

# Flow interruption of the distal radial artery: treatment for finger ischemia in a matured radiocephalic AVF

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**Abstract: Purpose:** To establish an effective approach for diagnosis and treatment of hand ischemia in matured radiocephalic arteriovenous fistulae (AVF).

**Methods:** One hundred and fifty end-stage renal disease patients (4% of our practice) presented to our outpatient vascular access facility complaining of a range of symptoms including coldness, numbness and pain in the fingers indicative of ischemia due to steal syndrome. In 15 patients the symptoms of steal syndrome were limited to the fingers, sparing the hand. Physical examination was indicative of steal syndrome caused by shunting of blood from the ulnar artery via the palmar arch, away from the fingers and into the fistula. To confirm the diagnosis, angiography was performed which demonstrated retrograde flow in the distal radial artery (DRA), a hypertrophied palmar arch, and a patent hypertrophied ulnar artery. Ischemia was treated with DRA flow interruption. Transcatheter coil embolization of the DRA (10 patients) was preferred because it proved to be a quick, safe and effective technique. Whenever embolization was not possible ligation of the DRA was performed in accordance with accepted surgical literature (five patients).

**Results:** DRA flow interruption was effectively accomplished by either ligation or coil embolization in all cases. All patients had symptomatic improvement. Complete symptom resolution was experienced by 100% (10/10) of patients who received DRA embolization and by 3/5 patients who required ligation. The average follow-up period was 9 months. There were no complications during the procedure or during the follow-up period.

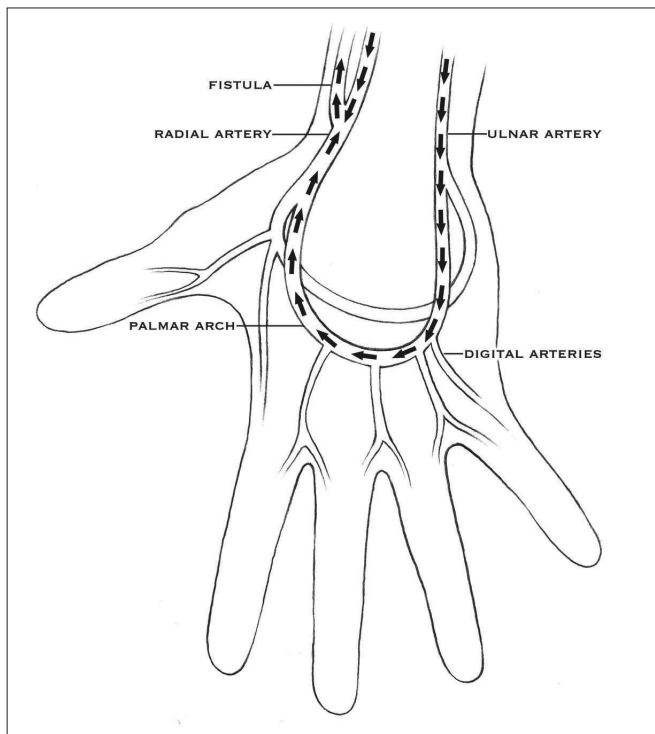
**Conclusion:** Diagnosis using physical examination, angiography and treatment with embolization or ligation of the DRA can be performed with great success in an outpatient setting. (J Vasc Access 2008; 9: 58-63)

**Key words:** Steal, Hand ischemia, Coil embolization, Radiocephalic fistula, Dialysis, Shunt

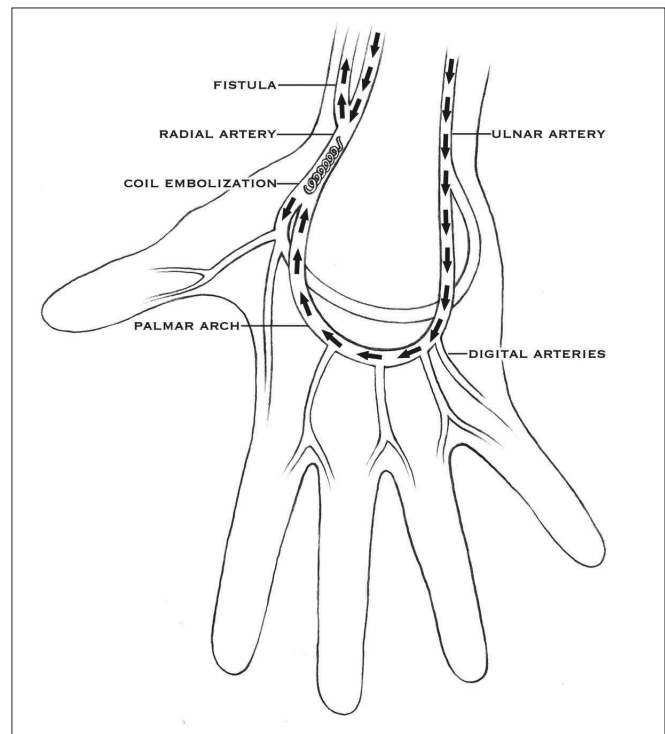
## INTRODUCTION

Dialysis associated steal syndrome (DASS) is a broad term referring to the diversion of blood into an arteriovenous fistula (AVF) or arteriovenous graft (AVG) which results in distal limb ischemia. The nature of an arteriovenous dialysis access is to shunt blood away from the normal circulatory anatomy. DASS is a clinical diagnosis with associated symptoms of hand numbness, coldness, pain (on and/or off dialysis), seldom with loss of function or tissue necrosis. True DASS refers to limb ischemia in the absence of angiographically identifiable arterial stenoses and classically appears in patients with an upper arm access (1-3).

The presence of steal syndrome in patients with a forearm AVF is less common and exhibits one of two distinct pathophysiologies. The blood can be stolen at the forearm arterial trifurcation away from the ulnar and interosseous arteries and into a hypertrophied radial artery flowing into the AVF leaving the hand deficient of arterial blood flow. This type of steal appears to occur in patients with diffuse arteriopathy (2, 3). The second scenario of vascular steal may result from shunting of blood from the ulnar artery towards the low-resistant arteriovenous access via a hypertrophied palmar arch and retrograde flow through the distal radial artery (DRA) away from the high-resistance digital arteries triggering distal hypoperfusion and peripheral ischemia (3, 4). The lat-



**Fig. 1a -** Characteristic blood flow of a patient with PASS. Due to the high resistance of the digit arteries and the low resistance of the fistula, blood flows towards the fistula and away from the digit arteries.



**Fig. 1b -** Ligation of the radial artery, which blocks retrograde flow in the DRA and promotes blood to flow to the digit arteries.

ter form of steal appears to occur in a fully matured, dilated AVF.

This paper presents a subset of steal syndrome that we will refer to as palmar arch shunt steal (PASS). It occurs in the most distal portion of the extremity macro-circulation and is presented in the setting of a forearm radiocephalic AVF, in the absence of arterial stenosis. This results in altered hand circulation in which flow travels the pathway of least resistance (towards the fistula) from both the radial and ulnar arteries (Fig. 1a). Flow from the radial artery follows a direct pathway to the fistula, while flow from the ulnar artery is shunted through the palmar arch and into the fistula, leaving minimal perfusion to the fingers. Hand ischemia related to retrograde flow in the DRA of a radiocephalic AVF has been documented as an acute complication following the creation of an access. When recognized it is treated with ligation of the DRA (5). However, cases of PASS physiology developing after the access has matured are not well documented. We address the proper diagnosis and treatment of hand ischemia in a matured forearm radiocephalic AVF. Once diagnosed through physical examination and angiography, PASS can then be treated in an outpatient setting by interrupting retrograde DRA flow with coil embolization or ligation (Fig. 1b).

## METHOD

Fifteen patients (Tab. I) were diagnosed with PASS. Examination included both a physical exam and an arteriogram. Physical findings included: 1) a warm palm with cold ischemic digits; 2) a prominent thrill palpable on the radial artery, distal to the arterial anastomosis; 3) DRA pulsation despite occlusion of the artery at the anastomosis (the pulse wave transmitted retrograde through the palmar arch from the ulnar artery indicates a widely patent shunt pathway); 4) the presence of a strong ulnar artery pulsation or thrill; 5) compression of the DRA resulting in improved perfusion of the fingers with ischemic symptoms going away in 2-3 min; and 6) a pulse oximeter on the second finger will demonstrate increased wave amplitude when the DRA is compressed.

If physical examination reveals possible PASS, an arteriogram is necessary to confirm the diagnosis. In all our cases the patients presented with acute on chronic steal symptoms. We felt immediate treatment to be necessary. Diagnostic angiography was performed with the intent to treat.

Access is gained in retrograde fashion toward the arterial limb of the fistula using an 18-gauge Angiocath (Terumo, Elkton, MD) which is upsized to a 6F vas-



**Fig. 2 - Arteriogram of a patient that illustrates the PASS phenomenon. There is hypertrophy of the palmar arch and atrophy of the digit arteries.**

cular sheath (Terumo, Elkton, MD). A 0.035 mm guidewire (Terumo, Somerset, NJ) in conjunction with a 4F Bern diagnostic catheter (Boston Scientific, Natick, MA) is advanced from the fistula through the radial artery and up to the brachial artery. A direct brachial artery puncture is not per-

formed in order to avoid bleeding and hematoma complications. Run-off angiography was performed from the brachial artery to the palmar arch in order to rule out a stenosis or occlusion of the ulnar artery as a cause for hand ischemia (Fig. 2). If the ulnar artery and palmar arch are patent, then the 4F diagnostic catheter is removed from the upper forearm arteries and is redirected into the palmar arch. Angiography is performed, and flow is visualized perfusing the palmar arch and then backing up into the fistula in a retrograde fashion through the DRA. Absence of antegrade flow in the DRA, absence of stenosis in the ulnar artery and lack of finger perfusion confirmed PASS.

In order to eliminate retrograde flow in the DRA, direct coil embolization is the preferred method (10 patients). Angiography is performed through a 4F catheter and the distance between the arterial anastomosis to the thenar artery is measured. If the distance is at least 3-4 cm, then deployment of two 5-3 mm Tornado coils (Cook, Bloomington, IN) can be performed safely into the DRA. Coil embolization (Fig. 3) is performed directly through an inflated over the wire (0.035 mm) fogarty catheter (Edwards Lifesciences, Irvine, CA) placed distally to the anastomosis, in the radial artery. External finger pressure was applied distally to the coil ensuring no coil migration in either direction during deployment. Direct fluoroscopic guidance is used during the entire procedure. A 4F diagnostic catheter is then utilized to perform post embolization imaging. Initially, flow slowed significantly.

**TABLE I**

Patient	Age	Sex	Co-morbid	Symptoms	Procedure	F/U duration	F/U
1	79	M	HTN	cold	DRA Coil	9 months	No Sx
2	65	F	HTN, DM	pain, numb	DRA Lig.	11 months	Cold, New Access
3	62	M	HTN	pain	DRA Lig.	17 months	Numb, Banding
4	48	M	DM	Cold	DRA Lig.	19 months	No Sx
5	68	F	HTN, DM	Numb	DRA Coil	4 months	No Sx
6	87	M	HTN	Pain, cold	DRA Coil	3 months	No Sx
7	52	M	HTN, DM	Cold	DRA Lig.	12 months	No Sx
8	64	F	HTN	Pain	DRA Lig.	32 months	No Sx
9	65	M	DM	Pain	DRA Coil	16 months	No Sx
10	89	F	HTN	Pain	DRA Coil	5 months	No Sx
11	41	M	HTN	Pain, Numb	DRA Coil	3 months	No Sx
12	61	M	HTN, DM	Numb	DRA Coil	2 months	No Sx
13	65	M	HTN	Cold, Numb	DRA Coil	6 weeks	No Sx
14	56	F	HTN	Cold	DRA Coil	1 month	No Sx
15	51	M	HTN	Cold	DRA Coil	1 week	No Sx

Lig. = Ligation; Sx = Symptoms; DRA = Distal Radial Artery; F/U = follow-up

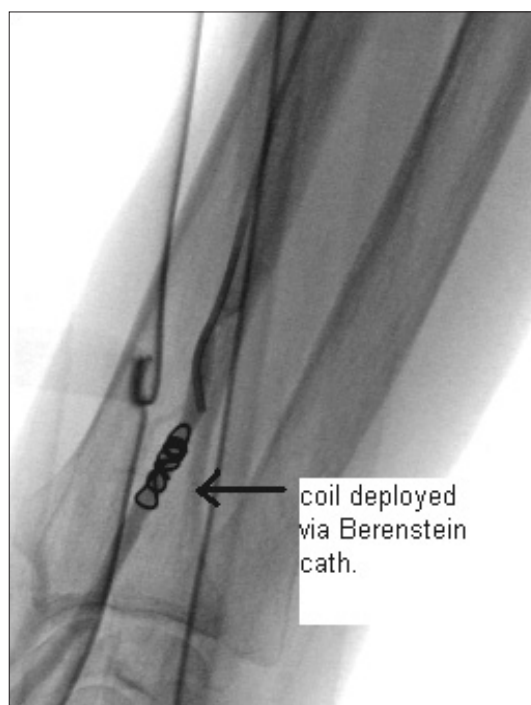
Fifteen patients presented with PASS symptoms and were treated with either coil embolization or ligation of the DRA

Complete occlusion of the DRA likely occurred within hours. Only on follow-up, in some cases, did we perform angiography to demonstrate complete radial artery flow interruption. These patients generally were following up for other access issues. We concluded, based on our findings, that follow-up angiography is not necessary and is no longer performed.

Ligation is performed when the distance between the anastomosis and thenar artery is less than 3-4 cm. Ligation is performed (five patients) using a 1.5 cm incision and blunt dissection to isolate the DRA. A 3.0 nylon suture (Ethicon, Somerville, NJ) is used to tie off the artery. Follow-up angiography is performed to demonstrate successful flow interruption in the distal radial artery.

## RESULTS

Fifteen patients were diagnosed with PASS. Ten patients were men, five were women. The mean age was 63.5 yrs. Renal failure was secondary to hypertension in 87% (13/15), and diabetes 40% (6/15). All 15 patients had an end vein to side artery radiocephalic AVF located in the wrist. All fifteen patients underwent either coil embolization (n=10) or ligation (n=5) of the DRA to treat shunt steal. There were no complications associated with interrupting the DRA flow. In the patients who underwent ligation, no infections occurred at the cut down site. The patients were all followed in approximately 2 weeks to confirm symptomatic improvement. Necrotic finger tips in two patients healed within 3 months. A median time of 9 months follow-up is available, during which 13 patients (87%, 13/15) had complete symptomatic relief and two patients (13%, 2/15) experienced significant symptomatic improvement. Patient 3 has a large anastomosis which over time has caused the radial artery to hypertrophy to twice its normal size. The hypertrophied artery began to steal flow from the ulnar and interosseous arteries at the level of the forearm arterial trifurcation resulting in DASS. MILLER banding procedure was successfully performed to alleviate the steal (6). Following the banding procedure steal symptoms completely resolved. Patient 2 experienced symptomatic improvement, but due to advanced diabetic microvascular disease the already necrotic left fifth digit still progressed and needed amputation. In order to assure good wound healing the left AVF was first ligated. A new access was created in the right hand. The right hand is now troubled by arterial insufficiency symptoms.



**Fig. 3 - Arteriogram of a patient that illustrates a coil deployed in the DRA in order to interrupt retrograde flow.**

## DISCUSSION

Hand ischemia due to steal syndrome is a clinical diagnosis. Steal syndrome physiology is common, and occurs in 73% of AVF, however is usually asymptomatic (7, 8). The literature reports symptomatic steal occurs in 1-4% of the dialysis population (6). The incidence of steal is about 4% (150/3500) of the dialysis population referred to our outpatient access center. The pathology of steal syndrome is dependent on the access site. Upper arm access steal is more common, 130/150 of the steal patients in our outpatient access center had an upper arm access (1-3). Steal in the forearm radiocephalic AVF is less common (20/150) and demonstrates a unique pathology.

Forearm steal is associated with one of two possible pathologies; either absolute arterial insufficiency due to diffuse atherosclerotic disease (5/20 cases), or shunting of blood into the fistula with regional ischemia to the most distal high resistance arteries (15/20 cases). In some cases distal arterial pathology secondary to diabetes mellitus (DM) was a contributing factor to the development of PASS. The distal microvascular arteriopathy creates the imbalance between high distal arterial resistance and low fistula resistance therefore setting up a shunt.

In a matured AVF, PASS occurs as a result of a gradually altered physiology. In our cases the minimum



time between fistula creation and onset of steal symptoms was approximately 12 months. As a radiocephalic AVF matures, fistula venous resistance decreases causing increased blood flow to shunt into the fistula away from the fingers. Flow from the proximal radial artery follows the pathway of least resistance and drains in its entirety into the fistula. Frequently the proximal radial artery is hypertrophied. Similarly, the ulnar artery, palmar arch and distal radial artery can hypertrophy delivering nearly all their blood directly to the fistula with resultant finger ischemia. The resistance gradient between the low resistance fistula and the high resistance digital arteries causes the blood to shunt through the DRA into the fistula causing hypoperfusion of the digits. This is easy to demonstrate with angiography. Treatments for steal syndrome are generally limited to access ligation, DRA interruption, banding, and revascularization. Revascularization procedures in the forearm have limited success due to small targets (4, 7-10). Banding can be used successfully to treat steal associated with high flow in the fistula by restoring resistance in the fistula (4, 8). Ligation is the most commonly used and the least favorable of the treatment options since dialysis access sites are limited (4, 7-10). In this study, 13/15 patients had complete symptomatic resolution after DRA flow interruption. DRA flow interruption via ligation or coil embolization appears to be the optimal treatment option.

DRA interruption by way of ligation has been a known treatment for finger ischemia. In our community, ligation of the access was preferred to ligation of the DRA because the pathophysiology of steal syndrome in a distal AVF was not well understood. If proper angiography is employed, then PASS can be documented and DRA ligation can be correctly performed. Without an accurate diagnosis, treatment for the wrong pathology of forearm steal could worsen symptoms significantly by eliminating one of the major sources of hand perfusion.

In our experience both DRA ligation and coil embolization are successful in relieving PASS associated finger ischemia. Coil embolization is preferred in our practice. The inherent risks of surgical intervention include infection at the cut down site, excessive bleeding, and nerve damage. As interventionalists we find coil embolization easier, less risky, and less time consuming. The cost of supplies for the embolization procedure is approximately \$320. A DRA ligation procedure in an outpatient surgery center would cost approximately \$160. The coil procedure bills the insurer approximately 2.5 times more than the ligation procedure. The increased charges arise from billable imaging codes.

Deployment of a coil does have some inherent risks such as migration toward the hand during deployment. Additionally, the coil is under retrograde arterial flow pressure and the risk of the coil migrating into the fistula and then into the central circulation or lungs is not without consideration. We diminished this risk by applying extrinsic pressure over the coil site distally to the coil during deployment preventing migration into the palmar arch. Migration of the coil in the fistula is prevented by deploying through an inflated Fogarty catheter positioned in the DRA. If upon angiographic study the distance between the anastomosis and the thenar artery is at least 3-4 cm, safe coil deployment can be achieved and embolization is the method of choice. If the distance is less than 3-4 cm, then ligation of the distal radial artery should be considered.

In certain cases DRA interruption may not completely alleviate hand ischemia. This may either be caused by advanced atherosclerotic disease in all the vessels perfusing the hand, in which case a new access must be sought. In other cases, a banding procedure may be required for complete symptomatic relief if a high flow forearm fistula is present.

## CONCLUSION

Finger ischemia in long-term hemodialysis patients is a serious concern that requires attention. A proper diagnosis is essential because a misdiagnosis may cause worsened ischemia and dysfunction of the hand with potential limb loss. This paper presents a subset of the steal phenomena we have named "palmar arch shunt steal", which is characterized as hypertrophy of the palmar arch and atrophy of the arteries of the digits. When this phenomenon occurs, blood flow travels according to the pathway of least resistance, which is towards the fistula from both the radial and ulnar directions. Interruption of retrograde flow into the DRA in our experience is a definitive treatment when steal occurs in forearm anastomosed fistulae. Flow interruption can be achieved by ligation or coil embolization of the DRA. In our experience both methods are highly successful with low associated morbidity.

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## REFERENCES

1. Morsy AH, Kulbaski M, Chen C, Isiklar H, Lumsden AB. Incidence and characteristic of patients with hand ischemia after a hemodialysis access procedure. *J Surg Res* 1998; 74: 8-10.
2. Bachleda P, Utikal P, Kojecy Z, et al. Autogenous arteriovenous elbow fistula for haemodialysis and upper extremity ischemia. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub* 2007; 151: 129-32.
3. Tordoir JH, Dammers R, van der Sandre FM. Upper extremity ischaemia and hemodialysis vascular access. *Eur J Vasc Endovasc Surg* 2004; 27: 1-5.
4. Leon C, Asif A. Arteriovenous access and hand pain: the distal hypoperfusion ischemic syndrome. *Clin J Am Soc Nephrol* 2007; 2: 175-83.
5. Davidson I. On Call. In Davidson I (ed): *Vascular Access - Surgical and Radiologic Procedures*. Georgetown, Texas: R.G. Landes Co, 1996; 30-2.
6. Goel N, Miller GA, Jotwani MC, Licht J, Schur I, Arnold WP. Minimally invasive limited ligation endoluminal-assisted revision (MILLER) for treatment of dialysis access-associated steal syndrome. *Kidney Int* 2006; 70: 765-70.
7. Hoek F van, Scheltinga MR, Kouwenberg I, Moret KEM, Beerenhout CH, Tordoir JHM. Steal in hemodialysis patients depends on type of vascular access. *Eur J Vasc Endovasc Surg* 2006; 32: 710-7.
8. Plumb TJ, Lynch TG, Adelson AB. Treatment of steal syndrome in a distal radiocephalic arteriovenous fistula using intravascular coil embolization. *J Vasc Surg* 2007 Oct 18; [Epub ahead of print].
9. Sessa C, Pecher M, Maurizi-Balzan J, et al. Critical hand ischemia after angioaccess surgery: diagnosis and treatment. *Ann Vasc Surg* 2000; 14: 583-93.
10. Valji K, Hye RJ, Roberts AC, Oglevie SB, Zeigler T, Bookstein JJ. Hand ischemia in patients with hemodialysis access grafts: angiographic diagnosis and treatment. *Radiology* 1995; 196: 697-701.