

# Vascular Access Surveillance

Controversial studies lead to a national debate.

BY THOMAS M. VESELY, MD

**H**emodialysis grafts and fistulas are plagued by the development of hyperplastic neointimal venous stenoses. These lesions are a biologic response to the hemodynamic changes that occur after surgical creation of an arteriovenous shunt using either native vessels (ie, fistula) or prosthetic graft material.

Vascular access surveillance is based on measurement and analysis of the hemodynamic and physiologic changes that often occur in hemodialysis grafts and fistulas. The fundamental tenet of vascular access surveillance is that periodic assessment of quantifiable physiologic parameters, such as intra-access blood flow or intra-access pressure, can provide early detection of a developing hyperplastic neointimal stenosis.

The rate of blood flow through a patient's arteries and veins increases nearly 20-fold after placement of a hemodialysis graft or fistula.<sup>1,2</sup> This marked increase in both rate and volume of blood flow causes stretching of the blood vessel walls. It is expected that these physiologic forces will incite dilatation and remodeling of the patient's arteries and veins. This process is termed *maturation* of the vascular access (ie, hemodialysis fistula or graft).

The blood vessel will be remodeled by the physiologic stresses that act upon it. Remodeling occurs by a complex process of cellular migration followed by neointimal tissue growth.<sup>3</sup> Localized deposition of neointimal tissue reshapes the pathway of blood flow through the vascular access circuit. Progressive growth (hyperplasia) of neointimal tissue causes narrowing

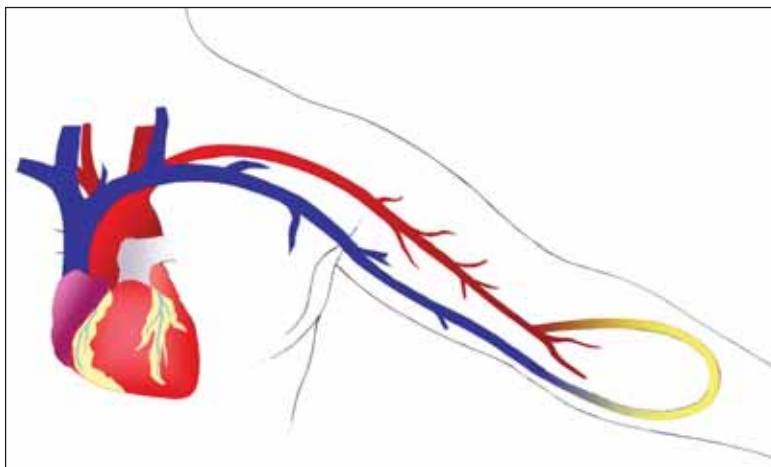


Figure 1. The vascular access circuit. Arterial inflow pathway (red), arteriovenous shunt (yellow), and venous outflow pathway (blue).

(stenosis) of the blood vessel lumen. Continued narrowing of the blood vessel reduces the rate of blood flow and thereby reduces the efficiency of a hemodialysis treatment. Aggressive growth of neointimal stenoses can lead to occlusion and thrombosis of a hemodialysis graft or fistula.

## VASCULAR ACCESS SURVEILLANCE

The National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (KDOQI) is a multidisciplinary collaborative project that is creating evidence-based guidelines for managing patients with end-stage kidney disease. The KDOQI Guidelines and Recommendations for Vascular Access are considered the best practices for management of hemodialysis vascular access.<sup>4</sup> The 2006 KDOQI guidelines define vascular access surveillance as "Periodic evaluation of the vascular access using tests that may involve special instrumentation and for

which an abnormal test result suggests the presence of dysfunction.” This definition is based on two important concepts: (1) periodic assessment of a fistula or graft can provide early detection of developing venous stenoses, and (2) expedient repair of a stenosis will decrease the incidence of vascular access thrombosis. Furthermore, it is believed that early identification and repair of stenoses will optimize the rate of blood flow and maintain efficient hemodialysis treatment.

Vascular access surveillance is performed at the time of hemodialysis treatment in the hemodialysis treatment center. Ideally, surveillance should be performed monthly. The 2006 KDOQI guidelines describe two methods for vascular access surveillance: (1) measurement of intra-access blood flow or (2) measurement of static venous pressure.<sup>4</sup> Analysis of sequential, monthly measurements and long-term trends has proven to be more useful than a single, isolated measurement.

The landmark study by McCarley et al provided strong clinical evidence to support the use of intra-access blood flow for vascular access surveillance.<sup>5</sup> They reported the results of a three-phase study comparing different surveillance methods, including no surveillance, surveillance using dynamic venous pressures, and surveillance using intra-access blood flow. During the course of this study, the graft thrombosis rate was reduced from 0.71 to 0.16 thromboses per patient-year at risk. Vascular access problems requiring hospital admission decreased from 1.8 days to 0.4 days per patient-year at risk. The number of missed hemodialysis treatments decreased from 0.98 treatments to 0.26 treatments per patient-year at risk. Catheter use was significantly reduced from 0.29 to 0.07 catheters per patient-year at risk. However, these important clinical improvements came at a price. The rate of percutaneous procedures (angioplasty) increased from 0.09 procedures to 0.54 procedures per patient-year at risk.

The study by McCarley et al and other clinical studies have popularized the use of intra-access blood flow for vascular access surveillance.<sup>6,7</sup> However, it is important to note that measuring intra-access venous pressure remains an acceptable surveillance method for prosthetic hemodialysis grafts.<sup>4</sup>

## BLOOD FLOW IN HEMODIALYSIS GRAFTS AND FISTULAS

Knowledge of the vascular access circuit is important for understanding the principles of vascular access surveillance. The vascular access circuit consists of the blood pump (ie, the patient’s heart), the arteries that provide the inflow pathway, the vascular access (ie, a hemodialysis graft or fistula), and the veins that pro-

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vide the outflow pathway to return the blood flow to the heart (Figure 1).

Normal circulation of blood through the arteries and veins of the upper extremity is analogous to a high-resistance electrical circuit. The very small arterioles and capillaries of the hand create vascular resistance that helps regulate the rate of blood flow through the upper arm and forearm. Construction of an arteriovenous shunt, such as a hemodialysis fistula or graft, provides an anatomic bypass that allows arterial blood to “short circuit” directly into the outflow vein. Creation of an arteriovenous shunt separates the high-resistance blood vessels of the hand (distal arterioles and capillaries) from the circulation of the upper arm. Removal of the distal vascular resistance induces an immediate and substantial increase in the rate of blood flow through the vascular access circuit.<sup>1,2</sup>

The rate of blood flow through a hemodialysis fistula or graft is dependent on the location and specific type of vascular access. Fistulas that are created using the radial artery (3 mm) near the hand have slower rates of blood flow compared to those that are created using the brachial artery (6 mm) near the elbow.<sup>1</sup> The expected rate of blood flow through a radiocephalic fistula is 600 to 700 mL/min compared to 1,300 to 1,500 mL/min for a brachiocephalic fistula.<sup>1,2</sup> The mean rate of blood flow through a prosthetic hemodialysis graft is 800 to 1,200 mL/min.

There are other important factors that affect the rate of blood flow through a hemodialysis fistula or graft. The performance of the blood pump (ie, the heart) determines the rate and volume of blood flow through the subclavian and brachial arteries. The patient’s blood pressure, cardiac ejection fraction, and cardiac rhythm have an impact on the rate of blood flow through the hemodialysis fistula or graft.<sup>8</sup> Cardiac output is affected by the patient’s fluid volume status, blood pressure medications, and concurrent cardiac disease. Atherosclerosis or diabetic nephrosclerosis can cause arterial stenoses or occlusions along the inflow arteries. Any factor that decreases the rate of intra-access blood flow can lead to suboptimal hemodialysis treatment and may eventually increase patient morbidity and mortality.

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## SURVEILLANCE METHODS

The choice of surveillance method depends on the type of vascular access and the availability of equipment at the hemodialysis treatment center.

Measurement of intra-access blood flow is the preferred method of surveillance for patients with prosthetic hemodialysis grafts.<sup>4</sup> The rate of intra-access blood flow is commonly measured using the ultrasound dilution technique but can also be measured using differential conductivity, glucose pump infusion, or Doppler ultrasound. The measurement of intra-access blood flow should be performed during the first 90 minutes of hemodialysis treatment to eliminate error caused by a decrease in blood pressure related to ultrafiltration.

The KDOQI guidelines state that if the rate of intra-access blood flow is < 600 mL/min, the patient should be referred for fistulography.<sup>4</sup> However, trend analysis of sequential blood flow measurements is more predictive of future access thrombosis. The KDOQI guidelines state that if the intra-access blood flow is < 1,000 mL/min and the rate of blood flow has decreased by > 25% during a 4-month period, the patient should be referred for fistulography.<sup>4</sup> Alternatively, the European Best Practices Guidelines state that if the rate of blood flow decreases by > 20% per month, the patient should be referred for fistulography.<sup>9</sup>

Development of a stenosis within a downstream blood vessel will increase the blood pressure within a graft or fistula. This increased intra-access blood pressure can be measured using the pressure transducers of the dialysis machine. Static venous pressure is measured under conditions of no blood flow and no ultrafiltration; the only pressure difference is due to the difference in height between the transducer and the level of the fistula or graft. The KDOQI guidelines state that if the mean static venous pressure ratio is > 0.5, the patient should be referred for fistulography.<sup>4</sup>

Variations in venous anatomy make surveillance of hemodialysis fistulas more challenging than for hemodialysis grafts. Measurement of intra-access blood flow in fistulas is often more reliable than measurement of intra-access venous pressure.<sup>4</sup> If the intra-access blood flow is < 300 mL/min in a forearm fistula or

< 500 mL/min in an upper arm fistula, the patient should be referred for fistulography.<sup>9</sup> However, it is important to remember that a single abnormal value is not necessarily indicative of a vascular access problem. Analysis of sequential measurements and long-term trends is more predictive of future vascular access thrombosis.

## THE CONTROVERSY

Vascular access surveillance is a controversial topic, generating significant national debate. Advocates for surveillance believe that there are numerous published studies that have proven that implementation of a vascular access surveillance program will result in significant clinical benefits. Opponents of surveillance argue that these clinical benefits remain unproven and that there are few, if any, studies that validate the effectiveness of any surveillance method.<sup>10</sup> Furthermore, opponents argue that surveillance leads to expensive angiographic procedures, administration of x-ray contrast material, and interventions (eg, angioplasty) that may adversely affect long-term survival of the patient's hemodialysis fistula or graft.<sup>11</sup>

The majority of published reports that substantiate the benefits of vascular access surveillance are nonrandomized observational studies that, arguably, provide low-quality scientific evidence to support such claims.<sup>10</sup> More recent randomized controlled studies have concluded that surveillance is not predictive of thrombosis, nor improves the life span of a hemodialysis graft or fistula. A committee organized by the Society for Vascular Surgery reviewed the published literature and concluded, “Surveillance of asymptomatic hemodialysis access for detection and treatment of stenosis may reduce the risk of thrombosis and prolong access survival more than usual clinical monitoring, but these comparisons were not statistically significant.”<sup>12</sup>

Paulson and colleagues have described several reasons that vascular access surveillance, as is currently practiced, is not accurate in predicting thrombosis.<sup>11</sup> Patients can experience significant variations in blood pressure during hemodialysis treatment and during the intradialytic period.<sup>13</sup> This variability in blood pressure alters the rate of blood flow through the patient's fistula or graft and thereby decreases the sensitivity and specificity of vascular access surveillance. Variations in blood pressure may be due to changes in intravascular volume (eg, hydration) or compliance with the cornucopia of blood pressure medications that is typically required for hemodialysis patients. Development of stenosis can occur slowly or rapidly.<sup>14</sup> During the early development of a stenosis, the rate of blood flow

*(Continued on page 57)*

(Continued from page 48)

through the vascular access remains unchanged. But at a critical degree of stenosis, there can be a rapid decrease in the rate of blood flow.<sup>15</sup> A rapid decrease in blood flow may go undetected by monthly surveillance, thereby resulting in thrombosis of the vascular access. Ram et al reported that 50% of access thromboses were not preceded by a measured reduction in blood flow, often because thrombosis occurred before a change could be measured.<sup>16</sup>

## CONCLUSION

Vascular access surveillance is based on the detection of physiologic and hemodynamic changes that occur during the life span of hemodialysis fistulas and grafts. These changes are biologically complex, not entirely predictable, and confounded by patient behavior. The extent to which these factors interfere with the accuracy and clinical value of vascular access surveillance remains the subject of intense national debate. ■

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