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Arterial Pressure Gradient of Upper Extremity Arteriovenous Access Steal Syndrome: Treatment Implications

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Abstract

Purpose—Treatment options after arteriovenous fistula(AVF) associated steal include: ligation, banding, and distal revascularization-interval ligation(DRIL). The purpose of this study was to evaluate arterial pressure gradients in upper extremity steal syndrome.

Methods—Pre-operative arteriography and sequential intra-arterial pressure readings were performed on consecutive AVF patients with hand ischemia. Analysis of variance(ANOVA) with repeated measures analyzed inter-subject comparisons, and post-hoc analysis identified anatomic locations with highest inflow pressures.

Results—Nine patients presented with ischemic hand symptoms after AVF. Pullback arterial pressure measurements revealed gradual increases in systolic and mean pressures as the catheter position was moved proximally from the AVF anastomosis. Post-hoc analysis after ANOVA revealed higher axillary artery systolic pressure compared to proximal brachial artery(153vs116.8,p=0.007).

Conclusion—AVF-related steal syndrome decreases arterial inflow pressure of the affected extremity more proximally than previously thought. When performing a DRIL procedure, consideration should be given to placing the anastomosis as proximally as possible.

INTRODUCTION

Dialysis access is the most frequently performed operation by vascular surgeons. Development of a steal syndrome secondary to brachial artery-based arteriovenous fistulas (AVF) remains a difficult to treat access complication. Clinically significant steal occurs in 5-10% of patients undergoing a brachial artery-based fistula.^{1, 2} Treatment options for a steal syndrome include: ligation, banding, plication, and distal revascularization-interval ligation (DRIL).³⁻⁵ The DRIL procedure has the advantage of preserving uncompromised fistula flow. Despite achieving success in 78-90% of patients, the reasons for its failures have not been well elucidated.^{6, 7} This study tested the hypothesis that the arterial pressure sink created by a functioning AVF may affect the brachial artery more proximally than previously thought.

MATERIALS AND METHODS

Nine consecutive patients with a brachial artery-based AVF and arteriovenous steal syndrome were prospectively enrolled in the study. After informed consent, all patients underwent arteriography. The angiograms were performed via a retrograde femoral artery approach. A 5 French sheath was placed and through that a pigtail catheter was advanced to the aortic arch and aortography was performed. In most instances a Weinberg catheter (Angiodynamics, Inc., Queensbury, New York) and Roadrunner guide wire (Cook, Inc. Bloomington, Indiana) were used to select the appropriate subclavian artery. An arteriogram and fistulogram were first performed. Manual compression of the fistula was utilized in order to get adequate run off views of the forearm and hand vessels.

The Weinberg catheter was then exchanged over a Rosen guide wire (Cook, Inc., Bloomington, Indiana) for a 120cm end hole straight red catheter (Cook Inc., Bloomington, Indiana). This was manipulated distal to the arteriovenous access anastomosis in the brachial artery. This catheter was then attached to a pressure transducer (PX260, Edwards Lifesciences LLC, Irvine, CA). Systolic and mean pressures were then recorded at the following anatomic locations: distal to the anastomosis, immediately proximal to the anastomosis, mid brachial artery, proximal brachial artery, axillary artery, and subclavian artery. All pressures were obtained with and without fistula compression. Once the pressures had been recorded the catheter was removed. Treatment of the steal syndrome was left to the discretion of the attending surgeon.

Analysis of Variance (ANOVA) with repeated measures was performed to identify significant pressure differences between the different anatomic locations, accounting for inter-subject variability. Post-hoc two-tailed student's tests compared the mean systolic pressure readings at each anatomic location to identify significant differences with respect to location. Sample size calculations were used to identify the number of patients needed to detect a significant difference in pressure readings with a power of 0.8. All statistical calculations were performed with STATA v9.0 (StataCorp, College Station, Texas).

RESULTS

Nine patients with a mean age of 59 years (range 38 – 76) presented after placement of an antecubital-based AVF. Eight (89%) patients had hypertension and seven (78%) had diabetes mellitus. Etiology of the chronic kidney disease was either hypertension, diabetes or a combination of the two in all patients. Six patients had been on dialysis for less than 26 months; in one patient hemodialysis had not yet commenced. Two patients were dialysis veterans having started 9 and 29 years ago. The interval between AVF placement and presentation with steal syndrome ranged from 3 days to 20 months. Configuration of hemodialysis access in this series included: 6 autogenous brachial-cephalic upper arm direct access (3 left and 3 right), 2 prosthetic brachial-axillary (one left and one right), and 1 autogenous brachial-basilic upper arm transposition (right).⁸ The presenting symptoms included ischemic rest pain in all patients. Two patients were only affected while on dialysis while two others also had tissue necrosis involving the fingers.

Diagnostic arteriography revealed normal subclavian, axillary and brachial arteries in all patients. Intra-arterial pressures recorded utilizing the end hole catheter included systolic (Figure 1) and mean (Figure 2) pressures. A systolic pressure index for each location was calculated based on the highest intra-arterial pressure measured (Figure 3). For the entire group, the mean of the systolic pressure indices at each location is shown in Figure 4. Measurements showed a trend toward increasing value as the catheter was positioned more centrally. A plateau in either the absolute systolic pressures or the systolic pressure index

was not reached until the catheter had been withdrawn to the proximal brachial artery in two patients, axillary artery in five patients and the subclavian artery in two patients.

ANOVA with repeated measures revealed a significant difference in the systolic pressures among the nine subjects ($p < 0.001$). Post-hoc testing revealed mean systolic pressure in the axillary artery was significantly higher than the proximal brachial artery (153 vs 116, $p = 0.007$). Mean systolic pressure was higher in the proximal brachial artery compared to the mid-brachial artery (116 vs 90, $p < 0.001$). Post-hoc comparison of the remaining anatomic locations revealed no difference in systolic pressure. Sample size calculations determined 18 patients would be required to definitively detect a pressure difference at each location with a power of 0.8.

DISCUSSION

Dialysis access surgery has its frustrations. Up to 20% of usable high flow arteriovenous accesses are accompanied by a symptomatic steal.⁹⁻¹¹ Treatment of arteriovenous access steal syndrome has evolved over the last several decades. Originally, steal syndrome was treated by either ligation or banding of the fistula. The obvious problem with ligation is that another form of dialysis access must be created. Despite various modifications, banding continues to be challenging as the fistula must be restricted enough to relieve the symptoms, but also permit enough flow to maintain useful patency.¹²⁻¹⁴

In the steal syndrome, blood flow in the artery distal to the arteriovenous anastomosis is either diminished or even reversed. As has been reported, if the brachial artery distal to the fistula is ligated, and therefore, reversed blood flow stopped, symptoms of the steal syndrome may be ameliorated.¹⁵ However, if antegrade flow in the artery distal to the fistula is still present, albeit reduced, then ligation of the vessel without an accompanying bypass should worsen the distal ischemia.¹⁶ These are the patients that benefit most from a DRIL.

This novel solution to the problem was introduced in 1988 when Schanzer et al¹⁷ reported three cases of brachial-based arteriovenous steal syndrome treated by creating parallel, but separate arterial systems: one to supply the fistula and one to supply the distal extremity. In their described technique the bypass around the arteriovenous fistula began five centimeters proximal to the fistula anastomosis. They provided hemodynamic data that supported clinical improvement seen in all three patients. The arterial pressures improved, but had not returned to normal.

A follow-up publication from the same institution described successful outcomes in thirteen of fourteen patients.¹⁸ They attributed the continued ischemia in the fourteenth patient to progression of distal disease. Based on the data presented in this analysis it is possible that the brachial artery to brachial artery bypass in their patient with continued ischemia did not originate far enough proximally.

Katz et al subsequently reported on six patients, five of whom completely resolved their symptoms.¹⁹ Berman et al then added twenty-one cases of arteriovenous access steal successfully treated using the technique originally described by Schanzer.⁴ This group subsequently reported a larger series of DRIL procedures with complete or near complete success in 47 of 52 (90%) patients,² however only 15 of 20 (75%) patients with digital ischemic lesions had healed by the time of the report.

Although DRIL has radically changed the treatment of arteriovenous access steal syndrome, it has not been universally successful. As described by Wixon et al there exists a pressure sink in the brachial artery proximal to the arteriovenous anastomosis.²⁰ If the bypass around the arteriovenous access has its proximal anastomosis in a location where the brachial artery

pressure is compromised, then the success of the DRIL is uncertain. Illig et al. conducted a thorough study examining hemodynamic and flow changes that occur before and after performance of a DRIL procedure.²¹ They concluded that arterial hemodynamics improve significantly proximal and distal to the AVF after a DRIL. They did not report hemodynamic results in the axillary artery, however. This current study shows that the arterial pressure sink extends more proximally than previously presumed. In only two of nine patients did the pressure in the brachial artery significantly improve within the previously recommended five centimeters. In addition the pressure gradient continued to improve at least to the axillary artery in the other seven patients.

CONCLUSION

The DRIL procedure may be successful when utilizing the previously published technique. However, to achieve maximal hemodynamic improvement, consideration should be given to making the DRIL bypass originate more proximal than previously recommended.

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Figure 1.
Intra-arterial Systolic Measurements According to Anatomic Location

Figure 2.
Intra-arterial Mean Measurements According to Anatomic Location

Figure 3.
Systolic pressure index as ratio of measured systolic pressure to highest mean pressure

Figure 4.
Mean systolic pressure index for group