Use of a Catheter-Based System to Measure Blood Flow in Hemodialysis Grafts during Angioplasty Procedures

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PURPOSE: The goals of this investigation were to evaluate the accuracy and reliability of the Angioflow meter system with use of in vitro and in vivo methods and to compare it to the standard Transonics HD01 system in a clinical setting.

MATERIALS AND METHODS: The Angioflow meter system consists of a 6-F endovascular catheter and a laptop computer containing proprietary software for this application. Bench-top testing with use of a flow model was performed to determine the accuracy of the Angioflow meter system. Initial in vivo studies were performed with use of an animal model to assess the endovascular performance of the Angioflow meter system. Subsequently, a human clinical trial was performed to compare the Angioflow meter to the standard Transonics HD01 system. Twenty-five patients with dysfunctional (<600 mL/min) hemodialysis grafts were referred for fistulography and angioplasty. Intragraft blood flow measurements were obtained before and after angioplasty with use of both the Angioflow meter system and the Transonsics HD01 system. A comparison of the two systems was performed.

RESULTS: Bench-top testing and animal studies demonstrated an excellent (r = .98) correlation between the measurements of the Angioflow meter and volumetric flow measurements. In the clinical trial, there was reasonable correlation (r = .72) between the blood flow measurements obtained with use of the Angioflow meter and Transonsics HD01 system. The reproducibility of consecutive measurements with the Angioflow meter was excellent (r = .98). The mean increase in intragraft blood flow after angioplasty was 320 mL/min.

CONCLUSION: The Angioflow meter is an accurate and reliable endovascular device for measuring intragraft blood flow during interventional procedures. Use of this catheter-based system should prove beneficial for quantifying the success of endovascular interventions, the assessment of arterial inflow, and identification of inconspicuous lesions.

Index terms: Angioplasty • Blood, flow dynamics • Catheters and catheterization, technology • Dialysis, shunts


Abbreviations: DOQI = Dialysis Outcomes Quality Initiative, PTFE = polytetrafluoroethylene

Routine, periodic surveillance of hemodialysis grafts can provide early detection of developing stenoses and thereby allow treatment of these lesions before graft thrombosis (1). Comparative studies of different surveillance methods have shown that the periodic measurement of intragraft blood flow is the most sensitive and specific method for the detection of access-related stenoses (2–4). A widely used technique for measuring intragraft blood flow is the ultrasound dilution method with use of the Transonsics HD01 system (Transonic Systems, Ithaca, NY). When using the Transonsics HD01 system, the intragraft blood flow measurements are obtained in the hemodialysis treatment center while the patient is connected to the hemodialysis machine. Inherent in the concept of vascular access surveillance is early treatment of developing stenoses. According to the Dialysis Outcomes Quality Initiative (K/DOQI) guidelines, a patient should be referred for diagnostic fistulography if the intragraft blood flow is less than 600 mL/min (1). Significant stenoses (>50%) that are identified during the fistulogram should be immediately treated with angioplasty or other appropriate endovascular techniques.

The effectiveness of an angioplasty procedure—the improvement in intragraft blood flow—is not known until follow-up measurements are per-
formed in the hemodialysis treatment center. The immediate measurement of intragraft blood flow during the angioplasty procedure would be beneficial to quantify the success of the procedure.

This report describes our experience with use of an endovascular catheter system to measure blood flow in hemodialysis grafts during endovascular procedures. This blood flow catheter system underwent preliminary testing with use of a bench-top flow model, followed by in vivo evaluation in an animal model. The blood flow catheter system was then used in a prospective, clinical study to compare it to the standard Transonic HD01 system.

MATERIALS AND METHODS

Endovascular Catheter System

The Angioflow meter is a catheter-based system that was developed by Transonic Systems. The endovascular catheter is manufactured by B. Braun Medical (Cherry Hill, NJ). The Angioflow catheter system consists of a single-use endovascular catheter, an external flow meter, and a laptop computer. The Angioflow catheter system is currently approved for investigational use.

The endovascular catheter is 6 F in diameter, 35 cm in length, and does not have a guide wire lumen (Fig 1). The catheter has an external injection port connected to a central lumen that allows injection of saline solution. The injected saline solution exits the catheter through two radial side holes located 6 cm proximal to the rounded distal tip. The catheter contains two temperature sensors (thermistors). One thermistor is located 1.5 cm from the distal tip of the catheter and is used to determine the thermodilution. The second thermistor is located in the proximal portion of the catheter, away from the blood stream, and is used to measure the temperature of the injected saline solution. The distal aspect of the catheter is curved to prevent contact between the distal thermistor and graft wall. The catheter is connected to an electronic flowmeter with a removable extension cable. The flowmeter is connected to a laptop computer that contains proprietary software designed for this application.

The Angioflow meter uses a thermodilution method to measure intragraft blood flow. The classical equations for dilution-based flow measurements cannot be directly applied to a catheter-based system within a hemodialysis graft. The standard equations must be adapted to account for the anatomic and hemodynamic conditions that exist within the graft and for the interactions that occur between the endovascular catheter and the graft lumen (5). Intragraft blood flow measurements obtained with use of the Angioflow meter are based on the following equation:

\[ Q = k \left( T_b - T_i \right) V / S - 0.5V / t \]

where \( Q \) is the intragraft blood flow; \( k \) is a coefficient related to the thermal properties of blood, saline, and the catheter and is considered to be 1.08; \( T_b \) is the temperature of the blood in the hemodialysis graft before injection; \( T_i \) is the temperature of injected saline solution; \( V \) is the volume of injected saline solution (10 mL); and \( S \) is the area under the temperature-time dilution curve resulting from the mixing of blood and injected saline solution; \( t \) is the width of the dilution curve at 50% height. The expression \((0.5V/t)\) is an average expected increase in blood flow through the graft as a result of the saline solution injection.

Bench Testing

The Angioflow meter system was evaluated with use of a simulated hemodialysis graft model to determine the accuracy of the flow measurement. The simulated graft model consisted of a loop-configuration plastic tube that was 6.5 mm in diameter and 24 cm in length. Water (37°C ± 2°C) was delivered through the plastic tubing with use of a variable-speed roller pump (Masterflex L/S; Cole-Parmer, Vernon Hills, IL). The precise water flow rate was measured volumetrically with use of calibrated clamp-on sensors connected to a H109 transit time flow meter (Transonic Systems). The blood flow catheter was positioned within the graft model so that the distal thermistor and injection holes were located within the flowing water stream. Flow measurements were performed by injecting 10 mL of room-temperature saline solution through the injection port of the catheter. The flow of water through the graft model was incrementally varied from 200 mL/min to 2,000 mL/min during these validation studies. At least six flow measurements were obtained at each different graft flow rate. In addition, several other parameters were altered to simulate different clinical scenarios and to determine their effect on flow measurements. These included moving the catheter tip (ie, thermistor) closer to the graft wall and varying the duration of the saline solution injection.

Animal Study

The animal investigation was approved by the Institutional Animal Care and Use Committee. Blood flow...
studies with the Angioflow meter system were performed in two adult ewes.

Under general anesthesia, a 6-mm polytetrafluoroethylene (PTFE) graft (W.L. Gore & Associates, Flagstaff, AZ) was constructed between the right common carotid artery and the right internal jugular vein. A perivascular flow probe (Transonic Systems) was affixed to the right carotid artery of each animal. The sterile wire lead of the flow probe was exteriorized at the back of the neck and secured beneath a bandage.

Intragraft blood flow measurements were performed 2 weeks after the graft implantation surgery. Under sterile conditions, the Angioflow catheter was introduced into the PTFE graft in an antegrade direction through a 6-F vascular sheath (Cook, Bloomington, IN). A series of 10-mL injections of room temperature isotonic saline solution were performed through the catheter and intragraft blood flow measurements were obtained. Blood flow measurements obtained from the flow probe on the carotid artery were simultaneously recorded. Four baseline blood flow measurements were obtained in each animal. Two additional measurements were obtained while compressing the venous limb of the graft to vary the intra-access blood flow. The blood flow measurements obtained with use of the Angioflow catheter were compared to those obtained with use of the perivascular flow probe.

Clinical Study

The Human Studies Committee at our institution approved enrollment of 25 patients into this prospective clinical study. Only patients who were undergoing chronic hemodialysis treatments and had a PTFE graft as their vascular access for hemodialysis were eligible for inclusion. Patients who were enrolled were referred from two outpatient hemodialysis treatment centers that are affiliated with our hospital.

All patients who met the following inclusion criteria were eligible for enrollment: (i) ability to give informed consent, (ii) a patent PTFE hemodialysis graft, and (iii) intragraft blood flow <600 mL/min. The only exclusion criterion was infection of the hemodialysis graft. Patients who fulfilled these criteria were referred to interventional radiology for a diagnostic fistulogram.

Twenty-four patients who met the inclusion criteria were prospectively enrolled between October 2000 and March 2001. No patients who met the inclusion criteria were excluded. One additional patient with an intragraft blood flow of 650 mL/min was referred for a diagnostic fistulogram because of rapidly declining intragraft blood flow measurements. This patient was also enrolled. Therefore, a total of 25 patients were included in this study.

Twenty patients (80%) were women and the mean age of all patients was 66.3 years (range: 32–89 y). All 25 patients had a PTFE loop configuration hemodialysis graft. Twenty patients had their graft in the forearm (16 left, four right) and five patients had upper arm grafts (four right, one left). The mean age of these hemodialysis grafts was 42.6 months (range: 2–125 mo). The age of one patient’s graft was not known.

Informed consent was obtained from each patient before diagnostic fistulography. With use of an 18-g needle, the apex of the graft was entered and a guide wire was advanced into the venous limb. A short 7-F vascular sheath (DialEase; Mallinckrodt Medical, St. Louis, MO) was inserted. A standard fistulogram was obtained via the vascular sheath to evaluate the venous limb of the graft and the native peripheral and central veins. Subsequently, the venous limb was manually compressed and contrast material was injected through the sheath to visualize the arterial limb of the graft and the arterial anastomosis. Lesions with ≥50% stenosis were considered to be significant and were treated. The degree of stenosis was approximated by visually comparing the narrowest diameter of the lesion to the diameter of a normal vein located just upstream from the stenosis. If, by visual estimate, the degree of stenosis was thought to be near 50%, the degree of stenosis was measured with use of the calibrated measuring software within the digital imaging system. Intravascular pressure measurements were not performed.

The Angioflow catheter was calibrated before insertion into the graft by placing the catheter tip into a small cup filled with room-temperature sterile saline solution and activating the calibration software. During the clinical studies, a modification of the software eliminated this calibration step. The Angioflow catheter was inserted through the 7-F vascular sheath and positioned so that the side holes in the catheter were within the hemodialysis graft, outside of the vascular sheath. Care was also taken so that the catheter did not cross a stenotic segment. For each measurement, 10 mL of sterile, room temperature, isotonic saline

Figure 2. Chart depicting the distribution of error in the flow values obtained with use of the Angioflow meter when compared to the true flow value.
solution was hand injected (3–4 sec) through the injection port of the catheter. The injection of saline solution automatically triggered the initiation of a blood flow measurement. Three separate blood flow measurements were obtained before and after the angioplasty procedure.

Analgesic and anxiolytic medications were administered before the angioplasty procedure. Heparin was not given. The angioplasty balloon was chosen such that the diameter of the balloon was 10%–20% larger than the caliber of the normal vein adjacent to the stenosis; a 7-mm-diameter balloon (Centurion; Bard, Covington, GA) was most commonly used. Under fluoroscopic observation, the angioplasty balloon was positioned across the stenosis and inflated until the waist was effaced or the balloon pressure reached 25 atm of pressure. The balloon inflation time was 30–60 seconds. After completion of the angioplasty procedure, the balloon catheter was removed and a fistulogram was obtained. A successful angioplasty procedure was defined as having <30% residual stenosis (6). As a result of significant (>50%) residual stenosis, two patients underwent endovascular stenting (S.M.A.R.T. stent; Cordis, Warren, NJ) of the lesion.

After the angioplasty procedure, the blood flow catheter was again inserted and appropriately positioned within the graft as previously described. Three postangioplasty blood flow measurements were obtained. At the completion of the procedure, the vascular sheath was removed and a purse-string suture was used to close the graft entry site.

Intragraft blood flow measurements were obtained in the outpatient hemodialysis center with use of the Transonic HD01 system for each study patient both before and after the angioplasty procedure. The intragraft blood flow value was recorded as the average of two separate measurements. When the two measurements differed by more than 10%, a third measurement was obtained. For each patient, the mean value of the blood flow measurements was calculated and reported.

**Data Analysis**

Intragraft blood flow values are reported as the mean ± SD. Comparisons of flow measurements were performed with use of the paired Student t test. The results from the reproducibility studies are expressed as the mean coefficient of variation for duplicate measurements: 2 × (first measurement − second measurement) / (first measurement + second measurement).

**RESULTS**

**Bench Testing**

During these validation studies with the Angioflow meter system, 397 separate flow measurements were obtained while varying the water flow in the hemodialysis graft model over the range that is clinically applicable (150–1,700 mL/min). There was excellent correlation (r = .98) between the flow measurements obtained with use of the Angioflow meter system and those measured by the volumetric flow meter. These results demonstrate that 60% of the flow measurements obtained with use of the Angioflow meter system were within 5% of the true flow value (Fig 2). In addition, 95% of the measurements were within 15% of the true flow value.

**Animal Study**

Unfortunately, the intragraft blood flow in the two study animals was lower than expected, in the 500-mL/min range. Eleven intragraft blood flow measurements were obtained with use of the Angioflow meter and compared to those measured by the perivascular probe. By externally compressing the graft, the intragraft blood flow was varied between 100 mL/min and 500 mL/min during these measurements. There was excellent correlation (r = .99) between the two methods (Fig 3).

**Clinical Study**

Twenty-four patients had a significant stenosis in the graft or primary outflow vein. In one patient, the fistulogram revealed an occluded outflow vein adjacent to the venous anastomosis and no endovascular intervention was performed. These findings demonstrate that the surveillance threshold value of 600 mL/min, as measured by the Transonic HD01 system, was highly predictive of a significant graft-related problem.

Forty significant stenoses were
identified in 24 patients. Eleven patients had a single stenosis, 10 patients had two stenoses, and three patients had three stenoses. Sixteen of these lesions were located at the venous anastomosis, four lesions were in the basilic vein, one lesion was in the cephalic vein, and three stenoses were at the arterial anastomosis.

Twenty-four of the 25 patients (96%) underwent an angioplasty procedure. The patient with the venous outflow occlusion was not treated. All 40 of the identified stenoses were treated. Thirty-six stenoses were dilated with use of a 7-mm-diameter angioplasty balloon; a 6-mm-diameter balloon was used for one stenosis and a 5 mm-diameter balloon was used to dilate the three arterial anastomotic stenoses.

Despite repeat inflation of the angioplasty balloon, five lesions in five patients had a significant (>30%) residual stenosis after angioplasty. Therefore, the anatomic success rate for the 24 treated patients was 79%. When calculated for the 40 separate stenoses that were treated, the anatomic success rate was 88% (35 of 40). The two lesions that had >50% residual stenosis were further treated with endovascular stents.

There was one complication associated with these angioplasty procedures. One patient had acute thrombosis of their hemodialysis graft during the angioplasty procedure and immediately underwent a successful percutaneous thrombectomy procedure with use of the Amplatz Thrombectomy Device (Microvena, White Bear Lake, MN).

Three of the 25 patients did not have follow-up blood flow measurements at the outpatient hemodialysis center. One patient who had occluded venous outflow did not undergo an endovascular intervention and therefore did not require a follow-up blood flow measurement. Two patients did not undergo their follow-up blood flow measurements because the Transonic HD01 system laptop computer was stolen from the outpatient hemodialysis center. The blood flow data from these three patients were not included in the analysis. Therefore, the final study group consisted of 22 patients with complete data.

Before the angioplasty procedure, the mean intragraft blood flow rate was 463 mL/min ± 154 as measured with use of the Transonic HD01 system and 495 mL/min ± 180 according to the Angioflow meter system (Fig 4). After the angioplasty procedure, the mean intragraft blood flow rate was 781 mL/min ± 221 with use of the Transonic HD01 and 779 mL/min ± 332 with use of the Angioflow meter. The mean increase in intragraft blood flow after the angioplasty procedure was 319 mL/min ± 256 with use of the Transonic HD01 and 324 mL/min ± 267 with use of the Angioflow meter system.

The mean time interval between the initial Transonic HD01 blood flow measurements, performed in the hemodialysis center, and the angioplasty

Figure 4. A comparison of mean blood flow rate as measured by the standard Transonic HD01 system and the Angioflow meter system before and after the angioplasty procedure.

Figure 5. Correlation of preangioplasty Transonic HD01 blood flow measurements to those obtained with use of the Angioflow meter.
The mean time interval between the angioplasty procedure and the follow-up Transonic HD01 blood flow measurements was 4.9 days (range: 0–16 d). Despite further evaluation of the graft and native veins, the etiology of the persistently low blood flow was not determined.

Another patient had multiple intragraft stenoses and a focal, high-grade stenosis at the venous anastomosis. After successful treatment of the intragraft stenoses and full inflation of the angioplasty balloon at the venous anastomosis, there was a persistent 30% residual stenosis at the venous anastomosis. Despite repeat balloon inflations, there was no additional improvement. The intragraft blood flow rate remained at 570 mL/min and no further treatment was performed.

A third patient had successful angioplasty of a venous anastomotic stenosis. However, during the subsequent 5-minute period, as postangioplasty blood flow measurements were obtained, there was progressive elastic recoil causing the return of a severe, focal stenosis at the venous anastomosis. The final intragraft blood flow rate was 528 mL/min. Endovascular stent placement was not performed because of the location and geometry of this lesion. The fourth patient had multiple intragraft stenoses plus a stenosis at the arterial anastomosis. Despite successful dilation of all lesions, repeat fistulography demonstrated visually slow blood flow through the graft. The measured intragraft blood flow rate was 380 mL/min. A diagnostic upper extremity arteriogram was then obtained by advancing an angiographic catheter retrograde through the arterial anastomosis and positioning the tip in the subclavian artery. A brachial arteriogram also revealed very slow blood flow, but no causative lesions were identified.

In one patient, the immediate postangioplasty blood flow rate was 890 mL/min. The follow-up blood flow measurement, performed 2 days later, was 470 mL/min. The etiology of this substantial decrease in blood flow is results demonstrate that sequential intragraft blood flow measurements have excellent reproducibility.

Four patients (17%) had intragraft blood flow rates of less than 600 mL/min immediately after the angioplasty procedure. One patient had multiple intragraft stenoses that were successfully treated with use of a 7-mm-diameter balloon. However, the postangioplasty intragraft blood flow rate was only 580 mL/min. Despite further evaluation of the graft and native veins, the etiology of the persistently low blood flow was not determined.

Another patient had multiple intragraft stenoses and a focal, high-grade stenosis at the venous anastomosis. After successful treatment of the intragraft stenoses and full inflation of the angioplasty balloon at the venous anastomosis, there was a persistent 30% residual stenosis at the venous anastomosis. Despite repeat balloon inflations, there was no additional improvement. The intragraft blood flow rate remained at 570 mL/min and no further treatment was performed. A third patient had successful angioplasty of a venous anastomotic stenosis. However, during the subsequent 5-minute period, as postangioplasty blood flow measurements were obtained, there was progressive elastic recoil causing the return of a severe, focal stenosis at the venous anastomosis. The final intragraft blood flow rate was 528 mL/min. Endovascular stent placement was not performed because of the location and geometry of this lesion. The fourth patient had multiple intragraft stenoses plus a stenosis at the arterial anastomosis. Despite successful dilation of all lesions, repeat fistulography demonstrated visually slow blood flow through the graft. The measured intragraft blood flow rate was 380 mL/min. A diagnostic upper extremity arteriogram was then obtained by advancing an angiographic catheter retrograde through the arterial anastomosis and positioning the tip in the subclavian artery. A brachial arteriogram also revealed very slow blood flow, but no causative lesions were identified.

In one patient, the immediate postangioplasty blood flow rate was 890 mL/min. The follow-up blood flow measurement, performed 2 days later, was 470 mL/min. The etiology of this substantial decrease in blood flow is
not known but may be a result of restenosis from elastic recoil.

**DISCUSSION**

The fundamental tenet of vascular access surveillance is that routine, periodic monitoring of hemodialysis grafts will lead to the early detection of developing venous stenoses. Early detection, combined with expeditious treatment of hemodynamically significant lesions, will decrease the incidence of vascular access thrombosis.

As described in K/DOQI Guideline 10, periodic monitoring of intragraft blood flow is the preferred access surveillance method (1). The Transonics HD01 system continues to be one of the most widely used methods for measuring intraccess blood flow in blood hemodialysis grafts and native fistulas.

This study has demonstrated that the new Angioflow meter system is an accurate and reliable device for measuring intragraft blood flow during endovascular procedures. The results obtained with use of this endovascular catheter are comparable to those obtained with use of the standard Transonics HD01 system. Repeat measurements with the Angioflow meter demonstrated a high degree of reproducibility, suggesting that technical errors such as minor variations in the speed or volume of saline solution injection do not compromise the accuracy of the measurements. Therefore, after an endovascular intervention, if sequential blood flow measurements demonstrate a progressive decrease in intragraft blood flow, the finding is likely a true observation and not a result of inaccuracy of the Angioflow meter system. This phenomenon of gradually decreasing blood flow immediately after a successful angioplasty procedure was observed in one patient and was caused by elastic recoil of the treated lesion.

As described in both the SCVIR Reporting Standards for Percutaneous Interventions in Dialysis Access document (6) and the K/DOQI document (1), stenoses should be evaluated with use of anatomic and physiologic criteria before an intervention. The anatomic definition of a significant stenosis is a lesion that causes >50% luminal narrowing when compared to an adjacent normal vessel. Importantly, such a stenosis should only be treated if it is causing a physiologic or clinical abnormality. Definitions of these abnormalities are listed in Guideline 19 of the K/DOQI document and include intragraft blood flow rate <600 mL/min, elevated venous dialysis pressure, abnormal dialysis kinetics, decreased intraccess blood flow, or abnormal physical examination results (ie, arm swelling). Of note, an intragraft blood flow value <600 mL/min was highly predictive of a significant stenosis (>50%) or venous occlusion in all 25 patients enrolled in this study.

After an endovascular intervention, the treated lesion should be reassessed to determine the success of the procedure. Anatomic measurements of the residual stenosis are commonly obtained. In addition, some interventionists perform trans-stenotic pressure measurements to determine the pressure gradient across the residual stenosis. However, these two types of quantitative measurements assess only the treated lesion. They do not provide any insight into the hemodynamic status of other segments of the vascular access circuit. Alternatively, the assessment of intragraft blood flow provides a quantitative assessment of the entire vascular access circuit including the venous outflow, the arterial inflow and the intragraft segments. In addition, the postprocedural blood flow results can be compared to the preprocedural values to determine the improvement in blood flow and to establish a new baseline. Documentation of the new baseline blood flow value is beneficial as a comparison for future graft surveillance assessments.

A successful repair of a stenosis should return the intragraft blood flow to normal levels. However, normal intragraft blood flow is patient-dependent and highly variable. Ahya et al (6) compared postangioplasty blood flows to the highest blood flow ever measured in each patient’s graft and demonstrated that a successful intervention can return the intragraft blood flow rate to baseline level. Interestingly, several different investigators have reported a similar value of 300 mL/min as the average increase in intragraft blood flow after angioplasty (7-9). Our current study group demonstrated a mean increase of 320 mL/min, which is also remarkably similar to these other reports. The explanation for these comparable results is unknown but intriguing.

Clinical studies have also reported that 20%-30% of patients have persistently low (<600 mL/min) blood flows after angioplasty (5,6,10,11). There are several possible reasons for these unexpected, suboptimal postangioplasty blood flow results. These include failure to identify all hemodynamically significant lesions, delayed elastic recoil after a successful angioplasty, or the presence of arterial inflow problems.

Hemodialysis graft dysfunction or thrombosis can be caused by multiple coexisting problems. In the current study, 40 separate stenoses were identified in 24 patients, an incidence of 1.67 lesions per patient. Ten patients had two stenoses and three patients had three stenoses. Failure to identify all significant stenosis can lead to continued dysfunction and possibly early thrombosis of the vascular access. Use of the Angioflow meter during endovascular procedures allows immediate assessment of the entire vascular access circuit. If the postangioplasty blood flow rate does not return to baseline, the circuit should be thoroughly reevaluated to identify any additional or recurring problems.

In some patients, the intragraft blood flow may normalize angioplasty but the duration of improvement may be short-lived. Spergel et al (10) reported a mean duration of less than 30 days for maintaining an intragraft blood flow rate >600 mL/min after angioplasty. However, Smits et al (11) reported that intragraft blood flow gradually returned to the preangioplasty value over a period of 2.5 months. Of note, two studies have reported that arteriovenous fistulas have a longer duration of improved blood flow after angioplasty (11,12).

In conclusion, the use of the Angioflow meter system to measure intragraft blood flow during endovascular procedures allowed immediate post-treatment evaluation of the stenosis and also provided additional insight into the hemodynamic status of the entire vascular access circuit.

**References**