoses. There was a moderate inverse correlation between the intragraft blood flow and the degree of stenosis (P = .08). Fifty-nine stenoses were treated with angioplasty. The mean postangioplasty blood flow was 796 mL/min (range, 470–1565 mL/min). The mean change in blood flow after angioplasty was 311 mL/min (range, 15–1154 mL/min). There was no association between the change in blood flow after angioplasty and the number, length, or degree of residual stenosis.

CONCLUSION: Intragraft blood flow <600 mL/min is an excellent predictor of the presence of at least one significant (>50%) stenosis. There was an inverse correlation between intragraft blood flow and the degree of stenosis. There was no association between the intragraft blood flow and the location, length, or number of stenosis.


Abbreviation: PTFE = polytetrafluoroethylene

ROUTINE surveillance of polytetrafluoroethylene (PTFE) hemodialysis grafts has proved to be beneficial for identifying patients who are at risk for thrombosis (1). Early referral for diagnostic fistulography, combined with early treatment of developing stenoses, has been shown to decrease the incidence of vascular access thrombosis (2,3).

Periodic measurement of intragraft blood flow is a common vascular access surveillance method. Although intragraft blood flow can be measured with a number of different techniques, the ultrasound (US) dilution technique has been widely used for both clinical and research applications. Several studies have demonstrated that an intragraft blood flow of less than 600 mL/min is predictive of impending graft thrombosis (4–6). Additional studies have reported the improvement in intragraft blood flow after angioplasty procedures (3,7,8).

The purpose of this study was to determine if the blood flow value of 600 mL/min is a useful predictor of a significant (>50%) stenosis and to correlate intragraft blood flow measurements with the anatomical characteristics of stenoses found during diagnostic fistulography.

MATERIALS AND METHODS

The Human Studies Committee at the authors’ institution approved this retrospective study. This investigation included all chronic hemodialysis patients who met the following criteria: i) received hemodialysis at the authors’ outpatient treatment facility, ii) had a PTFE vascular access graft for hemodialysis, iii) were referred to interventional radiology for low (<600 mL/
min) intragraft blood flow, and iv) had angioplasty of a significant (≥50%) stenosis.

A search of the interventional radiology database combined with a review of the medical records at the authors’ outpatient hemodialysis treatment facility identified 40 patients who satisfied these inclusion criteria. The medical records of each patient were reviewed to obtain demographic information and vascular access history.

**Blood Flow Measurements**

Patients receiving chronic hemodialysis at the authors’ outpatient facility undergo periodic surveillance for graft dysfunction with use of the ultrasonic dilution method (Transonic Systems, Ithaca, NY). The majority of chronic hemodialysis patients undergo a blood flow measurement every 2 months. Patients with low (<800 mL/min) or declining blood flow values undergo these measurements every month.

Intragraft blood flow was recorded as the mean of two blood flow measurements. If the two measurements differed by greater than 10% a third measurement was taken. Patients were referred to radiology for diagnostic fistulography if the intragraft blood flow value was less than 600 mL/min.

The primary intent of this retrospective investigation was to correlate the anatomic characteristics of stenoses with the intragraft blood flow values. All 40 study patients underwent a blood flow measurement before diagnostic fistulography. A review of the medical records yielded postangioplasty blood flow measurements for 31 of the study patients. These measurements were included if they had been performed within 90 days of the angioplasty procedure. In the remaining nine patients, there was no follow-up blood flow measurement or blood flow measurement had been performed more than 90 days after the angioplasty procedure.

**Diagnostic Fistulography and Angioplasty**

Diagnostic fistulography was performed by inserting a 21-gauge butterfly needle into the arterial limb of the PTFE hemodialysis graft. Water-soluble contrast material was injected and multiple digital subtraction images of the graft and native veins were obtained. Suspected stenoses were imaged in at least two orthogonal planes. A significant stenosis was defined as having a luminal narrowing of ≥50%. Lesions that caused less than 50% stenosis were not treated.

Angioplasty was performed by inserting an 18-gauge needle into the venous limb of the graft in an antegrade direction. An angiographic catheter was used to advance a guide wire across the lesion(s) to be treated. An 8-F vascular sheath was inserted into the graft. Most commonly a 7-mm diameter high pressure angioplasty balloon (Centurion; Bard Peripheral Vascular, Covington, GA) was inflated for approximately 60 seconds. The balloon was deflated, slightly repositioned and inflated a second time. A final fistulogram was obtained to assess the success of angioplasty. The vascular sheath was removed and hemostasis was obtained by purse string suture. Heparin was not used for the angioplasty procedures.

The 40 angioplasty procedures were performed between January 1, 2001 and March 30, 2002. All of the procedural films were retrospectively reviewed. Each stenosis was characterized by i) anatomic location ii) length of stenosis, and iii) degree of stenosis before and after the angioplasty procedure. The length of stenosis and degree of stenosis were determined with a millimeter ruler to measure luminal diameter and recorded to the nearest 10%. The degree of stenosis was calculated as follows:

\[
\text{% stenosis} = \left(\frac{\text{reference diameter} - \text{stenosis diameter}}{\text{reference diameter}}\right) \times 100
\]

The reference diameter was a normal segment of vein adjacent to the stenosis.

When available, postangioplasty blood flow measurements were recorded.

**Statistical Analysis**

The goal of analysis was to measure and test the association between blood flow, a continuous variable, and a variety of demographic and anatomic descriptors. When the other variables were continuous in nature, such as age, or stenosis length and degree, patterns of association were examined with scatter plots, measured by calculating Pearson correlation coefficients, and tested for statistical significance. When the other variables were categorical in nature, such as stenosis or graft location, or the number of stenoses, patterns were examined by calculating and comparing means and standard deviations. Patterns were tested for statistical significance with independent sample Student t tests or analysis of variance (ANOVA). All statistical analysis was performed with JMP software (SAS Institute, Cary, NC).

**RESULTS**

Forty patients met the inclusion criteria. The mean age of the study patients was 65 ± 13 years (range, 33–87 years). There was a weak inverse correlation between patient age and intragraft blood flow that did not reach statistical significance (\(P = .12; r = -.26\)). Female patients represented 80% of the study group and 92.5% were of black ethnicity. Diabetic nephropathy was the most common etiology of end-stage renal disease (Table 1).

All 40 patients had loop configuration PTFE hemodialysis grafts. Thirty-three patients had forearm grafts and seven patients had upper arm grafts. The intragraft blood flow was very similar for right (510 mL/min) and left (480 mL/min) upper arm grafts, but was considerably lower for left forearm grafts (330 mL/min), a pattern

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of 40 Patients Undergoing Angioplasty</th>
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<tr>
<td>Mean age</td>
<td>65 ± 13 years</td>
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<tr>
<td>Female sex</td>
<td>80%</td>
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<tr>
<td>Race</td>
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<tr>
<td>White</td>
<td>7.5%</td>
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<tr>
<td>Black</td>
<td>92.5%</td>
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<td>Diabetes</td>
<td>52.5%</td>
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<tr>
<td>Hypertension</td>
<td>30%</td>
</tr>
<tr>
<td>Other</td>
<td>17.5%</td>
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that was statistically significant ($P = .015$). There were no study patients with right forearm grafts.

The mean age of the graft was 1,019 days (range, 81–3,862 days). Interestingly, the blood flow values directly correlated ($P = .02$; $r = .40$) with graft age. Older grafts had higher blood flows.

The mean pre-fistulography blood flow was 476 mL/min (range, 270–600 mL/min). The mean time interval from the initial blood flow measurement to the diagnostic fistulography and angioplasty procedure was 21 ± 18 days.

Seventy-one stenoses were identified in these 40 patients. Seventeen patients had one stenosis, 16 patients had two stenoses, five patients had three stenoses, and two patients were found to have four stenoses. There was no association between the intragraft blood flow value and the number of stenoses ($P = .50$). The location of these 71 stenoses is provided in Table 2.

When all 71 stenoses are considered, there is no correlation ($P = .17$) between the intragraft blood flow value and the location of the stenosis. However, the majority (79%) of the stenoses were located at the venous anastomosis or within the graft (Table 2). When blood flow was analyzed with respect to only these two locations the correlation with blood flow approached statistical significance ($P = .09$).

The mean length of stenosis was 11 mm (range, 3–70 mm). There was no correlation between the intragraft blood flow value and the length of the stenosis ($P = .75$; $r = -.05$).

The mean degree of stenosis for all 71 lesions was 62% (range, 18%–82%). Fifty-seven of these lesions had greater than 50% stenosis and 14 lesions had less than 50% stenosis. However, all 40 patients had at least one significant (≥50%) stenosis. When analyzing the data from all 40 patients, with 71 total stenoses, there was a moderate inverse correlation between the degree of stenosis and blood flow ($P = .08$; $r = -.29$). The intragraft blood flow declined as severity of stenosis increased. However, to evaluate the effect of multiple stenoses, a subgroup analysis was performed in 17 study patients who had only one stenosis. This subgroup analysis revealed that there was a stronger inverse correlation ($P = .03$; $r = -.26$) between blood flow and the degree of stenosis when the patient had only one stenosis.

Fifty-nine of the 71 stenoses were treated with angioplasty. Twelve stenoses in eight patients were not treated; eight of these lesions had less than 50% stenosis and therefore were not appropriate lesions for angioplasty. Two significant stenoses were not treated because the patients refused to undergo the angioplasty procedure. The reasons why the two other significant stenoses were not treated is unknown.

Postangioplasty blood flow measurements were obtained in 31 patients. The median interval between the angioplasty procedures and the follow-up blood flow measurement was 32 days (range, 14–60 days). The mean postangioplasty blood flow was 796 mL/min (range, 470–1,565 mL/min). The mean change in blood flow after angioplasty was 311 mL/min (range, 15–1,154 mL/min) There was no correlation between the change in blood flow and the number ($P = .35$; $r = -.18$), length ($P = .91$; $r = -.02$) or degree of residual stenosis ($P = .76$; $r = -.06$).

After the angioplasty procedure 14 patients had at least one lesion with greater than 30% stenosis but less than 50% stenosis. An analysis of this subgroup revealed that in five of these 14 patients (36%) the intragraft blood flow remained less than 600 mL/min after the angioplasty procedure. However, in the 17 patients who had all of their stenoses reduced to <30%, nearly all (94%) had an intragraft blood flow > 600 mL/min after the angioplasty procedure.

### DISCUSSION

The National Kidney Foundation’s Dialysis Outcomes Quality Initiative guidelines recommend diagnostic fistulography if the intragraft blood flow is less than 600 mL/min, or if the blood flow is less than 1,000 mL/min and there has been a decrease in blood flow by more than 25% during a 4 month period (9).

All 40 of our study patients had an intragraft blood flow less than 600 mL/min and all were found to have at least one significant (>50%) stenosis. These results are similar to other studies which also reported that an intragraft blood flow less than 600 mL/min is predictive of the presence of at least one significant stenosis (8,10,11).

The primary goal of this study was to correlate the intragraft blood flow values with the characteristics of the stenoses as defined by fistulography. When all 40 patients are included in the analysis there was no correlation between the blood flow value and the location, number, or length of the stenoses. However, there was a weak inverse correlation ($P = .08$) between the intragraft blood flow and the degree of stenosis. When the data was further analyzed to include only the 17 patients with a single stenosis, the correlation between intragraft blood flow and the degree of stenosis was statistically significant ($P = .03$). This suggests that in patients who have only one lesion the measurement of intragraft blood flow may be useful for monitoring the progression of the stenosis. However, the majority (57.5%) of the patients in this study had more than one stenosis and several patients had multiple stenoses combined with areas of irregularity within their hemodialysis graft. With respect to the entire vascular access circuit, these stenoses are located in series and, therefore, their hemodynamic affects are cumulative. This study suggests that intragraft blood flow values are less helpful for characterizing and monitoring the progression of stenosis in patients with complex or multiple lesions.

The fundamental tenet of vascular access surveillance is that routine, periodic monitoring of grafts and fistulas will lead to the early detection of developing stenoses. Early detection, combined with expeditious treatment
of hemodymanically significant lesions, will decrease the incidence of vascular access thrombosis. However, as recently reported by Moist et al (12), this does not necessarily lead to an improvement in graft patency or longevity. They reported that an intragraft blood flow of less than 650 mL/min had a positive predictive value of 87% for the detection of significant stenoses. Despite the early identification and treatment of stenoses there was no improvement in the long-term survival of the hemodialysis graft as stated by these investigators, the use of blood flow measurements obtained in the dialysis centers with use of the postangioplasty blood flow values that were available for 31 study patients. After the angioplasty procedure, 14 patients had at least one lesion with greater than 30% stenosis. Analysis of this subgroup revealed that in 36% of these patients the intragraft blood flow was less than 600 mL/min after the angioplasty procedure. Whereas in the 17 patients who had all of their lesions reduced to less than 30% stenosis, nearly all (94%) had an intragraft blood flow greater than 600 mL/min after the angioplasty procedure. This suggests that lesions that cause greater than 30% stenosis can reduce the blood flow thorough the graft and that these lesions may be appropriate for treatment. The assessment of intragraft blood flow during angioplasty procedures may provide additional information regarding the hemodynamic importance of lesions that have greater than 30% but less than 50% stenosis (14). Another related and interesting topic is the determination of technical success for endovascular interventions. Fistulography provides minimal hemodynamic information and the interpretation of angiographic images is subjective. The use of “pull-back” pressure measurements can provide a direct hemodynamic assessment of a single stenosis but the parameters of success and overall clinical usefulness is not well defined (13). A new catheter-based system can be used to measure intragraft blood flow during endovascular procedures and there is good correlation with the blood flow measurements obtained in the dialysis centers with use of the standard Transonic HDO1 system (14). Such information may prove useful for optimizing the success of endovascular interventions and thereby improve long-term durability of the hemodialysis graft.

A related topic is the hemodynamic effect of non-significant (<50%) stenoses. According to the National Kidney Foundation’s Dialysis Outcomes Quality Initiative guidelines and the Society of Interventional Radiology standards documents only those lesions which are causing > 50% stenosis should be treated (9,15). In addition, both of these documents define a successful angioplasty as having less than 30% residual stenosis. But what should be done with those lesions that have greater than 30% stenosis but less than 50% stenosis? According to the National Kidney Foundation’s Dialysis Outcomes Quality Initiative guidelines and the Society of Interventional Radiology standards, these lesions should not be treated. However, it is the authors’ belief that these lesions do have a hemodynamic effect on blood flow through a hemodialysis graft. A subgroup analysis was performed with use of the postangioplasty blood flow values that were available for 31 study patients. After the angioplasty procedure, 14 patients had at least one lesion with greater than 30% stenosis. Analysis of this subgroup revealed that in 36% of these patients the intragraft blood flow was less than 600 mL/min after the angioplasty procedure. Whereas in the 17 patients who had all of their lesions reduced to less than 30% stenosis, nearly all (94%) had an intragraft blood flow greater than 600 mL/min after the angioplasty procedure. This suggests that lesions that cause greater than 30% stenosis can reduce the blood flow thorough the graft and that these lesions may be appropriate for treatment. The assessment of intragraft blood flow during angioplasty procedures may provide additional information regarding the hemodynamic importance of lesions that have greater than 30% but less than 50% stenosis (14).

In agreement with other investigators, this study demonstrated that an apparently successful angioplasty procedure does not always result in a final blood flow value greater than 600 mL/min (7,8,16). There are several reasons why intragraft blood flow may not return to normal after a successful intervention. These reasons include: i) failure to identify all hemodynamically significant lesions, ii) delayed elastic recoil causing recurrence of the stenosis, iii) unidentified arterial inflow problems, and iv) poor cardiac output. Any one of these factors could cause a persistently low blood flow (<600 mL/min) after an angioplasty procedure.

This study failed to demonstrate a correlation between the intragraft blood flow value and the location, length, or number of stenoses. If such a correlation does indeed exist there are several reasons why this study may have failed to detect these relationships. The quantitative measurement methods had several potential sources of error. The measurement of intragraft blood flow with use of the ultrasound dilution technique (Transonic Systems) has a repeatability error of approximately 10% (17). In addition, the anatomic characteristics of the stenotic lesions were measured retrospectively with a millimeter ruler placed on the radiograph images. Although this is an acceptable technique, there was likely a moderate amount of error when this method was used to measure the length and degree of stenosis. However, this study did reveal a statistically significant correlation (P = .03) between intragraft blood flow and the degree of stenosis in those patients who would be most likely to demonstrate such a direct correlation, those patients with only one stenosis. This would suggest that the blood flow measurements and anatomic measurements were reasonably accurate.

Another source of potential error was the substantial time interval between the original blood flow measurement and the fistulography procedure. The mean time interval was 21 ± 18 days. This 3 week delay may have contributed to the failure to identify a correlation between intragraft blood flow and the characteristics of a stenosis. Patients could have had variable progression of their stenoses dur-
ing this time period, which subsequently confounded analysis.

And finally, the eccentricity of stenoses, the multiplicity of stenoses in an individual patient, and the effect of untreated lesions (>30% stenosis) are all likely factors which are responsible for the inability to directly correlate the intragraft blood flow values with the characteristics of a stenosis.

This retrospective analysis of a small group of patients has demonstrated that the complexity of graft-related pathology prevents a straightforward correlation between intragraft blood flow and the angiographic findings.

References