Screening and Assessment of Dialysis Graft Function

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Dialysis graft thrombosis is a major cause of morbidity for patients on chronic hemodialysis. Recent evidence supports the implementation of routine graft surveillance programs to detect early access dysfunction and allow prophylactic repair before complete graft failure occurs. Graft dysfunction may be detected through direct or indirect measurement of changes in graft flow. The principal indicators of graft function include direct physical examination and measurements of blood flow, venous pressure, arterial inflow, and dialysis efficiency. Balloon angioplasty or surgical revision of stenoses detected through periodic graft monitoring reduces the incidence of graft thrombosis and prolongs graft patency.

Dialysis access failure is the plague of patients on chronic hemodialysis and of physicians and nurses involved with access care. Most patients with dialysis grafts experience failure of their graft at some point. Graft failure is responsible for significant morbidity, cost, discomfort, and inconvenience for the dialysis population. There are many causes of failure, including infection of the graft, development of pseudoaneurysms in the graft leading to skin ischemia and skin breakdown, atherosclerosis of the arterial inflow vessels, and, most commonly, thrombosis. The causes of thrombosis can vary, including altered platelet function, hypercoagulable state, external pressure on the graft, and in the vast majority of cases, the development of a stenosis in the outflow veins. These stenoses can develop within the graft, within the central veins, or, most commonly, in the venous outflow just above the graft-venous anastomosis. It is clear that the ideal approach is to intervene before thrombosis of the graft. There is some interval between stenosis developing in the veins and failure (thrombosis) of the graft. The challenge is to catch the graft in the critical time period when failure is imminent. The need for methods of predicting graft failure has received increased emphasis due to the National Kidney Foundation Dialysis Outcomes Quality Initiative (NKF-DOQI), which has issued standards for quality of care in dialysis.[1] Some of the goals of the DOQI guidelines include reducing graft thrombosis to less than 0.5 thrombotic episodes per patient year at risk, and increasing patency rates for dialysis grafts to 70% at 1 year, 60% at 2 years and 50% at 3 years. Various methods for evaluating dialysis graft function and the potential benefits of prophylactic repair of failing grafts will be discussed.

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Types of Dialysis Access

The arteriovenous fistula is considered the most favorable type of dialysis access. Unfortunately, a majority of patients either are not candidates for a native arteriovenous fistula, or, once a native fistula is placed, it does not develop properly. Of the arteriovenous fistulas created, 30% to 40% are early failures.[2] As the number of patients on chronic hemodialysis has grown, the number of patients requiring alternative methods of access has also grown. For patients unable to have a native fistula, expanded polytetrafluoroethylene (PTFE) grafts are used. PTFE grafts are inert, with relatively low thrombogenicity, and have sufficient durability to withstand repeated punctures.[3]

Both types of dialysis access are prone to stenoses in the venous outflow, which leads to thrombosis of the access. The stenoses develop as a consequence of neointimal hyperplasia.[4] Thrombosis accounts for almost 80% of the complications observed with dialysis access.[2] The average patency for a PTFE graft is only 18 months.[5]

Dialysis Graft Hemodynamics

The primary indicators of dialysis graft function are blood flow rate and intragraft pressure. The blood flow rate in a normally functioning synthetic bridge graft is often >800 mL/min.[6] Adequate and efficient dialysis requires that the inflow rate from the graft equal the pump rate, which ranges from 250 to 600 mL/min. The intragraft pressure just beyond the arterial anastomosis is about half of the pressure in the inflow artery. There is a gradual decrease in graft pressure up to the venous anastomosis.[7]

The most common reason for dialysis graft failure is stenosis in the conduit, usually at or beyond the venous anastomosis. A small percentage of patients have arterial anastomotic/inflow stenoses, stenoses within the graft, or nonobstructive causes for graft thrombosis. Progressive obstruction in the graft causes graft flow to decrease and graft pressure to increase. Venous anastomotic stenoses produce larger increases in pressure than central venous stenoses. Severe arterial anastomotic stenoses can cause an overall reduction in graft pressure. Numerous studies have shown a high correlation between decreasing blood flow rates and subsequent graft thrombosis. The risk of synthetic graft thrombosis increases when the flow rate decreases below about 600 mL/min. When the graft flow rate is <450 mL/min, there is a high likelihood of early thrombosis.[8] However, arteriovenous fistulas can remain functional for long periods at flow rates well below 600 mL/min.

Methods for Graft Surveillance

Changes in blood flow, pressure, and dialysis efficiency are the basis for detecting high-risk hemodialysis grafts.

Venous pressure measurement is the single best indicator of dialysis graft dysfunction and one of the simplest and least expensive to perform.[9-12] A pressure in the venous limb of the graft above 125 to 150 mm Hg (through 15-gauge needles at dialysis rates of 200 to 225 mL/min) is predictive of a venous stenosis. Dynamic pressures taken during dialysis are somewhat less accurate than static pressures, but are easier to obtain. The normalized pressure ratio (venous pressure/systolic pressure) may be more accurate in detecting graft dysfunction. A pressure ratio of more than 0.4 indicates a significant graft stenosis.[7] No absolute value or percent increase in venous pressure predicts graft failure.[3] For all of these techniques, pressure trends are more valuable than solitary readings. If pressures are elevated for several consecutive hemodialysis sessions, the accuracy improves.

Physical examination has proven to be an excellent screening tool for detecting grafts at risk for thrombosis.[13-15] A normally functioning graft has a thrill at all points. If a stenosis develops in the graft or venous outflow, the thrill is replaced by a pulse up to the point of narrowing, an abnormal thrill or bruit at the site of stenosis, and a diminished pulse beyond. Other physical findings of graft malfunction include prolonged bleeding after needle removal and arm swelling. Physical examination alone has been shown to be an extremely reliable, simple, and inexpensive method for following dialysis grafts. In one study, an abnormal exam was the sole indicator of a graft stenosis in almost one quarter of patients subsequently studied by angiography.[13]

Arterial inflow pressure is carefully monitored through the arterial needle as the pump rate is gradually increased to the desired level. A highly negative arterial pressure associated with inability to attain a 300 mL/min flow rate during dialysis may indicate an arterial inflow stenosis.

Recirculation percentage is defined by the formula

$$\frac{\text{systemic BUN} - \text{arterial needle BUN}}{\text{systemic BUN} - \text{venous needle BUN}} \times 100\%.$$

This figure reflects the quantity of blood that is returned from the dialyzer through the venous needle and then re-dialyzed through the arterial needle rather than entering the systemic circulation. A urea-based recirculation percentage of more than 10% to 15% is considered abnormal. On-line dilution recirculation methods have recently gained popularity. At best, this test is a moderately good indicator of dialysis graft dysfunction, but a relatively late one.[10,16] In some studies, recirculation values were found to be highly variable and without any correlation to graft patency.[3] Recirculation is a better predictor of shunt stenosis in arteriovenous fistulas.

Dialysis efficiency is an indirect sign of graft function.[17] A decrease in the delivered dialysis dose may indicate graft dysfunction, although many other factors influence these values.

Blood flow rates during dialysis do not seem to be predictive of graft patency. Average flow rates for grafts that fail are comparable to the flow rates of grafts that remain patent.[3]

Duplex and color Doppler sonography are useful for detecting graft stenoses and measuring reductions in overall blood flow.[18-21] In one study, a significant graft stenosis or graft volume flow $<$450 mL/min was predictive of subsequent graft thrombosis within less than 2 months.[8] Despite their accuracy, these techniques are too costly and impractical to be used for routine screening.

The ideal screening tool for dialysis graft dysfunction would be highly accurate, simple, inexpensive, and completely safe. Because no such test exists, the Vascular Access Work Group of the National Kidney Foundation has recommended a multifaceted surveillance program to assess graft function at intervals of 1 month or less.[1] The program involves frequent dynamic or static venous pressure measurements and routine physical examination of the graft.

In this country, the majority of patients on chronic hemodialysis have indwelling synthetic bridge grafts. A minority of patients undergoes dialysis through arteriovenous fistulas. Fistulas usually develop stenoses at more central sites, which allow collateral veins to be recruited. For this reason, fistula pressure may not increase significantly and is less predictive of impending access failure.[10,12] Other screening techniques, such as duplex sonography and recirculation measurement, are more useful in these patients.

Benefits of Graft Surveillance

The sensitivity of long-term surveillance programs for hemodialysis graft dysfunction has not been established. However, several retrospective studies have shown that routine dialysis pressure measurements and/or physical examination, along with periodic assessment of other parameters, have an accuracy above 90% in detecting a graft abnormality. These figures are comparable to or even better than results with duplex or color Doppler sonography.

Early thrombosis occurring within 6 weeks of implantation is usually the result of a technical or mechanical error. Late thrombosis is usually secondary to venous intimal hyperplasia and generally begins to occur approximately 3 months after placement of the graft.[3]

The primary impetus for detecting graft dysfunction is early repair to prevent complete graft failure. Schwab et al popularized the concept of prophylactic balloon angioplasty to prevent graft thrombosis.[9] Since that time, several other studies have proven that a routine surveillance program with early treatment of failing grafts (by angioplasty or surgical revision) significantly reduces the frequency of graft thrombosis.[10,13,22,23] In our series, the incidence of graft thrombosis decreased from 48% to 17% with the introduction of routine dialysis graft monitoring. Other advantages of prophylactic treatment of failing grafts include the following:

1. reduced morbidity;
2. efficient, continuous, uninterrupted dialysis;
3. less need for temporary dialysis catheters;
4. fewer hospital days for access-related problems;
5. increased graft longevity;
6. reduced rate of graft replacement;
7. improved quality of life.

Avoiding a surgical intervention and treating patients as much as possible with percutaneous therapy has several advantages. Probably the most important advantage is that the venous anatomy is preserved. Placing a new graft or surgically revising an old graft requires using another vein or different area of vein. In patients with limited venous sites, preserving veins may be crucial. Percutaneous therapy also decreases hospitalization and cost, because the procedure is done on an outpatient basis. Patients are also more comfortable with a percutaneous procedure. There is no incisional pain and lower risk of infection.

The primary patency rate after balloon angioplasty of dialysis graft stenoses in functioning grafts is approximately 50% (range, 35% to 65%) at 6 months. These results are better than those for angioplasty of thrombosed grafts, although the 2 populations are somewhat difficult to compare.[24] Prophylactic treatment of graft stenoses may be an efficient way to maintain graft function. One study randomized patients with more than 50% stenosis on both duplex ultrasound and angiography to either observation or angioplasty treatment. This study showed that there was no difference in the graft patency between the 2 groups.[25] However, a relatively large study compared a group of patients not subjected to any organized graft surveillance with a group of patients who were followed with venous pressure measurements and found a significant decrease in thrombosis and graft replacement in the latter group. The surveillance group was benefited by an increase in primary surgical patency and graft survival.[22]

The long-term benefit and cost of a prophylactic treatment approach to the dialysis population seems to be logical. However, to better define the best surveillance method and to establish the benefits and costs of surveillance, a randomized trial comparing surveillance and percutaneous intervention with no surveillance should be performed.

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