

## EDUCATIONAL ARTICLE

# Strategies for Predicting and Treating Access Induced Ischemic Steal Syndrome

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*Access induced ischemia is an uncommon but devastating complication for patients maintained on hemodialysis. A number of clinical risk factors have been identified to select patients at risk. Intraoperative measurement of the digital–brachial index may further distinguish at-risk patients when the DBI is <0.45. Once clinically significant steal has developed, surgical strategies to treat this problem should ideally reverse the ischemia while maintaining uninterrupted access for hemodialysis. To date, the distal revascularization–interval ligation or DRIL procedure has been the most consistently successful tactic in achieving these dual objectives. A number of alternative strategies have recently been proposed and will be discussed.*

*Keywords: Hemodialysis complications; Ischemia.*

### Introduction

As the number of patients maintained on hemodialysis increases, our healthcare system is faced with increasing expenditures for access related complications. The most common problem encountered is access failure or thrombosis. Access related ischemia is a far less common problem, but presents a significant challenge to clinicians caring for end-stage renal disease (ESRD) patients.

The following discussion reviews the topic of access related ischemia. The first section evaluates attempts to identify patients at risk with intraoperative measurements of digital perfusion. The second section examines options to treat access-induced ischemia with emphasis on our experience with the use of distal revascularization/interval ligation, also known as the DRIL procedure.

### Identifying Patients at Risk for Access Related Ischemia

Although some degree of steal occurs with all arteriovenous fistulas, the incidence of significant steal requiring fistula takedown, revision or extremity revascularization to prevent ischemic tissue loss ranges from 1 to 10%.<sup>1</sup> Schanzer *et al.* reported that significant steal occurs in approximately 1% of arteriovenous (AV) fistulas and 2.7–4.3% of arteriovenous grafts.<sup>2</sup> Steal syndrome complicating hemodialysis access has been extensively studied and the treatment options that restore distal circulation and maintain fistula patency are now well known.<sup>3,4</sup> Identifying immediate ischemic steal at the time of fistula construction should be obvious by the findings of a cool, pale hand without wrist or palm Doppler signals or flat digital blood pressure phlethysmography and low digital–brachial indices (DBI).

Noninvasive testing of digital blood pressures at the time of fistula construction may give an accurate assessment of the degree of extremity steal from a functioning AV fistula.<sup>5</sup> Goff *et al.* reported that a follow-up DBI less than 0.6 may identify patients at risk for steal, but intraoperative DBI cannot be used to predict which patients will develop steal.<sup>6</sup> Whilst a wide range of DBI's may be tolerable in patients

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undergoing fistula construction, certain risk factors and graft configurations may predispose these patients to debilitating or limb threatening steal.

In an effort to identify patients who develop significant steal after AV access construction we performed a prospective evaluation of extremity perfusion on 100 consecutive new AV access fistulas and grafts over a 12-month period. Photoplethysmography was utilized to obtain intraoperative measurements of digital blood pressure before and after access construction, and with and without access compression in a separate follow-up visit (Fig. 1). The digital pressures measured were used in conjunction with the contralateral brachial blood pressure to calculate the digital-brachial index (DBI). Digital pressures were obtained from the third (middle) finger using a digital pneumatic cuff 1.2× the diameter of the finger attached to a hand held sphygmomanometer. Photoplethysmography was performed with a sterile finger pulse-oximeter probe recorded on a standard hemodynamic monitor. Patients were followed for the development of ischemic symptoms in the ipsilateral hand. Seventeen patients (17%) developed some element of steal; 6 (6%) of whom required revascularization for critical extremity ischemia. Steal was more common in females (34%) versus males (2.5%) ( $p < 0.01$ ). A wide range of intraoperative DBI's was noted at the time of fistula construction (0.10–1.1). Intraoperative DBI at the time of access surgery with the fistula open was significantly lower in patients who went on to experience steal ( $0.47 \pm 0.21$ ) compared to those who were symptom free ( $0.62 \pm 0.25$ ) ( $p = 0.027$ ). This difference was preserved in the 42 patients who had follow-up outpatient testing. There was not a significant difference, however, in DBI between patients with mild steal ( $0.52 \pm 0.24$ ) and those



**Fig. 1.** Intraoperative measurement of digital pressure to calculate digital-brachial index.

with severe steal ( $0.42 \pm 0.17$ ) ( $p = 0.37$ ). Receiver operator characteristic analysis of intraoperative DBI was most predictive of steal at a DBI value of 0.45 with a sensitivity, specificity, positive and negative predictive values of 80, 70, 30 and 97%, respectively (Table 1).<sup>7</sup> The most striking result was the marked incidence of severe steal noted in female patients with intraoperative DBI's of  $< 0.45$  at the time of upper arm arteriovenous loop graft placement (68%).

The wide range of digital-brachial pressure indices observed further supports the multifactorial nature of steal. The hemodynamics of steal are well described and comprise the complex interaction of high flow into a low resistance vein, reversal of flow away from the higher resistance distal arterial bed, and competing distal circulatory autoregulation which is dependent upon adequate collateral blood flow to the distal extremity.<sup>8</sup> Some degree of asymptomatic steal is expected in nearly all fistulas, with reversal of flow noted in the artery distal to the fistula and decreased finger pressures noted in the majority of patients during follow up.<sup>8–10</sup>

Few studies have employed intraoperative techniques to evaluate the hemodynamic effects of the fistula on the distal circulation.<sup>11</sup> Goff *et al.*, in their retrospective review and prospective measurement of DBI's at the time of fistula construction, reported a DBI of  $< 0.6$  as being the most sensitive predictor of steal with a specificity and positive predictive value (PPV) of 59 and 18%, respectively.<sup>6</sup> Similarly, we observed a specificity and PPV of 43 and 21%, respectively, for a DBI threshold of 0.6. However, our data suggests a DBI of 0.45 to be a more accurate predictor of significant steal (sensitivity 80%, specificity 70%; Table 1). Unfortunately, a relatively low PPV is obtained for a wide range of intraoperative DBI levels as many patients can tolerate low finger perfusion and remain asymptomatic. One-half of patients had asymptomatic DBI  $< 0.6$  and 25% of patients had asymptomatic DBI's  $< 0.45$ .

As described, DBI's are easy to obtain at the time of fistula construction and when normal, their high specificity assures the surgeon the distal circulation is intact. However, when DBI's are low, a high index of suspicion and close follow up are indicated to identify which patients will require intervention to

**Table 1.** Results of intraoperative digital-brachial indices

DBI	0.2	0.3	0.35	0.4	0.45	0.5	0.6	0.7
Sensitivity	0	.33	.40	.60	.80	.87	.94	.94
Specificity	.96	.88	.83	.77	.70	.64	.43	.34
PPV	0	.33	.27	.29	.30	.28	.21	.19
NPV	.86	.88	.90	.92	.97	.97	.98	.97

DBI, digital-brachial index; PPV, positive predictive value; NPV, negative predictive value.

prevent permanent ischemic damage and possible tissue loss. Our data is in agreement with most authors who speculate certain risk factors such as female gender and origin of the AV fistula from the proximal brachial artery may predispose patients to a higher risk of ischemic steal.<sup>3,12,13</sup> Moreover, significant steal was noted in 36% of female patients undergoing construction of an upper arm brachio-axillary bridge graft. Even more striking is the 67% incidence of severe steal in female patients undergoing upper arm AV grafts with intraoperative DBI <0.45.

There are several alternatives available to the access surgeon when low intraoperative DBI's suggest significant steal. If Doppler signals are obtainable at the wrist and palm, one can simply observe the patient closely in the postoperative period for development of steal symptoms with intervention indicated if significant symptoms develop. If no Doppler signals are obtainable at the wrist and palm at the time of access construction, the following steps should be taken: (1) optimize patient hemodynamics and environmental temperature, (2) if (1) fails to return perfusion to the hand than the surgeon could either attempt to band down the fistula while checking fistula and distal arterial signals, with a goal DBI of >0.45 or (3) obtain intraoperative arteriography and perform distal revascularization—interval ligation (DRIL) at the time of fistula construction to relieve ischemia.<sup>3,10,11,14–16</sup>

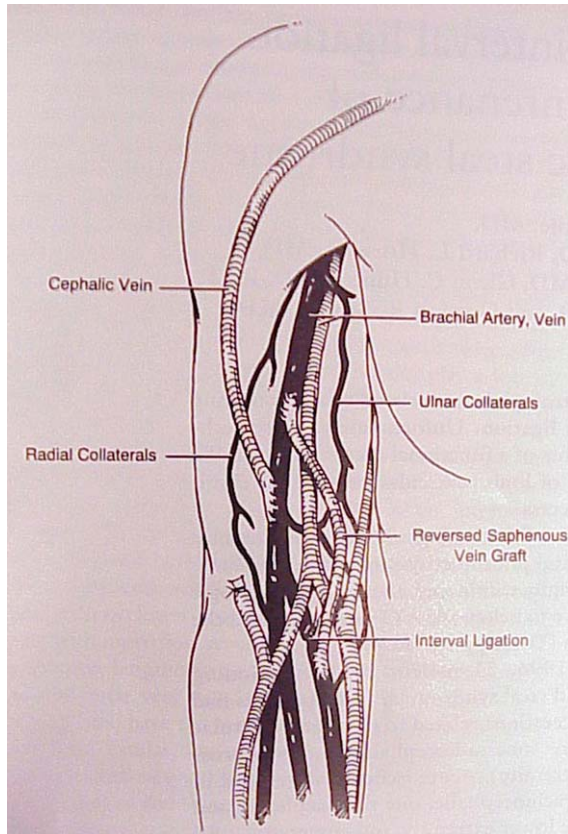
### Treatment of Access Related Ischemia

It is estimated that approximately 80% of patients with a functional AV access will demonstrate physiologic steal (i.e. a demonstrable reduction in distal perfusion pressure). Lazarides and associates<sup>17</sup> prospectively measured SPI (systolic pressure index = systolic forearm pressure in the index arm distal to AV fistula divided by the contralateral arm systolic pressure) in 69 consecutive patients. Ninety-four percent of these patients had SPI < 0.8, and the mean SPI 24 h following fistula creation was 0.55. The vast majority of these patients were asymptomatic, however, and by 11 months postfistula creation, the mean SPI had risen to 0.74. This gradual improvement in SPI is due to compensatory distal arterial vasodilation and to the progressive development of a rich arterial collateral network around the fistula. A large AV fistula is a most potent stimulus for such collateral arterial development. Physiologic steal is usually compensated by multiple mechanisms including the development of abundant arterial collaterals and distal vasodilatation. However, if these mechanisms are

insufficient to maintain adequate distal perfusion pressure, the patient develops clinically significant steal which occurs in only 6–8% of hemodialysis patients.<sup>4,6,9</sup>

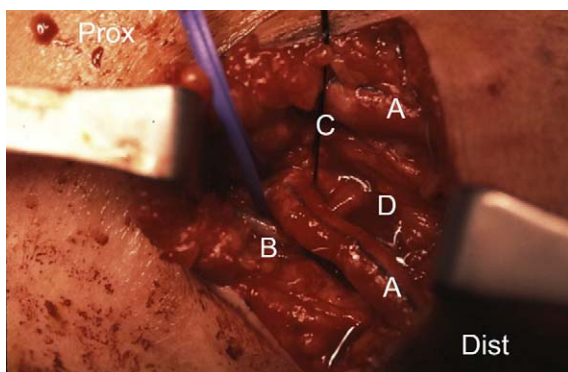
Evaluating patients with clinically significant steal begins with a simple physical examination. Often, in patients harboring severe ischemic pain, simple compression of the access will immediately bring relief and verify the diagnosis. Doppler studies are helpful to confirm the diagnosis. Digital pressures are performed with and without access compression. Though absolute values of digital pressures seen with steal have a broad range, patients tend to have a significant drop in digital pressure with the access open. Moreover, manual occlusion of the access should normalize the digital pressure or DBI. A DBI of less than 0.45 would be considered significant. Duplex imaging may be helpful in excluding any inflow lesions in the axillary, subclavian or brachial inflow arteries. However, we perform angiography on all patients either prior to or at the time of revascularization to document patency of the inflow arteries from the arch vessels to the access. This affords the opportunity to treat inflow lesions, usually with balloon angioplasty and stenting.

We have had considerable long-term experience with the use of the DRIL procedure, as originally described by Schanzer, to address this difficult problem.<sup>3,14–16</sup> A retrospective review was conducted of patients undergoing the DRIL procedure at our institutions in Tucson, Arizona.<sup>15</sup> Performance of the DRIL procedure was similar to that described originally by Schanzer *et al.* and subsequently reported by Berman *et al.*<sup>3,15</sup> Briefly, a bypass constructed of reversed autogenous vein is anastomosed to the brachial artery (Fig. 2). This graft is then anastomosed distally in the forearm to either the brachial, radial or ulnar artery. The recipient artery is then ligated just proximal to the distal bypass anastomosis to eliminate direct retrograde flow towards the fistula (Fig. 3). Between January 1995 and May 2001, 1138 primary hemodialysis access procedures were placed in 599 men and 539 women of which 55 DRIL procedures were performed in 52 patients for an overall incidence of significant steal of 4.6% in this retrospective review. The indications for the DRIL procedure included 27 patients (52%) with rest pain, 20 patients (38%) with tissue loss, four patients (8%) with loss of neurologic function and one (2%) with persistent pain during dialysis treatments. DRIL was performed in over twice as many women as men, and Hispanic women comprised the largest subgroup of patients, accounting for 42% of the entire series. In fact, the incidence of ischemic steal syndrome in our series by sex is 2.8% in



**Fig. 2.** Diagram of the distal revascularization-interval ligation procedure.

men and 6.5% in women. Women were statistically more likely than men to have rest pain as the indication for the DRIL ( $p = 0.04$ , Chi square = 8.1); 60% of women suffered from rest pain compared to only 35% of men. The primary indication for DRIL in men was tissue necrosis (59%).



**Fig. 3.** Intraoperative photo of the DRIL procedure to correct steal in a brachial PTFE forearm loop. The distal revascularization bypass (B) is visible under the access graft (A); silk suture marks the site of ligation (C).

The index access procedure resulting in the steal syndrome included 19 (36.5%) brachiocephalic AV fistulae, 19 (36.5%) upper arm AV bridge grafts, 12 (23%) forearm AV grafts, and two (4%) basilic vein transposition AV fistulae. Three of the 19 upper arm bridge grafts were constructed using 4–7 mm tapered ePTFE grafts. All these fistulae were based on brachial arterial inflow. The DRIL procedure successfully alleviated ischemic symptoms in 47 of 52 patients (90%). In three patients, the DRIL failed to adequately resolve the ischemia and access ligation was required. In three other patients, a second DRIL procedure was successfully performed after the first DRIL failed due to graft thrombosis. These patients all developed recurrent symptoms marked by rest pain. Following repeat bypass, these three patients had resolution of their symptoms. Primary patency of the initial DRIL procedure in these three latter patients was 8.7 months. In two patients, no improvement in symptoms was seen, but access ligation was not required. These patients were felt to no longer have symptoms related to steal, but rather due to ischemic monomelic neuropathy. Postoperative noninvasive testing that demonstrated pulsatile digital arterial waveforms, significant improvement in digital pressures, and abnormal nerve conduction studies, supported this diagnosis. The primary life-table patency of the index access procedure causing the ischemic steal syndrome was 83% at 12 months and 71% at 36 months. The primary patency of the DRIL procedure by life-table methods was 86% at 12 months and 80% at 48 months. Life-table patient survival was 86% at 12 months and 56% at 48 months.

Once severe steal has been identified in the outpatient setting, a number of options for treatment have been proposed. Ligation of the AV access universally eliminates the ischemia problem, but with a significant penalty: loss of the access. Ligation does have a role to play in access-induced ischemia though in a limited, defined circumstance. When severe ischemia occurs distal to a radiocephalic AV fistula at the wrist, ligation of the distal radial artery effectively eliminates the steal without adversely impacting the access. In our own experience, this technique has been used on only two occasions (not included in this series) with complete relief of ischemia.

Another technique designed to treat access-induced ischemia is banding of the access (Fig. 4). Banding is based upon the premise that increasing fistula resistance will indirectly increase perfusion to the extremity distal to the fistula origin. The reported clinical experience with banding has been mixed, but generally poor. A number of authors have recently promoted the use of intraoperative perfusion measurements during the banding procedure to quantify

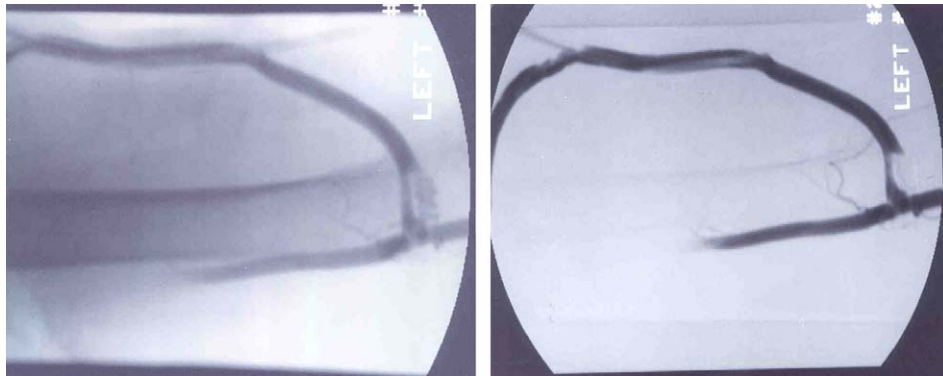


Fig. 4. Intraoperative banding technique using hemoclips to increase resistance through the access graft.

the degree of banding required to achieve the delicate balance.<sup>18,19</sup> Odland recently reported a series of patients treated with banding using intraoperative photoplethysmography.<sup>18</sup> Using this strategy they achieved access patency of 62.5% at 6 months and 38.5% at 12 months. In a review by DeCaprio *et al.* of all patients presenting with steal syndrome over a 3-year period, banding was used in 11 of 18 patients with all but one fistula occluding within 6 months of banding.<sup>12</sup>

The concept of treating significant access-induced ischemia with a bypass graft and ligation of the artery between the fistula and the bypass was first reported by Schanzer *et al.* in 1988 in three patients followed by 14 patients in 1992, and 23 patients in 1996.<sup>14,20,21</sup> In the 1996 series, he demonstrated improvement in all 23 patients undergoing the DRIL procedure with a bypass patency rate of 95.6% at 2 years. Unfortunately, despite these reports of near universal success in relieving the ischemia and maintaining access patency, this technique still received little recognition. Katz and Kohl subsequently published a small series of six patients treated with revascularization and ligation with similar success.<sup>16</sup> The premise behind the procedure is simple, elegant, and physiologically sound. In a recent prospective study, Illig *et al.* used intraoperative measurements of pressure and flow at the time of DRIL to determine the impact of the operation on access flow.<sup>22</sup> They determined that the increase in flow to the forearm, as a result of the DRIL, was due to increase pressure at the point where flow splits to supply the forearm and the access. This increase in pressure at the 'split point' is secondary to a relative increase in resistance through the artery supplying the access.

In 1994, we published what was then the largest series of patients undergoing this procedure.<sup>3</sup> In that report, we coined the acronym DRIL to describe the critical components of the procedure. Since that

publication the awareness of the DRIL procedure as a superior alternative to banding or ligation has become evident. However, what was lacking both in our previous report and those of other investigators, was long-term data regarding the durability of the DRIL procedure in both relieving the ischemia and maintaining access patency. Our most recent study not only provides the largest reported experience to date with the DRIL procedure, but also establishes the durability of the technique in fulfilling the dual challenges of access-induced ischemic steal syndrome.<sup>15</sup> In that report, 47 of 52 (90%) patients demonstrated significant or complete symptomatic improvement. All patients with tissue loss have healed or are currently healing their lesions. Moreover, prosthetic AV grafts have a reported 12-month primary patency of 40–50% with native AV fistulas achieving a primary patency of 80% at 12 months.<sup>23,24</sup> However, in our most recent report, the 12-month actuarial primary patency of prosthetic AV grafts was nearly 85%.<sup>15</sup> The superior AV graft patency in this subgroup of patients is likely due to selection bias. With a 48-month primary patency of 80%, the DRIL procedure, therefore, reliably improved distal perfusion without sacrificing significant fistula blood flow.

A number of alternative strategies have been proposed to treat access-induced ischemia caused by brachial-based AV grafts and fistulas that similarly increase forearm flow while preserving the access. One such alternative has been given the acronym RUDI, which stands for revision using distal insertion (Fig. 5). This procedure is accomplished by ligating the arterial end of the access and revising the access inflow using an interposition graft to either the radial or ulnar artery. A small series of four RUDI procedures were recently published by Minion *et al.* demonstrating successful alleviation of ischemia.<sup>25</sup> The authors suggested that one significant advantage of RUDI is that native forearm and hand perfusion is

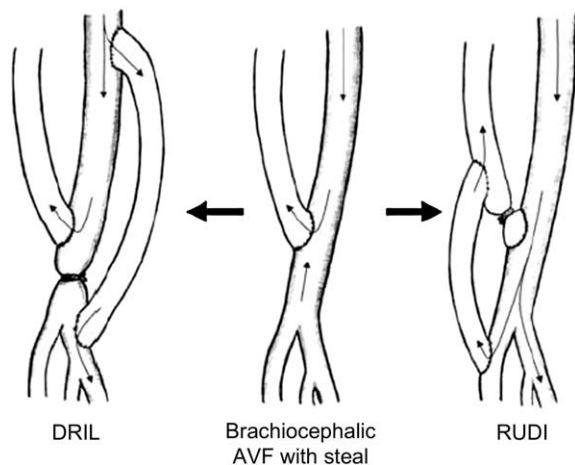


Fig. 5. Diagram of the revision using distal insertion technique.

undisturbed and only the access is placed in jeopardy. Using a similar strategy, Ehsan *et al.* published a series of 32 autologous fistulas in patients considered high risk for steal.<sup>26</sup> Dubbed the 'Extension technique', this approach comprises the anastomosis of the median vein to either the radial or the ulnar artery thereby preserving part of the direct blood supply to the hand. By contrast, with DRIL the forearm and hand are vulnerable by being dependent upon the bypass graft remaining patent. To date, limb ischemia from bypass failure subsequent to the DRIL procedure has not been reported. Another approach to treat ischemia touted by Gradman and Pozrikidis is to move the arterial anastomosis of an upper arm AV graft or fistula from the brachial artery to the axillary artery creating an upper arm loop access.<sup>27</sup> Similar to the RUDI procedure, this increases the flow to the forearm by increasing the pressure at the point where flows is split between the arm and the access. Though this concept is supported by the mathematical model reported by Gradman limited clinical experience exists with this approach. Moreover, in the experimental flow model reported by Gradman, DRIL had the greatest increase in distal arm flow.<sup>27</sup>

### Summary

- Significant access induced ischemia uncommon; occurs in 6% of all accesses.
- Intraoperative digital-brachial index <0.45 may identify high risk patients undergoing brachial artery access.
- Successful treatment defined as:
  - Alleviating ischemia;
  - Preserving the access.

- Strategies all share similar physical principles:
  - DRIL;
  - RUDI;
  - Axillary loop.

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