Flow in hemodialysis grafts after angioplasty: Do radiologic criteria predict success?

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Background. The anatomic success of percutaneous angioplasty of venous stenosis is determined by the improvement in cross-sectional diameter of the vessel. A successful outcome is defined as a residual stenosis of <30%. The purpose of this study was to determine whether the angiographic assessment of a venous stenosis correlates with the change in graft blood flow following angioplasty.

Methods. Twenty-two hemodialysis patients with decreased intragraft blood flow (<700 mL/min) underwent diagnostic fistulography and angioplasty. All grafts were patent at the time of the procedure. Intragraft blood flow was measured before and after angioplasty using the ultrasonic dilution technique. Change in graft blood flow after angioplasty was correlated with the morphologic changes of the treated stenosis.

Results. The mean preangioplasty and postangioplasty graft blood flows were 457 ± 136 and 818 ± 202 mL/min, respectively. The mean degree of stenosis before angioplasty was 74 ± 15% and 18 ± 14% after dilation (P < 0.001). The only variable that significantly correlated with postangioplasty blood flow was preangioplasty flow (r² = 0.22, P < 0.001). The postangioplasty blood flow was not significantly different than the highest recorded blood flow measured in that graft (798 ± 213 mL/min, P = NS). There was no significant correlation between the change in blood flow and the change in percentage of stenosis.

Conclusion. Following angioplasty of a venous stenosis, the graft blood flow is most closely predicted by the preprocedural blood flow and is similar to the highest recorded blood flow ever measured in that graft. Angiographic criteria to assess the success of angioplasty are not predictive of changes in blood flow.

Venous stenoses are a common cause of hemodialysis graft dysfunction and thrombosis. The Dialysis Outcomes Quality Initiative (DOQI) document recommends monthly surveillance of hemodialysis grafts to identify developing stenoses prior to thrombosis [1]. Although several different surveillance methods are considered acceptable, periodic measurement of graft blood flow has been shown to be the most predictive of impending graft thrombosis [2]. Furthermore, the DOQI guidelines recommend that venous stenoses associated with access dysfunction and stenoses that cause a greater than 50% luminal reduction should be treated with angioplasty or surgical revision.

Criteria for assessing the results of access-related interventions have been previously defined (SCVIR Reporting Standards) [3]. Following angioplasty of a venous stenosis, the success of the procedure can be assessed by anatomic, hemodynamic, or clinical criteria. Anatomic success is determined by the improvement in the cross-sectional diameter of the vessel at the site of the stenosis. A successful outcome is defined as a residual stenosis of 30% or less. Alternatively, hemodynamic success is assessed by measuring venous pressure or intragraft blood flow following angioplasty [4]. Finally, clinical success is judged by the ability to use the vascular access for at least one hemodialysis treatment following the endovascular intervention [3].

The purpose of this study was to compare the results of venous angioplasty using two different methods of evaluation. A visual or angiographic assessment of the stenosis was compared with a hemodynamic assessment of graft blood flow using the ultrasonic dilution technique.

METHODS

This retrospective study included all chronic hemodialysis patients who (1) received hemodialysis at our outpatient treatment facility, (2) had a polytetrafluoroethylene (PTFE) vascular access graft, (3) underwent an angioplasty procedure for a hemodialysis-related venous stenosis over an 11-month period, and (4) had preangioplasty and postangioplasty blood flow measurements using the ultrasonic dilution technique.
A review of the medical records at the hemodialysis treatment center (180 total patients) combined with a search of the interventional radiology database identified 22 patients who satisfied these inclusion criteria. The hemodialysis records of each patient were reviewed to obtain demographic information and vascular access history. The value of “highest recorded blood flow” in the graft was defined as the highest blood flow ever recorded during prior routine surveillance measurements.

Patients receiving chronic hemodialysis via a PTFE graft underwent periodic surveillance for graft dysfunction using the ultrasonic dilution method (Transonic Systems, Inc., Ithaca, NY, USA). Flow studies were done using a saline-release method. Normal saline was released into the prepump arterial bloodline for approximately three seconds. An assessment for recirculation was done prior to the measurement of access flow. Graft blood flow was recorded as the mean of three blood flow measurements. When any two of the three measurements differed by greater than 10%, a repeat measurement was taken. Patients were referred to radiology for a diagnostic fistulogram if the graft blood flow was less than 700 mL/min. Surveillance was done every one to three months. In addition, a flow study was done for an unexplained reduction in hemodialysis adequacy, defined as a drop in Kt/V not attributable to any other cause. Flow screening was initiated in 1998, and the observation was done for approximately 20 months before the current data were collected. Patients had a median number of flow measurements of five (range 1 to 9) prior to the measurement prompting intervention.

The diagnostic fistulogram was performed by inserting a 21-gauge butterfly needle into the arterial limb of the patient’s hemodialysis graft. Water-soluble contrast (Malinckrodt, St. Louis, MO, USA) 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. Anastomotic or native vein stenoses producing greater than 50% diameter reduction were treated using standard angioplasty techniques [5].

For the angioplasty procedure, the venous limb of the graft was accessed in an antegrade direction using an 18-gauge needle. An angiographic catheter was used to advance a guide wire across the lesion(s) to be treated. A number 6F vascular sheath was inserted into the graft. Most commonly, a 7 mm diameter by 4 cm long high-pressure angioplasty balloon was used to dilate the stenosis. The balloon was inflated for one to two minutes. The balloon was deflated, slightly repositioned, and inflated a second time. The balloon was subsequently deflated and removed. A follow-up fistulogram was performed to assess the success of angioplasty. The vascular sheath was removed, and hemostasis was obtained using manual compression or a purse-string suture. Heparin was not administered for these angioplasty procedures.

Table 1. Characteristics of 22 hemodialysis patients undergoing percutaneous transluminal angioplasty

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
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<tbody>
<tr>
<td>Mean age (years)</td>
<td>63 ± 14</td>
</tr>
<tr>
<td>Female sex (%)</td>
<td>77</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>White (%)</td>
<td>18</td>
</tr>
<tr>
<td>Black (%)</td>
<td>82</td>
</tr>
<tr>
<td>Etiology of ESRD</td>
<td></td>
</tr>
<tr>
<td>Diabetes (%)</td>
<td>64</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>18</td>
</tr>
<tr>
<td>Other (%)</td>
<td>18</td>
</tr>
</tbody>
</table>

All of the procedural films were retrospectively reviewed. Each stenosis was characterized by anatomic location, length of stenosis, and the percentage stenosis before and after angioplasty. The percentage of stenosis was determined using a millimeter ruler to measure the luminal diameter, divided by the diameter of an adjacent segment of normal vein, and recorded to the nearest 10%. After angioplasty, the stenoses were reevaluated, and the percentage of residual stenosis was determined in the same manner. Two observers estimated the percentage of stenosis before and after the angioplasty procedure. Neither observer was aware of the results of the blood flow measurements. A significant stenosis was defined as luminal narrowing of 50% or greater. Anatomic success of angioplasty was defined as residual stenosis of 30% or less.

Statistics

The Student paired t test was utilized to determine the significance of the change in the degree of stenosis and graft blood flow before and after angioplasty. Simple linear regression was used to delineate the relationship between different variables. Differences were considered statistically significant when the P value < 0.05. All data were expressed as means ± SD. The Sigma Stat version 2.03 and Sigma Plot version 5.0 (SPSS, Inc., Richmond, CA, USA) were used for data analyses.

RESULTS

Twenty-two patients met the inclusion criteria. The mean age of the study patients was 63 ± 14 years. Seventy-seven percent of the patients were female, and 82% were African American. Diabetic nephropathy predominated as the most common etiology of end-stage renal disease (ESRD; Table 1).

All 22 patients had loop configuration PTFE grafts, with 21 in the forearm and 1 in the upper arm. The duration of time from graft placement to the blood flow measurement prompting the intervention ranged from 7 to 114 months, with a mean of 35 ± 26 months. The mean time from the abnormal blood flow study to the angioplasty procedure was 10 ± 8 days. The mean time
Table 2. Characteristics of stenoses

<table>
<thead>
<tr>
<th></th>
<th>Pre-PTA</th>
<th>Post-PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean %</td>
<td>74 ± 15</td>
<td>18 ± 14</td>
</tr>
<tr>
<td>Mean length mm</td>
<td>14 ± 8</td>
<td></td>
</tr>
<tr>
<td>Mean days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>from flow study to PTA</td>
<td>10 ± 8</td>
<td></td>
</tr>
<tr>
<td>from PTA to flow study</td>
<td>10 ± 13</td>
<td></td>
</tr>
<tr>
<td>P-value</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
</tbody>
</table>

Data are means ± SD.
*Pre-PTA versus post-PTA stenosis

Table 3. Vascular access flow before and after percutaneous angioplasty compared to highest recorded flow prior to angioplasty

<table>
<thead>
<tr>
<th></th>
<th>Highest recorded</th>
<th>Pre-PTA</th>
<th>Post-PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>798 ± 213</td>
<td>457 ± 136</td>
<td>818 ± 202</td>
</tr>
<tr>
<td>Minimum</td>
<td>385</td>
<td>80</td>
<td>395</td>
</tr>
<tr>
<td>Maximum</td>
<td>1440</td>
<td>675</td>
<td>1155</td>
</tr>
<tr>
<td>P-value</td>
<td>NS</td>
<td></td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

*Post-PTA versus highest recorded flow
*Pre-PTA flow versus post-PTA flow

from the angioplasty procedure to the follow-up blood flow study was 10 ± 13 days. In this group of 22 patients, 20 had previously undergone an angioplasty or thrombectomy procedure prior to inclusion in this study.

The treated stenoses were located at the venous anastomosis (N = 17), native basilic or cephalic veins (N = 7), intragraft (N = 3), and native brachiocephalic vein (N = 1). Twenty-five percent of the patients (N = 7) had more than one area of stenosis that required angioplasty. For simplicity, our data analyses included only the lesion with the highest degree of stenosis. The length of stenoses ranged from 3 to 33 mm, with a mean length of 14 ± 8 mm.

During the 11 month period, the 22 study patients underwent 28 angioplasty procedures. Three patients had recurrent stenosis at intervals ranging from three months to seven months following the initial procedure and were treated with a second angioplasty. One patient underwent angioplasty three times during an eight month period for treatment of a recurring stenosis. With angioplasty, the mean percentage of stenosis decreased from 74 to 18% (Table 2). Dialysis graft blood flow increased by 79% with angioplasty (Table 3). The mean postangioplasty blood flow was similar to the highest-recorded flow rate. The mean reduction in the percentage of stenosis was 57 ± 20%. Three of the 28 procedures had a residual stenosis of greater than 30%.

There was a significant positive correlation between the postangioplasty blood flow and the preangioplasty blood flow (r² = 0.22, P = 0.01; Fig. 1). There was no significant correlation between the change in percentage of stenosis and the improvement in blood flow following angioplasty (Fig. 2). In addition, there was no correlation between postangioplasty flow and residual stenosis (Fig. 3). Furthermore, there was no significant correlation between postangioplasty blood flow and reduction of stenosis (r² = 0.015, P = NS) or stenosis length (r² = 0.00026, P = NS).

The postangioplasty angiographic images were reviewed to determine anatomic success. Eighty-nine percent (N = 25) of the angioplasty procedures were successful, having less than a 30% residual stenosis. Despite a technically successful angioplasty, approximately one third (N = 8) of patients had an increase in blood flow of less than 300 mL/min. In three patients, the angioplasty was considered unsuccessful as defined by residual stenoses ranging from 30 to 50%. The mean postangioplasty blood flow was 1026 ± 77 mL/min in these three patients.
including the venous and arterial anastomoses and the native venous outflow, extending from the graft to the superior vena cava. Studies have reported that the lesion most often responsible for graft dysfunction or thrombosis is a focal stenosis located at or near the venous anastomosis [5]. As described in DOQI Guideline 19, a significant stenosis is defined as a >50% luminal diameter reduction, which is also associated with a clinical or physiologic abnormality [1]. These include abnormal monitoring tests, an unexplained decrease in hemodialysis adequacy, or an abnormal physical exam.

In addition to the angiographic assessment of the vascular access, an interventional radiologist can also evaluate the hemodynamic significance of a stenosis by measuring the static pressure in the graft or the pressure gradient across the lesion [11, 12]. Successful endovascular treatment should reduce the intragraft pressure to a value that is less than 50% of the patient’s systemic systolic blood pressure. Alternatively, following successful angioplasty the trans-stenotic pressure gradient should be reduced to less than 10 mm Hg. In the current investigation, these types of pressure measurements were not obtained. The decision to perform the angioplasty procedure was based on an abnormal monitoring test, a blood flow of <700 mL/min, and an angiographic assessment of the stenosis. Stenoses that had more than 50% luminal diameter reduction, as viewed in two or- thogonal planes, were treated with angioplasty. Procedural success was also judged by anatomic criteria, as specified in the Reporting Standards document [3]. Further assessment of the stenoses, by measuring pressure gradients before and after angioplasty, may have provided greater insight leading to better flow improvements. Nevertheless, we do not use pressure measurements during routine angioplasty procedures, and the intent of this study was to compare angiographic criteria with a hemodynamic assessment of graft performance.

In this investigation, the hemodynamic response to angioplasty was determined using intragraft blood flow measurements. A previous study evaluated the intragraft pressure before and after angioplasty [4]. These authors had previously shown that the ratio of intragraft pressure to systolic blood pressure of greater than 0.4 was predictive of an outflow venous stenosis. After angioplasty, the ratio fell from 0.66 to 0.36. The degree of stenosis fell from 66% preangioplasty to 31% postangioplasty. However, they did not attempt to correlate the relationship between change of stenosis and the degree in reduction of intragraft pressure.

Ideally, an intervention for treating a stenosis should lead to a marked improvement in the blood flow within the vascular access. Following a successful intervention, the blood flow should significantly exceed the 600 to 700 mL/min threshold that is used to characterize a dysfunctional graft. This group of 22 patients underwent...
28 angioplasty procedures, of which 89% were successful, and had a mean postangioplasty blood flow of \(818 \pm 202\) mL/min. We had anticipated a larger improvement in graft blood flow following an apparently successful angioplasty. Further review of graft surveillance records showed that the highest recorded blood flow value ever measured in each patient’s graft was only \(798 \pm 213\) mL/min. As in most centers, graft blood flow surveillance has only been available for the past one to two years. We may be dealing with a select group of patients that have always had lower graft blood flow rates. Alternatively, they may have underlying arterial disease not detected by routine angiography. Future studies with graft surveillance from the time of access placement will help to solve these questions.

The mean postangioplasty blood flow (818 mL/min) exceeded the mean highest recorded blood flow ever measured in the graft. In the majority of patients in this small cohort, the angioplasty procedure was successful, as judged by both anatomic and hemodynamic criteria. However, the angiographic assessment of the residual stenosis or the change in percentage of stenosis was not predictive of the change in graft blood flow.

We conclude from these observations that angioplasty can return the intragraft blood flow to near normal, achieving a blood flow value similar to the highest recorded blood flow ever measured in the graft. It was surprising to learn that an angiographic or visual assessment of the lesion following angioplasty fails to predict the hemodynamic success of the procedure. In those patients who have a poor hemodynamic response to angioplasty, we suspect that other flow-limiting lesions may be present. A more thorough assessment of the arterial inflow may yield evidence of other flow-limiting lesions. The ability to measure blood flow rates in the angiography suite, immediately following an intervention, would be advantageous. If the blood flow failed to improve, a more thorough search for additional pathology could be performed.

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