Distal Revascularization Interval Ligation (DRIL) for the Treatment of Dialysis Access Steal Phenomenon

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The incidence and prevalence of end-stage renal disease continues to grow, even as treatments improve. The vascular steal phenomenon is an infrequent but often debilitating complication of dialysis access placement, and management can be difficult. A specific technique called distal revascularization–interval ligation, or the DRIL procedure, has been used with success in managing this problem. Anatomically, the site of the steal is bypassed, and the native vessel just distal to the steal site is ligated, making duplex sonography evaluation complex. An examination algorithm is presented, with illustrative examples, to assist the sonographer in evaluating dialysis access patients when they have had the DRIL procedure. The algorithm is based on breaking the study into more easily managed components: (1) duplex sonographic evaluation of arterial inflow and runoff as well as venous outflow, (2) duplex sonographic evaluation of the bypass graft, (3) duplex sonographic evaluation of the fistula/shunt, and (4) physiologic testing of flows to the hand and digits. Based on the knowledge of the pathophysiology of steal and the configuration of the DRIL reconstruction, a complete and accurate evaluation can be performed with confidence.

Key words: dialysis access, vascular steal, DRIL procedure

The incidence and prevalence of end-stage renal disease (ESRD) continues to grow, even as treatments improve. The number of patients undergoing hemodialysis each year has grown to almost 350,000, an almost three-fold increase from 1988.¹ The annual cost of hemodialysis and maintenance
of dialysis access now exceeds $30 billion in the United States alone. To combat some of these problems, the Kidney Disease Outcomes Quality Initiative (KDOQI) has been implemented to increase the use of autologous fistulae for dialysis access compared to shunts, which have a higher early failure rate. With a typical time to failure (thrombosis) of only 18 months for a dialysis access shunt, shunt revision has become one of the most common surgical procedures done in the United States. Other complications that may lead to access failure include inadequate flow, aneurysm formation, infection, and vascular steal. This article focuses on the treatment of vascular steal phenomenon, an infrequent but often debilitating complication of dialysis access placement, and a specific management technique called distal revascularization–interval ligation or the DRIL procedure.

**Steal Syndrome**

It has been reported that some degree of hemodynamic steal results in up to 80% of cases following placement of dialysis access. However, it is only considered clinically significant when the patient is symptomatic, which occurs in only 6% to 8% of cases. Symptoms are similar to those reported with arterial ischemic disease: hand pain, pallor, paresthesia, weakness, and, in severe cases, ulceration, gangrene, or ischemic neuropathy.

Steal syndrome is the result of a direct artery-to-vein communication after the placement of an arteriovenous bridge graft (shunt) or creation of an arteriovenous fistula (AVF). The key to understanding the underlying mechanism of a steal is Poiseuille’s law, which states that flow resistance is inversely related to the fourth power of vessel lumen radius: Resistance $\propto \eta \times L/r^4$. When an arteriovenous fistula is placed in the arm for dialysis access, the resistance to runoff into the hand created by the microvasculature of the digits is orders of magnitude greater than the venous outflow resistance of the relatively large diameter fistula and axillo-subclavian venous system. In favorable situations, collateral flows or increased flow in the ulnar artery to the hand, for example, can compensate for a steal caused by a radio-cephalic (Cimino) wrist fistula. However, for a brachial artery to basilic vein fistula, there is often no adequate source of collateral or compensatory flow, and a steal is more likely to be clinically significant in this case. Also, diabetic patients often have calcified arteries and are unable to achieve adequate proximal dilation to provide increased flow through the fistula and maintain antegrade flow to the hand.

Prior to any treatment, the diagnosis of a clinically significant steal can be made as part of a noninvasive vascular evaluation of the dialysis access when the patient reports any of the previously described symptoms. A duplex sonographic examination should include a complete evaluation of (1) arterial inflow to the fistula or shunt to detect any underlying obstructive disease and to ensure adequacy of inflow, (2) the access conduit, and (3) the arterial outflow in the native artery and hand distal to the arterial anastomosis of the access. Particular attention must be paid to flow direction at this site; flow reversal away from the hand and toward the arterial anastomosis is indicative of hemodynamic steal. Additional physiologic testing using photoplethysmography (PPG) is done to evaluate perfusion to the digits, including waveforms at rest, resting digit systolic pressure, and changes in the flow waveforms and digit pressures during manual compression of the fistula or shunt. During access compression, significant increases in waveform amplitude should be seen in patients with steal, and digit systolic pressures should increase to normal readings.

**Treatment of Steal**

After diagnosis of a clinically significant steal syndrome based on a patient’s symptomatic presentation, a complete physical examination, and appropriate noninvasive testing as described above, attention is turned to the decision for treatment. One method to increase the flow resistance through the access is to decrease the cross-sectional diameter of the arterial anastomosis, encouraging distal perfusion to the hand. This can be accomplished by one of several procedures. One method is to place a band around the access arterial limb and gradually tighten it until optimal flow is obtained. Another is
clipping, which uses clips to reduce the anastomotic diameter. Plication is similar to clipping but uses sutures to reduce the diameter. An interposition graft, with a smaller diameter or tapered segment, can be placed between the donor artery anastomotic site and the venous outflow vessel (AVF) or the proximal graft (shunt). In more severe cases, the AVF or shunt can be ligated and a new site for access placement used.

An additional option for managing a steal is the distal revascularization–interval ligation (DRIL) procedure (Figures 1 and 2). First described by Schanzer et al. in 1988, this is a more complex treatment method but has been associated with favorable access patency rates and symptom alleviation. This procedure uses a small-diameter bypass graft beginning 5 cm proximal to the arterial anastomotic site and extends just distal to the arterial anastomotic site. The native artery is ligated just distal to the access but proximal to the distal bypass graft anastomosis. The bypass graft maintains antegrade blood flow to the hand while maintaining the functioning dialysis access; the ligature addresses steal by the access by preventing blood flow reversal from the affected hand.

The conduit of choice for the DRIL is a segment of the reversed great saphenous vein; however, depending on availability, other conduits such as the cephalic vein, polytetrafluoroethylene (PTFE) or Dacron grafts, or cryopreserved vein can be used. The DRIL procedure can be performed for patients with either an arteriovenous fistula or an arteriovenous graft.

Noninvasive Assessment of DRIL Procedures

The first step in evaluating a patient after an intervention with which the sonographer may not be familiar is to review the operative notes. If the operative notes are not available, a thorough physical examination of the involved extremity will often provide enough anatomic data on surgical sites to
get the examination started. The fistula or shunt itself is typically very superficial and readily seen at its site in the forearm or upper arm. If the access is functioning properly, there should be a palpable thrill at that site. The site of the access will also indicate which artery is used for inflow; if the site is the distal upper arm, the brachial artery likely has been used, and if the site is in the forearm, the radial artery has been used. Venous outflow is typically superficial near the site of access and should be readily visible on inspection.

To accurately evaluate a DRIL reconstruction used to treat a steal syndrome, one must have an organized protocol. The added complexity in this case is that a complete evaluation of a DRIL procedure involves multiple separate studies, using direct duplex sonographic examination and physiologic testing to evaluate digital perfusion, that have been combined into one. The easiest way to approach this study is to divide it into more easily managed segments: (1) duplex sonographic evaluation of the arterial inflow and runoff and of the venous outflow, (2) duplex sonographic evaluation of the bypass graft, (3) duplex sonographic evaluation of the fistula/shunt, and (4) physiologic testing of flows to the hand and digits. A summary of a typical evaluation protocol is shown in Table 1.

### Duplex Sonographic Evaluation Protocol for DRIL

#### INFLOW/OUTFLOW

The standard sites for examination of arterial inflow and runoff typically include the subclavian, axillary, brachial, radial, and ulnar arteries and may possibly include the palmar arch. Arterial inflow proximal to the DRIL procedure site, typically in the brachial or radial artery, should be strongly hyperemic with significant sustained diastolic flow, as shown in Figure 3. Decreased diastolic flow velocities are almost always indicative of significant obstruction involving the access, and the site of this obstruction must be identified and documented. When evaluating a DRIL, one must remember that the patient has a known history of steal, which means retrograde flow away from the hand; therefore, it is imperative to maintain proper angles for Doppler flow measurements and carefully document the direction of flow (Figure 4). Immediate venous outflow typically involves the cephalic or basilic vein and also should have a

<table>
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<th>TABLE 1. Typical Protocol for Distal Revascularization–Interval Ligation Procedure Evaluation</th>
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<td>1. Arterial inflow and runoff; venous outflow (duplex sonography)</td>
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<tr>
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![FIGURE 3. Doppler spectral waveform in inflow (radial) artery proximal to bypass graft (BPG).](http://jdm.sagepub.com/)

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BYPASS GRAFT EVALUATION

Duplex sonographic evaluation of the bypass graft is similar to evaluating any other bypass graft, paying attention to the anastomotic sites along with surveillance of the entire graft length to evaluate for any possible obstruction or other graft abnormalities (Figure 5). Peak systolic velocities at the anastomotic sites may be mildly elevated compared to the graft itself, a normal finding, but a focal doubling or more of peak systolic velocity within the graft should be considered indicative of a greater than 50% diameter reduction.

DIALYSIS ACCESS EVALUATION

The third part of the study is direct duplex sonographic evaluation of the fistula/shunt. This can be done using a standardized laboratory testing protocol, again paying particular attention to anastomotic sites and including a measurement of volume flow. The segment of arterial inflow between the bypass graft proximal anastomosis and the access site should be carefully evaluated to document strong hyperemic flow signals (Figure 6). Typical peak systolic inflow velocities at this site for a properly functioning access will range from 150 to 300 cm/s, with end-diastolic velocities ranging anywhere from 60 to 200 cm/s; turbulent flow signals are normally seen with marked spectral broadening throughout the cardiac cycle. This is also the best site for volume flow measurements if the access is a fistula because it typically is a relatively straight, constant diameter vessel segment, unlike the venous outflow side, which is likely tortuous and widely variable in lumen diameter. If the access procedure involves a shunt, volume flow measurements are best taken at a site near mid-shunt, where no pathologic changes are seen. As with any Doppler measurement, proper angle correction (parallel to the vessel walls) is necessary and the sample volume size adjusted to span from one vessel wall to the other. Doppler gain and scale should be adjusted to give a relatively noise-free waveform (Figure 6), which will allow the most accurate calculation of mean velocity. Vessel lumen diameter must be measured at the site where the sample volume was placed.

Because of variability in volume flow measurements, it is best to take an average of three successive measurements. Volume flow for a properly functioning access is typically greater than 600 to 800 mL/min. Volume flows less than 400 to 500 mL/min are worrisome and indicative of a poorly functioning access and likely short-term failure/thrombosis. Direct evaluation of the fistula/
shunt should also be done looking for any evidence of stenosis characterized by a significant focal increase (greater than two- to three-fold) in peak systolic velocity.

Plethysmographic Evaluation of Digital Perfusion

The final step is physiologic testing of the hand and digits, using PPG sensors to evaluate distal perfusion to the fingers with and without graft compression. A successful DRIL procedure will have restored digit PPG waveforms to nearly normal amplitude; there may be a small residual component of hemodynamic steal, which is no longer of clinical significance, causing a slight decrease in PPG waveform amplitude compared to the opposite hand. During manual compression of the access, obstructing the pathway for the residual hemodynamic steal, there will likely be a slight increase in PPG waveform amplitude, although not nearly the magnitude seen prior to the DRIL procedure (Figure 7). Likewise, digit systolic pressures will show little change during access compression (Figure 8).

Discussion

The number of patients undergoing hemodialysis has increased dramatically in the past 30 years, almost seven-fold from 1978. As more patients have hemodialysis access procedures, more complications will follow, resulting in additional surgical and endovascular revisions such as the DRIL procedure, now used widely to treat clinically significant steal. Because many of the access failures occur relatively early, these patients require frequent follow-up with surveillance studies every three months for the first two years. Because sonographers are
responsible for evaluating these reconstructions, it is important to understand the anatomy and hemodynamics. It is important to understand exactly what procedure was done, using the operative notes as a reference whenever possible and performing a good physical examination, and to have an organized noninvasive testing protocol. When evaluating a DRIL in a patient with known history of steal, a clear depiction of flow directions is imperative. From this knowledge of the pathophysiology of steal and the configuration of the DRIL reconstruction, a complete and accurate evaluation can be performed with confidence.

References