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Minimally invasive limited ligation endoluminal-assisted revision (MILLER) technique as a compelling and less invasive alternative for salvaging dialysis fistulas, offering precision modulation of flow while preserving vascular access integrity in the management of dialysis access steal syndrome (DASS) without significant feeder arterial stenosis

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Abstract
Introduction: Dialysis Access Steal Syndrome (DASS) complicates 1-8% of arteriovenous fistulas (AVFs), ranging from mild ischemic discomfort to severe limb-threatening ischemia (1).
Case Presentation: We describe a 47-year-old male with end-stage renal disease (ESRD) on hemodialysis, presenting with classical symptoms of DASS in a right brachiocephalic AVF, without significant inflow arterial stenosis.
Intervention: A hybrid Minimally Invasive Limited Ligation Endoluminal-Assisted Revision (MILLER) procedure was performed, combining surgical ligation with balloon-assisted intraoperative calibration to reduce fistula diameter and restore distal arterial flow (2). Central venous occlusion was concurrently managed with balloon angioplasty and stenting.
Outcome: The procedure relieved ischemic symptoms, normalized distal saturation, and preserved vascular access.
Conclusion: The MILLER technique represents a safe and effective option for managing DASS in patients requiring fistula preservation (2, 3).

Keywords: Dialysis access steal syndrome, hemodialysis, miller technique, arteriovenous fistula, case report

Introduction
Dialysis access steal syndrome (DASS) is a significant complication of AVFs, reported in up to 8% of patients (1). It arises from the diversion of arterial blood into the fistula, resulting in distal hypoperfusion (3). Conventional options such as surgical ligation, DRIL, RUDI, or PAI carry the risk of access loss or are technically demanding (7-11). The MILLER technique offers minimally invasive precision in modulating fistula flow while preserving access (2).
This report highlights its successful application in a patient with multiple access failures and central venous occlusion.

Patient Information
- **Demographics:** 47-year-old male with ESRD on thrice-weekly hemodialysis.
- **Chief Concerns:** Tingling, numbness, blackish discoloration of right-hand fingers, and upper arm swelling.
- **History:** Multiple prior AVF failures (radiocephalic, brachiocephalic), recurrent permacath insertions, central venous occlusion (CVO) previously treated with venoplasty.
- **Family/Psychosocial History:** Not contributory.
- **Relevant Past Interventions:** Central venous plasty and multiple access revisions.

Clinical Findings

- Blackish discoloration and ischemic changes in right-hand fingers.
- Upper arm swelling.
- Absent distal arterial pulses on physical examination.

Timeline

Timeframe	Clinical Events & Findings	Intervention	Outcome
Past years	Multiple AVF and permacath failures	AVF creation, venoplasty	Partial temporary improvement
Current presentation	Right-hand ischemic symptoms	USG Doppler, pulse oximetry	Flow 1.5 L/min, absent radial/ulnar flow, no digital saturation
Procedure day	Hybrid MILLER + central venoplasty & stenting	Ligation across balloon, angioplasty & stenting	Restoration of distal perfusion
Post-procedure	Follow-up exam & oximetry	—	Normalized digital saturation, fistula preserved

Diagnostic Assessment

Investigations

- **USG Doppler:** Patent brachiocephalic AVF, PSV 240-260 cm/s (brachial artery), 350-400 cm/s (cephalic vein), flow ~1.5 L/min, no radial/ulnar flow (12).
- **Pulse oximetry:** No reading in right index finger.
- **Diagnosis:** Dialysis Access Steal Syndrome (DASS) with high-flow AVF and compromised distal perfusion.
- **Differential Considered:** Peripheral arterial occlusive disease; inflow arterial stenosis (excluded on angiography).
- **(See Figure 1, 2:** Pre-procedure Doppler study.)

Therapeutic Intervention

Procedure

- Retrograde cephalic vein access with angiography confirmed complete diversion of brachial artery flow into the fistula (Figure 3, 4).
- Local exploration of the draining vein by local incision at elbow joint was done with placement of 5 x 40 mm balloon (Figure 5).
- Surgical exposure of the cephalic vein at fistula site with control of the proximal and distal ends of cephalic vein. (Figure 6).
- Suture was taken across the balloon inflated draining vein. This reduced the diameter of the AVF to 5 mm at the new suture site. Balloon was deflated and check angiogram was taken which revealed mild improvement in forward flow. (Figure 7).
- Subsequently, 4 x 40 mm balloon was placed at juxtra-anastomtic fistula vein and suture was taken across the balloon inflated draining vein. Balloon was deflated and check angiogram was taken which revealed significant improvement in forward flow seen with opacification of the radial and ulnar artery at wrist joint. Post procedure pulse oximetry showed improved saturation in right index finger. (Figure 8).
- Concurrent CVO management with sequential balloon angioplasty (10 × 60 mm, 12 × 40 mm) and stenting (14 × 40 mm) (Figure 9).

Rationale: Avoid blind banding, preserve fistula, enable real-time distal perfusion assessment (2, 4, 5).

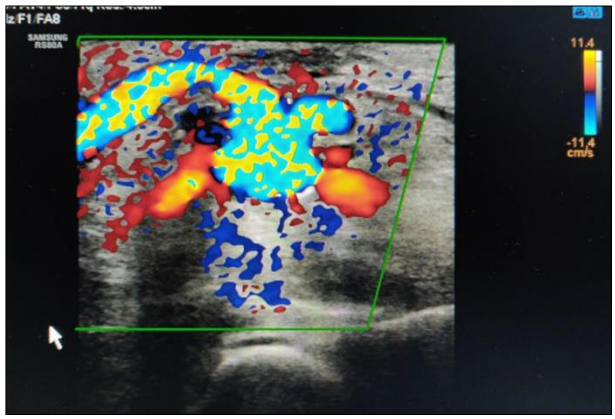
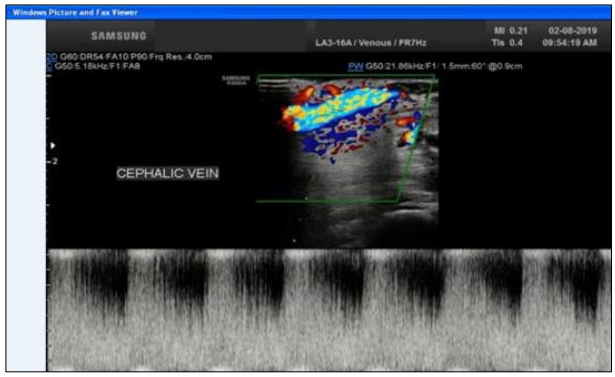


Fig 1: Patent brachio-cephalic fistula



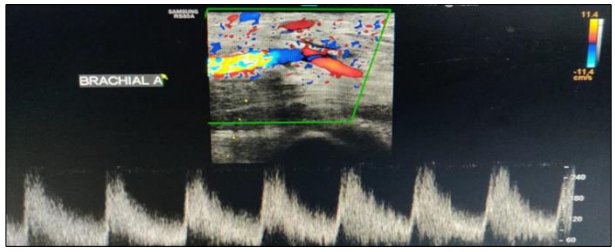


Fig 2: High flow in cephalic vein and brachial artery

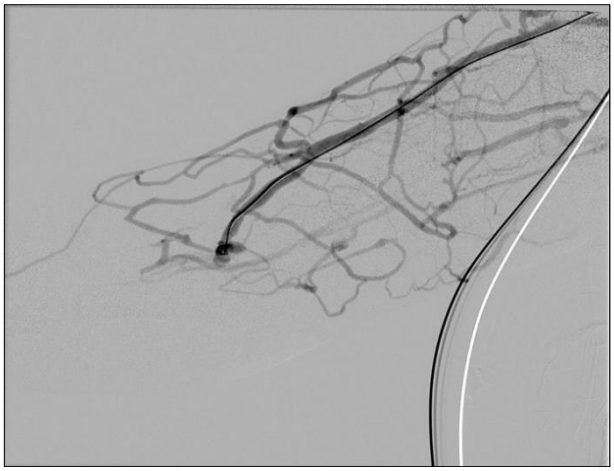
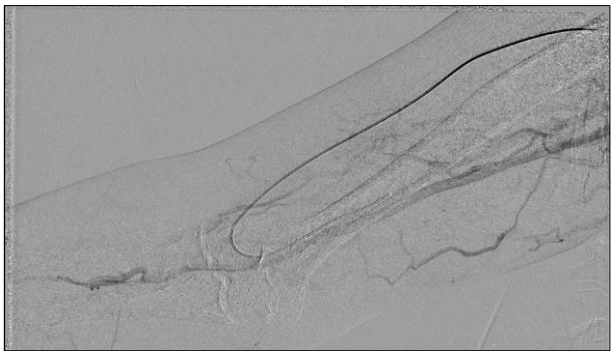


Fig 3: Retrograde cephalic vein access was taken with 6F sheath.



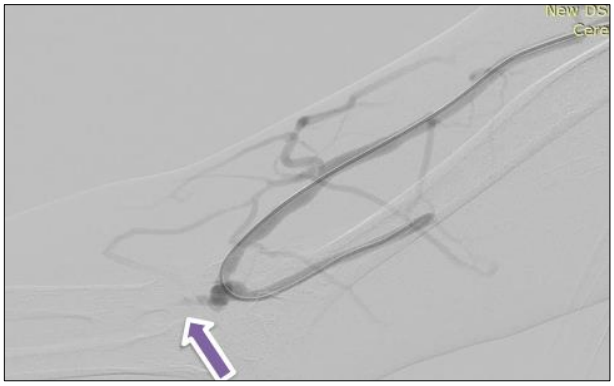
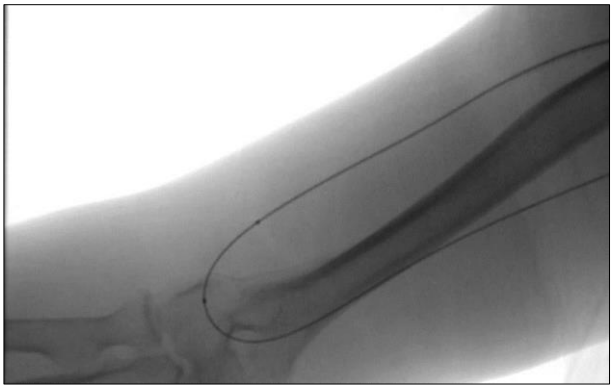


Fig 4: 4F H1 catheter was placed in the left brachial artery.

Angiogram revealed near complete shunting of the brachial artery flow through fistula with no forward flow in radial and ulnar artery beyond fistula level (arrow).
On pulse oximetry there was no reading in right index finger at this stage.



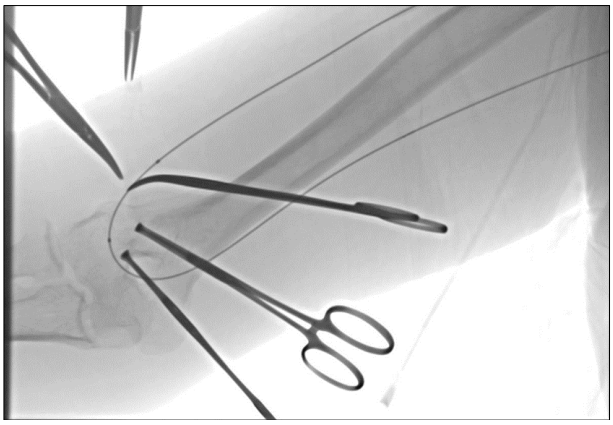


Fig 5: 5 x 40 mm balloon was placed at juxta-anastomtic fistula vein.

Local exploration of the draining vein by local incision at elbow joint was done.

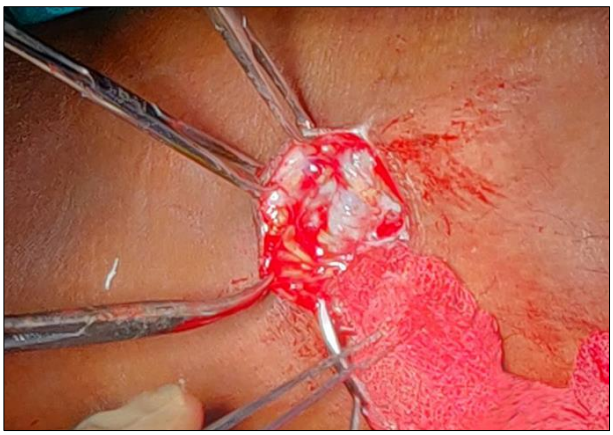


Fig 6: Surgical exposure of the cephalic vein at fistula site with control of the proximal and distal ends of cephalic vein.

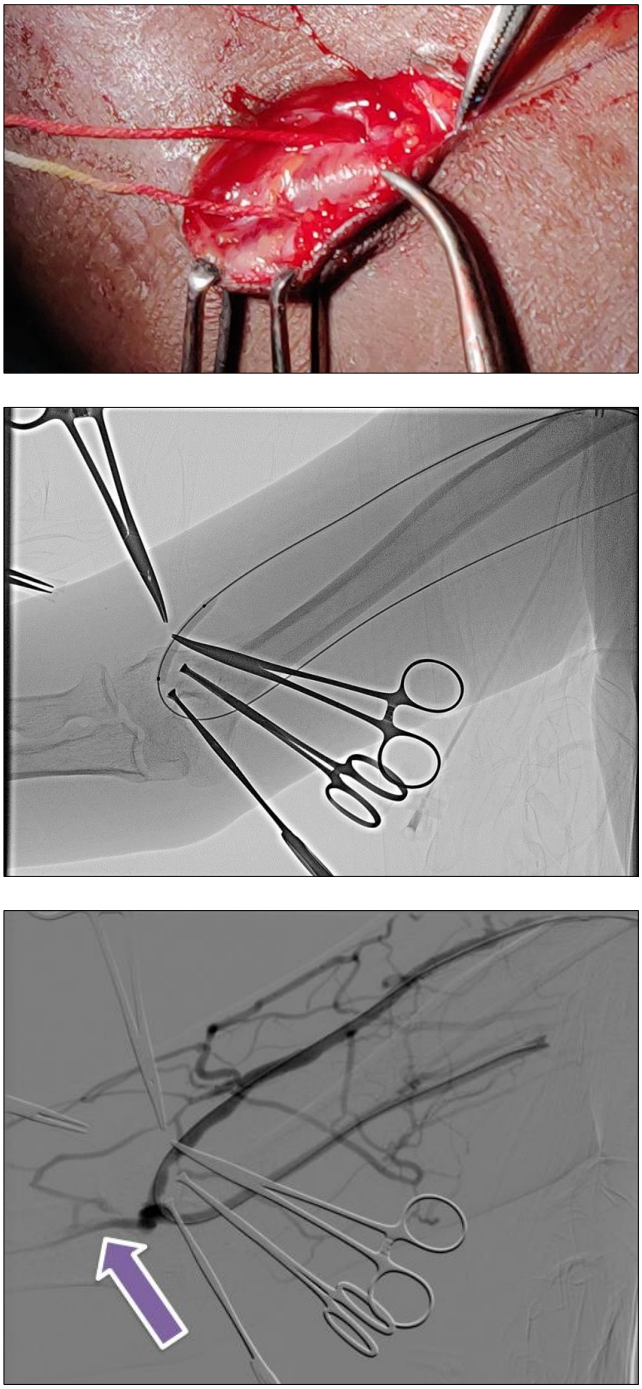


Fig 7: The 5 x 40 mm balloon was inflated.

Suture was taken across the balloon inflated draining vein. This reduced the diameter of the AVF to 5 mm at the new suture site.

Balloon was deflated and check angiogram was taken which revealed mild improvement in forward flow (arrow)

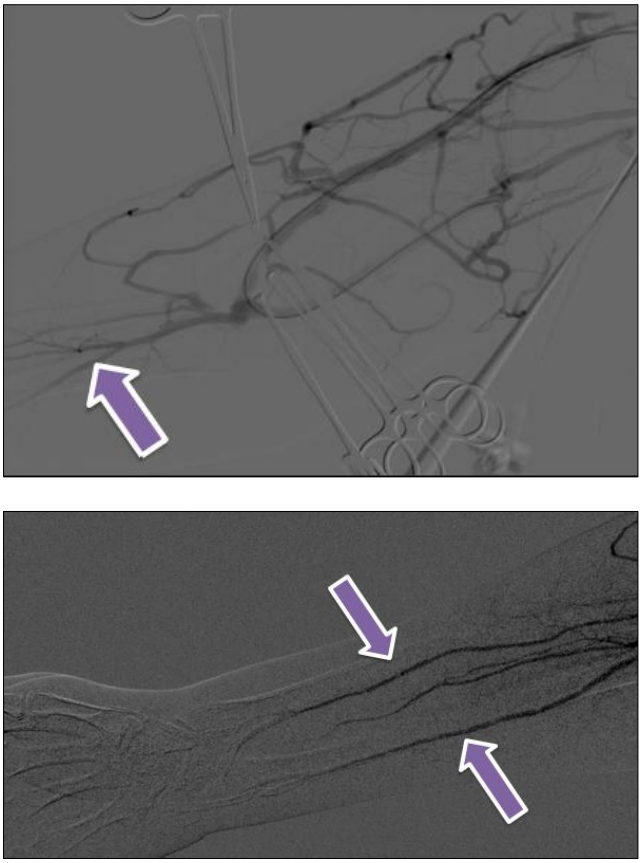
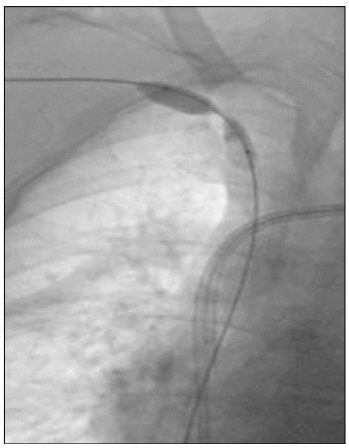


Fig 8: The 4 x 40 mm balloon was placed at juxtra-anastomtic fistula vein and suture was taken across the balloon inflated draining vein.

Balloon was deflated and check angiogram was taken which revealed significant improvement in forward flow (arrow) seen with opacification of the radial and ulnar artery at wrist joint (arrow). Post procedure pulse oximetry showed improved saturation in right index finger.



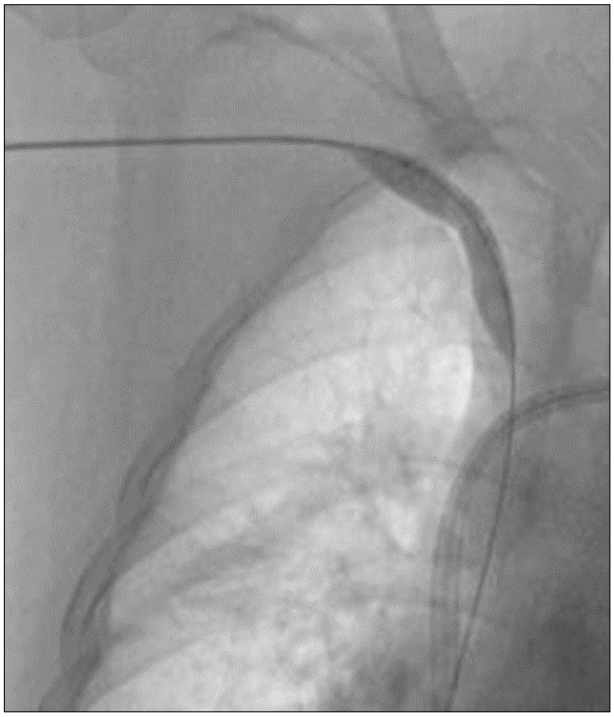


Fig 9: Balloon angioplasty was done with 2 balloons (10 x 60 mm and 12 x 40 mm). However due to persistent narrowing Stent (14 X 40 mm) was inserted.

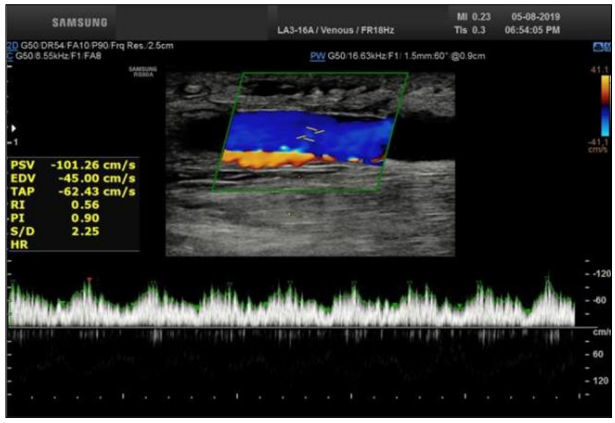
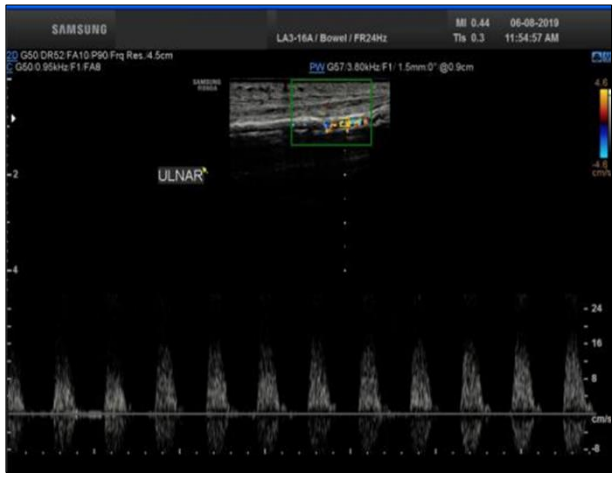


Fig 10: Patent fistula. Reduced fistula flow rate of 1L/min (left). Reduced flow in the cephalic vein [PSV - 101 cm/s] (right)



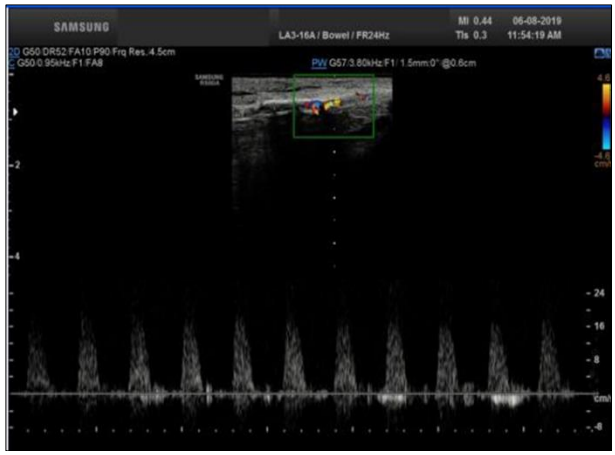


Fig 11: Improved flow in radial and ulnar arteries which was observed at 2 weeks and 3 months follow up USG

At 3 month follow up USG, fistula was patent. No e/o digital ischemia.

Follow-Up and Outcomes

- **Immediate outcome:** Normalization of digital oximetry readings, restoration of radial and ulnar flow.
- **Intermediate outcome:** Symptom relief with preservation of vascular access.
- **Tolerance/Adverse events:** No peri-procedural complications.

- **(See Figure 8:** Post-procedure angiography showing restored distal flow.)
- Post-procedure patent fistula and reduced fistula flow rate of 1L/min across the anastomotic site was achieved with reduced flow in the cephalic vein [PSV-101 cm/s]. (Figure 10).
- Improved flow in radial and ulnar arteries which was observed at 2 weeks and 3 months follow up USG. (Figure 11).
- At 3 month follow up USG, fistula was patent. No e/o digital ischemia.

Discussion: An AV fistula is surgically created by connecting an artery and vein to provide vascular access for hemodialysis treatment. Once a fistula is made, the bulk of blood flow in the feeding artery (brachial, radial, ulnar) is diverted into the arterialized vein due to shunting of arterial blood into the low-pressure venous system resulting in a "physiological" or “silent” steal phenomenon (3).

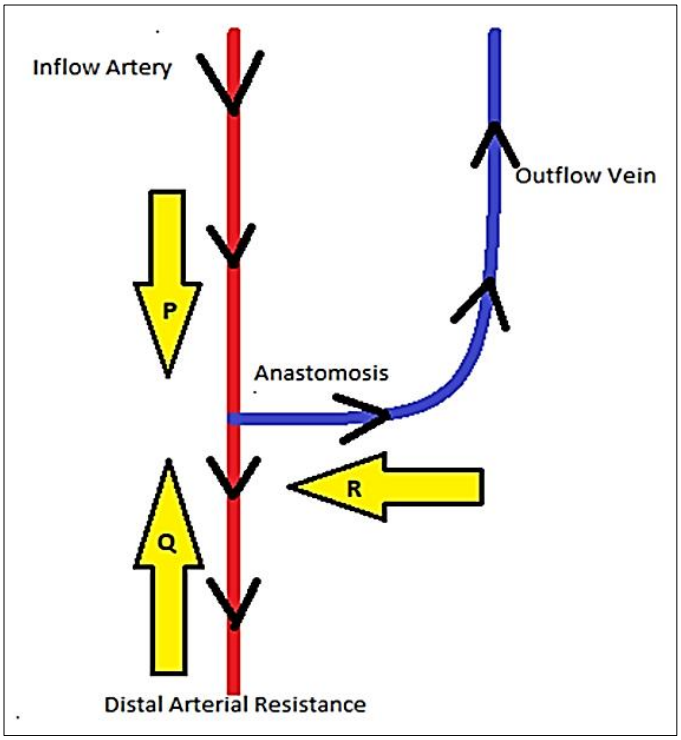


Fig 12: demonstrates simplified schematic representation of a normal AVF/AVG.

The black arrows along the vasculature denote the normal blood flow in a functional access without steal. The yellow arrows (P, Q and R) denote the hemodynamic pressures that are acting at the anastomotic site. (In a liquid, hemodynamic pressures are exerted in all directions equally). The occurrence of DASS depends on the balance between these three pressures. (3)

6.1 Advantages of a fistula compared to a graft and temporary/permanent dialysis catheter

- Best long term patency rate
- Improved quality of life
- Associated with lowest mortality

6.2 Dialysis access steal syndrome (DASS) or distal hypoperfusion ischemic syndrome (DHIS)

It is defined as the development of ipsilateral ischemic symptoms in the presence of a functioning fistula.

6.2.1 Etiology

- Peripheral arterial disease (PAD) increases resistance in vascular bed and simultaneously impairs the function of natural collaterals. In this case, during diastole, all blood from the collaterals will drain into the AVF.(3)
- Upstream arterial stenosis prevents increased blood flow. Atherosclerosis (likely focal) and medial calcinosis (likely diffuse) can be associated with stenosis.(4)
- Lack of collateral flow reserve results in increased flow demand from the AV conduit.(5)

6.2.2 Incidence and Complications of DASS

Incidence rate: 1-8%. (1)

DASS can not only result in significant pain and discomfort but can also lead to tissue necrosis and the eventual loss of digits and even the entire hand. Early detection and treatment are essential. (1)

6.2.3 Clinical Presentation

Clinical symptoms range from pain and coldness during dialysis to digital necrosis. (3, 6) In order of severity these range from;

- Nail changes
- Occasional tingling
- Extremity coolness
- Tingling and numbness in fingers
- Muscle weakness
- Pale to whitish or cyanotic fingernail beds
- Rest pain
- Sensory and motor function deficit
- Fingertip ulcerations
- Tissue loss

6.2.4 Staging

- **Stage 1:** Retrograde diastolic flow but no complaints; steal phenomenon
- **Stage 2:** Pain on exertion or during hemodialysis
- **Stage 3:** Rest pain
- **Stage 4:** Ulceration/necrosis/ gangrene. (6)

6.2.5 Management approach

6.2.5 Treatment: Based on these available options, a fistula can be closed or preserved in a case of DASS using the following options (7-11):

For fistula closure

- Intravascular coil insertion
- Intravascular plug insertion
- Surgical Banding or ligation

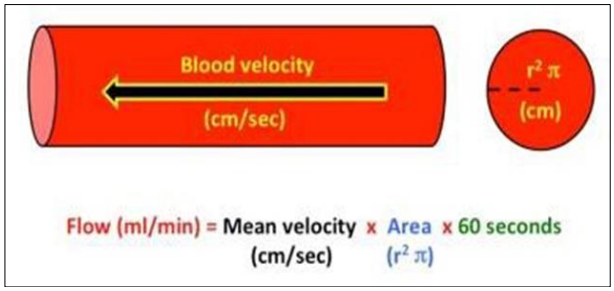
For fistula preservation

- Distal Revascularization-Interval Ligation (DRIL)
- Revascularization Using Distal Inflow (RUDI)
- Proximalization of Arterial Inflow (PAI)
- Open Surgical Banding and Plication
- Tapered graft insertion
- Insertion of vascular clipping system (VCS)

The calculation of flow volume
It is based on the equation

$Q = \pi.r2 \times TAVM$ [$\pi.r2$ x mean velocity x 60]

where r = vessel radius and TAVM = time averaged velocity integral of the mean velocity of the parabolic profile layers, as the velocity is higher in the middle of the vessel and slower towards the vessel walls because of friction. $\pi.r2$ = transactional lumen area in cm2. Time averaged mean velocity averages velocity changes during the cardiac cycle. (12)



7. Conclusion

An AVF is the preferred vascular access due to superior patency and reduced mortality (6). However, DASS can cause significant morbidity, including tissue loss and even limb threat if untreated [1, 3]. In this patient, ischemia was secondary to a high-flow AVF without inflow stenosis, making precise flow modulation critical.

The MILLER technique, first described by Sheaffer *et al.* [2, 8], offers a minimally invasive solution that permits intraoperative assessment of distal flow. Compared to DRIL, RUDI, or PAI, it is faster, less invasive, and maintains fistula function [7-11]. The concurrent management of CVO with angioplasty and stenting further exemplifies the hybrid advantage of combining endovascular and surgical expertise.

Patient Perspective

The patient reported significant relief of ischemic symptoms, improved hand comfort during dialysis, and satisfaction with preservation of his functioning access after multiple prior failures.

Informed Consent

Written informed consent was obtained from the patient for the procedure and for publication of this case report.

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