

Management of finger gangrene caused by steal syndrome in vascular access for hemodialysis

Personal experience and a brief review of the literature



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INTRODUCTION: Severe dialysis-associated steal syndrome (DASS) is an uncommon and severe complication after arteriovenous fistula (AVF) creation that can lead to finger gangrene and amputation. As the number of patients on hemodialysis increases in western countries the number of patients at risk for DASS will continue to rise.

METHODS: We retrospectively reviewed all patients who underwent a surgical intervention for the management of DASS with finger gangrene from January 2004 to July 2013. Demographic data, pre-operative work-up, procedure details and outcomes were collected. A literature search using MEDLINE's Medical Subject Heading terms was used to identify recent articles. Cross-references from these articles were also used.

RESULTS: A total of nine patients were identified. Mean age was 53 years, 67% were women. All patients presented with finger tissue loss or gangrene. Surgical procedures included AVF closure/ligation (5), distal artery ligation (DRAL) (2), distal revascularization with interval ligation (DRIL) (1), banding (1). All patients had improvement of symptoms during follow-up. No major amputation occurred.

CONCLUSIONS: Surgical interventions to correct DASS in patients with finger gangrene are mandatory while conservative management is not recommended. The decision for which type of procedure is made individually, according to clinical symptoms, technical findings, and patients' general state of health.

KEY WORDS: Arteriovenous fistula, Steal syndrome, Surgery

Introduction

The arterio-venous fistula (AVF) remains the gold standard for hemodialysis vascular access in treating patients

with end-stage renal insufficiency. Vascular access may cause significant local and general changes to the bloodstream and may compromise perfusion of the hand. About 1-2% of patients on chronic hemodialysis experience the steal phenomenon the so-called DASS (Dialysis Associated Steal Syndrome)¹. Manifestations of symptomatic ischemia range from intermittent claudication to severe pain at rest, with neurologic deficits and digital gangrene. Finger gangrene is a more advanced and critical form of hand ischemia that is usually seen in young diabetic patients with diffuse vascular disease. In these cases how to improve this ischemic condition and the hand salvage is a challenging problem to surgeons.

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Aim of this study is build a literature review starting from our personal experience in the management of diabetic patients with finger tissue loss or gangrene associated to DASS.

Methods

Between January 2004 and July 2013, all patients on chronic hemodialysis with a history and/or clinical signs of DASS in last stage were identified. All patients were submitted to digital pressure (DP)/ brachial pressure (BP) index, which was diagnostic for DASS if it was equal or less than 0.4. A Duplex scan was performed in all patients with a significant DP/BP index. Duplex scan was diagnostic for ischemia if it showed retrograde flow within the distal artery and abnormal arterial duplex waveforms. The fistula flow was measured according to the formula: time averaged velocity (TAV; $\text{cm} \times \text{s}^{-1}$) $\times$ cross-sectional area ($r^2\pi$; cm^2) $\times$ 60 = flow volume (ml/min) in all patients, and this index was used as a reference in the choice of therapy². Angiography was performed to confirm the diagnosis in all patients with a significant Duplex scan, to identify the status of the vessels distal to the fistula, to evaluate a good anastomotic site and eventually to perform a percutaneous transluminal angioplasty (PTA). Data were collected by chart review and patient interview on demographic data, medical history, and type of dialysis access and clinical features of DASS.



Fig. 1: Fingers gangrene of patient n. 9 at time of surgery.

DASS has been divided into four stages denoting increasing levels of severity of the problem based upon the signs and symptoms that are manifested:

Stage I: No clinical symptoms discrete signs of mild ischemia are present. The hand is cool or cold (compare to the opposite hand), with cyanosis of the nail beds. Numbness and paresthesia may be present. The arterial pulse at the wrist is often reduced, as the systolic finger pressure.

Stage IIa: Symptoms of pain with dialysis or exercise that are tolerable. In addition, cramps and paresthesias may occur along with the signs listed for Stage I.

Stage IIb: Clinically identical to Stage IIa, except that symptoms are intolerable.

Stage III: Pain at rest and/or loss of motor function.

Stage IVa: Tissue loss is present but its extent is limited. There are trophic changes characterized by the development of ischemic ulcers and dry gangrene of one or more digits. There is the potential for preserving hand function if the ischemic changes can be reversed.

Stage IVb: Irreversible tissue loss of the hand or proximal parts of the extremity. There may be significant loss of hand function³.

In this study were considered only patients in stage IV (both *a* and *b*) (Fig. 1)

TYPE OF PROCEDURES (Table I)

Distal Revascularization Interval Ligation (DRIL) should be considered the standard operation to manage DASS because it manages the ischemia while maintaining the functional fistula. Briefly, the artery is ligated distally to the anastomosis, and a vein or PTFE bypass is created from proximal of the anastomosis to distal of the ligation in a patent forearm vessel. DRIL procedure provides an added low-resistance collateral vessel, which reduces the total peripheral resistance to the distal extremity. It is recommended that creation of the proximal anastomosis should be at acceptable distance (>5 cm) from the access to prevent diastolic retrograde flow, and thereby recurrence of steal phenomenon within the bypass⁴. (Fig. 2C)

Proximalization of the arterial inflow (PAI): is considered to be the preferred surgical intervention for patients with access flow volume ≤ 800 ml/min. The PAI is the only optimal way to correct ischemia and improve access flow in a low-flow AVE. This procedure is designed to convert the arterial supply of the A-V access to a more proximal arterial level, first by closing the original hemodialysis access ligating the cephalic vein close to the former arterio-venous anastomosis and then, by implanting a graft prosthesis between the axillary artery and the cephalic vein.

This results in an arterio-venous loop consisting of both prosthetic material and part of the old fistula vein⁵. (Fig. 2D)

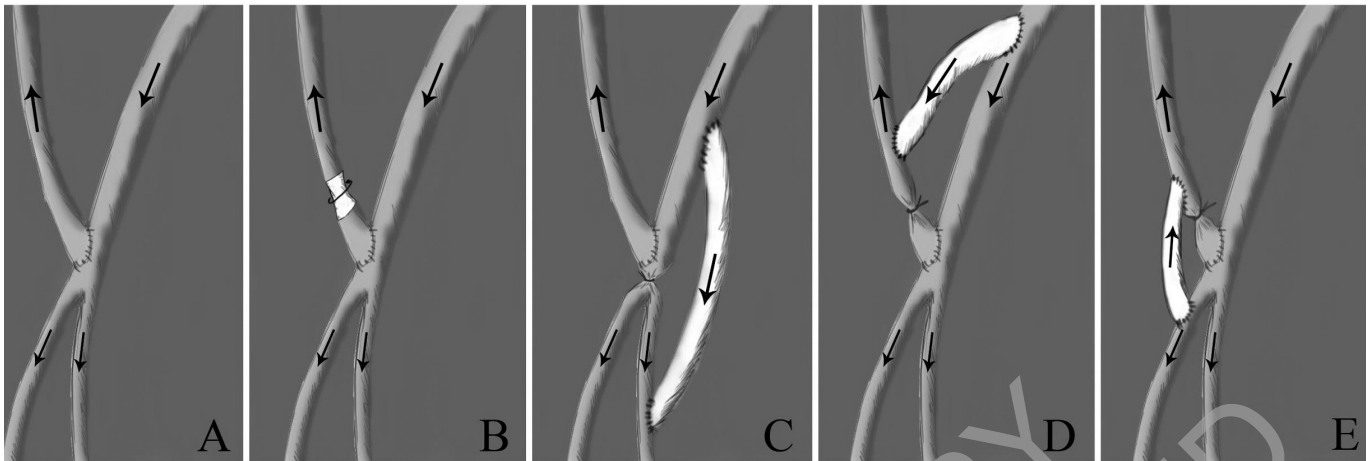


Fig. 2: Overview of surgical techniques for the treatment of DASS (explanation in the text).

Revision using distal inflow procedure (RUDI): Rudi technique consists in move the arteriovenous anastomosis further distal on the arterial tree by closing the original brachial artery arteriovenous anastomosis at the elbow, and interposing a saphenous vein bypass or ePTFE graft or preferably, by direct anastomosis. This essentially converts a brachial artery-based access to a radial artery-based access, thereby preserving antegrade flow in the brachial artery and augmenting the perfusion to the hand. The potential advantage to this approach is that it maintains perfusion through the axial artery. However the drawback of this technique is the high risk of secondary stenosis, given the smaller caliber of the radial artery and the high prevalence of occlusive disease in the forearm vessels, especially in the elderly, diabetics and women⁶. (Fig. 2E)

Banding: Access banding aims to create a narrow vessel segment within the access, close to or at the level of the anastomosis. Native fistulae can be banded by non-absorbable sutures, small caliber interposition grafts or by narrowing the vein with a tight Dacron or PTFE cuff⁷ or with a polyethylene terephthalate carotid patch, shaped with a slit at one end and saw tooth edges (resulting in a "Christmas tree" shape) so as to provide a ratchet mechanism to progressively constrict the draining vein⁸. Banding aims at a reduction of access flow. Thus it can successfully be performed only in patients with a high flow DASS. Banding a low-flow access can result in inefficient dialysis treatment or even AVF thrombosis. (Fig. 2B)

Miller Procedure: Minimally invasive limited ligation endoluminal-assisted revision (MILLER) for the treatment of access-induced steal syndrome was recently described by a group of US interventional nephrologists. In patients with brachial AV accesses, they exposed the access vein or graft proximal to its anastomosis to the artery and performed banding by tying a non-resorbable

suture around the access over an inflated 4 or 5 mm dilatation balloon under fluoroscopic control to gain a defined reduction in the vessel diameter. The MILLER procedure is no more than a simplified banding procedure and should therefore (if at all) be used only in high flow associated steal. It can be performed quickly and easily in the radiology unit immediately after diagnostic angiography for the evaluation of steal. Banding an access to a defined diameter, however, bears the risk of inadequate post-interventional access flow or inadequate therapy of steal symptoms. Pre- and per-interventional flow measurements would enhance therapeutic certainty⁸.

Distal radial artery ligation (DRAL): DASS is unusual with distal radial-based AVF. However when it occurs, ligation of the radial artery distal to the anastomosis can prevent retrograde flow in the distal vascular bed eliminating the steal phenomenon. This can be done either by surgical ligation or by placing an endovascular plug/coil in the vessel. Nevertheless, it is mandatory to assess an adequate perfusion of the hand from the ulnar artery before closing the radial artery. This can be easily done through an ulnar artery angiogram. Amputations distal to the wrist were considered as limb salvage.

Results

Nine Caucasian diabetic patients (3M, 6F) were identified presenting DASS with finger tissue loss or gangrene. The mean age was 52.9 years (range between 23 to 68), five had hypertension, three were current smokers, two patients had necrotic lesions parceled and the other six had major loss of tissue and gangrene. The symptoms occur between 164-450 days after creation of the last functioning AVF. Six patients (66.7%) had history of multiple AVF creation. On four subjects the AVF was present at the wrist (radio-cephalic) while in the remain-

TABLE I

Patient	Gender	Age	Vascular access	Latency Between HA and DASS (days)	HA flow (ml/min)	Aneurysm	Treatment	OUTCOME @12 months
1	F	52	Brachial based	260	1430	BVA	Resection BVA; CLOSURE HA	Finger ray amputation
2	F	59	Brachial based	450	960	CVA	Resection CVA +PTFE interposition	Healed ulcer
3	M	62	Radial based	223	540	No	DRIL	Improved ulcer
4	M	45	Brachial based	164	780	No	CLOSURE HA	Healed ulcer
5	M	68	Radial based	312	1230	No	BANDING	Thumb tip amputation
6	F	23	Radial based	234	570	No	DRAL	Improved ulcer
7	F	52	Brachial based	365	1670	BVA	Resection AVB; CLOSURE HA	Healed ulcer
8	F	64	Radial based	296	650	No	DRAL+ Ulnar PTA	Improved ulcer
9	F	54	Brachial based	414	780	CVA	Resection CVA+closure HA	Fingers tip amputation

Legend: HA: Haemodialysis Access; DASS: Dialysis-Associated Steal Syndrome; BVA: Brachial Vein Aneurysm; CVA: Cephalic Vein Aneurysm; PTFE: Polytetrafluoroethylene.

Table II - Permanent options for DASS

Access ligation
Correction of arterial inflow stenosis/occlusion
Flow limiting procedures (ie, banding, outflow reduction, Miller procedure)
Proximalization of arterial anastomosis
Revision using distal inflow
Ligation of artery distal to anastomosis
Distal revascularization and interval ligation
Distal revascularization without interval ligation

ing patients the fistula was created at the elbow. In 4 patients with brachial-based AVF a large venous aneurysm was also present (two of the cephalic vein and two of the basilic vein) (Fig. 3). All patients were susceptible to surgical correction of blood flow. Major peri-operative and post-operative features are summarized in Table II. The completion angiography, which was always performed in these patients, showed a normalization of flow at the end of the intervention. In all cases there was a regression of ischemic symptoms and digital trophic lesions. Fingers amputation was necessary in three patients after surgical correction of DASS.

Discussion

Patient with chronic renal failure who depend on long-term hemodialysis for survival require adequate vascular access. Construction of an AVF for hemodialysis frequently results in reduction of blood flow to the hand. The development of hand ischemia with finger gangrene in patients on chronic hemodialysis is a rare but potentially devastating complication and it can occur with either an arterio-venous graft (AVG) or an AVF. The real incidence is not well reported with a wide range of incidence, 1.6%-10%^{11,12-17}, depending by the surgical team, and too many contradictions: Morsy et al reported an incidence between 2.7 and 4.3% in patients with AVG and an incidence less than 1% in patients with AVF while Valentine et al. referred an higher incidence in AVF (43% vs 14%, $P = .009$)¹⁸. Ischemic manifestations is due to reverse of blood flow in the portion of the artery distal to the fistula so that arterial blood is diverted from the higher to the lower resistance vascular circuit: from hand to the access (steal syndrome). However, reversed flow is not always associated with hand ischemia, so steal alone is not sufficient



Fig. 3: Huge cephalic vein aneurysm in patient n.2 at time of surgery.

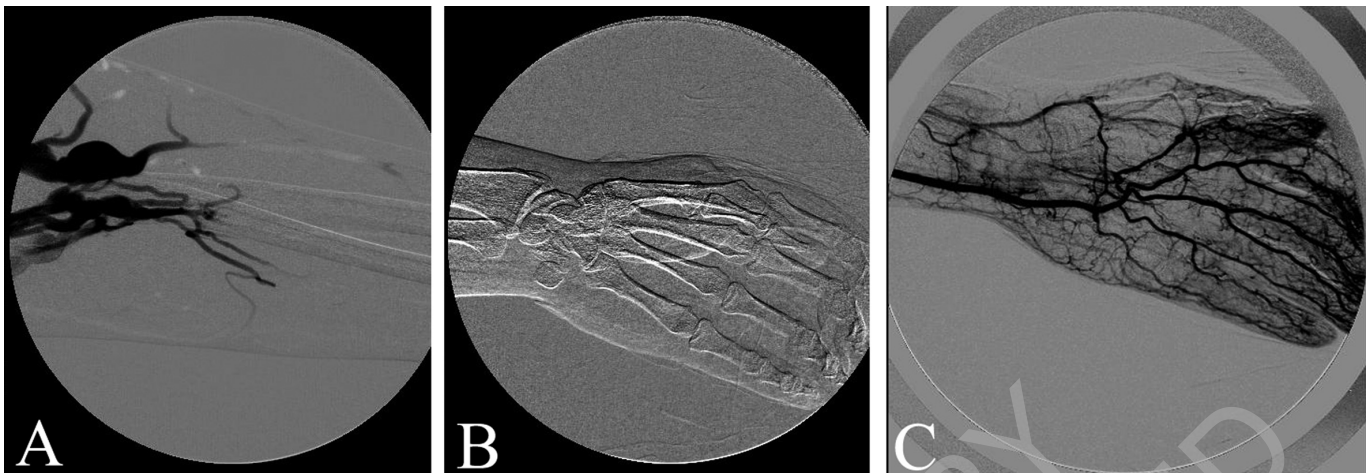


Fig. 4: Intraoperative angiogram showing no distal *run-off* while maintaining the AVF open (A,B); good distal *run-off* is seen after compression of the venous out-flow of the AVF (C).

to produce hand ischemia; arterial collaterals in fact maintain perfusion and the patients remain asymptomatic.

Many additional factor that can induce hand ischemia in hemodialysis patients include: use of brachial artery for inflow, diabetes, female gender, coronary artery disease, hypertension, tobacco use, multiple previous ipsilateral access procedures and systemic lupus erythematosus^{16,19,20,21}.

It is difficult pre-operatively to identify patients at risk of developing DASS and a treatment strategy, described in literature, for prevention of steal have not been described. Digital-Brachial index, obtained on the day of surgery, has been suggested as an useful test with a specificity of around 76%²². Ischemic manifestations are not predictable and could arise immediately after surgery or after a period of weeks, months or even years^{23,24}.

A wide spectrum of symptoms and signs may occur such as sensory loss and paresthesia, cold hand, diminished or absent distal pulses, muscle weakness and drop hand, hand pain usually during dialysis, muscle atrophy, and even tissue loss and digital gangrene²⁵.

DASS, in its milder form, is represented by patients with exercise-associated symptoms or ischemic symptoms during dialysis while, in its extreme form, is noticed at the end of surgery as a severe ischemic state. The initial diagnostic work-up is non-invasive²⁶. History is characteristic with typical symptoms of hand ischemia and physical examination aimed to identify signs of hand ischemia is straightforward:

- radial artery pulsations are weak or absent^{19,27}
- after manual compression of AVF, artery pulsation may return and lowered finger pressures may increase;
- significant retrograde flow and the reduction or absence of flow in the distal arteries on Ultrasound evaluation with normal direction of the bloodstream after temporary compression.

A first invasive diagnostic procedure is angiography with visualization of the inflow arterial tree and measurement of intraluminal pressure in order to quantify the haemodynamic effect.

Its value lies in distinguishing between physiologic steal and an anatomic obstructing lesion. Some patients will have contrast flow into the downstream artery with the pressure of the injection; instead some patients will have reversal of flow because of an asymptomatic physiologic steal. Angiography, with an evaluation of the entire arterial inflow, can see arterial stenosis and make a correct diagnosis²⁵. During the angiogram a compression maneuver on the venous outflow of the AVF can highlight the *run-off* (Fig.4). Afterwards, as already mentioned, a variety of remedial treatment strategies could be adopted for treating DASS, including concomitant PTA, ligation, banding, DRIL, RUDI, PAI, DRAL. Recently, some authors have reported that the use of spinal cord stimulation can significantly reduce pain and increases blood supply²⁸.

The “gold standard” is ligation of the AV access, leaving the patient without permanent access. Ligation has the lowest combined morbidity and mortality owing to the simplicity of the operation.

Banding was the first described technique for DASS, but access thrombosis rates of 90% and persistence of steal²⁹, making banding a historically less favorable option. DRIL has emerged as a popular form of management of DASS, with an excellent improvement of symptoms (80%-100% patient improvement)^{4,30,31} and fistula preservation. However, DRIL is a major vascular procedure: it may require general anesthesia, it necessitates ligation of a normal brachial artery and has a longer operative time. For this reason it should be performed only on patients with good surgical risk with a life expectancy that justifies preservation of autologous access.

To date, there have been no large studies comparing the outcomes of the different surgical procedures for DASS.

Leak et al.³² made comparisons between DRIL vs other procedures: DRIL had significantly fewer complications and better symptom improvement compared with RUDI and banding and had the highest access preservation. In comparison to the current gold standard procedure, ligation, DRIL had similar resolution of symptoms and complications but with full fistula preservation³².

Riassunto

INTRODUZIONE: L'ischemia della mano associata a sindrome da furto (dialysis-associated steal syndrome - DASS) è una complicanza rara e grave dopo confezionamento di fistola artero-venosa (AVF) che può portare a gangrena delle dita e successiva amputazione. Poiché il numero di pazienti in emodialisi è in aumento nei paesi occidentali, conseguentemente, anche il numero di pazienti a rischio di DASS continuerà ad aumentare.

METODI: Abbiamo retrospettivamente studiato tutti i pazienti che hanno subito un intervento chirurgico per correzione della DASS con gangrena delle dita dal gennaio 2004 al luglio 2013. Sono stati valutati ed analizzati i dati demografici, le indagini pre-operatorie, le procedure terapeutiche ed i risultati. Una review della letteratura usando MEDLINE con *Medical Subject Heading terms* è stata usata per evidenziare i lavori scientifici recenti. Sono stati utilizzati anche i riferimenti incrociati di questi articoli.

RISULTATI: Sono stati identificati in totale nove pazienti che presentavano DASS e lesioni trofiche e/o gangrene digitali. L'età media dei pazienti era di 53 anni ed il 67% donne. Le procedure chirurgiche di correzione della DASS sono state 5 chiusura/legatura della fistola, 2 legatura distale dell'arteria radiale (DRAL), una rivascolarizzazione distale con intervallo di legatura (DRIL), un banding della vena. Tutti i pazienti hanno avuto un miglioramento dei sintomi durante il follow-up. Non è stata necessaria alcuna amputazione maggiore (al di sopra del polso).

CONCLUSIONI: il management conservativo della DASS in pazienti con gangrena digitale non è raccomandato, poiché il rischio di perdita d'arto è elevato. La scelta della procedura più idonea è fatta individualmente, in base ai sintomi clinici, risultati tecnici, lo stato generale del paziente di salute e, non ultimo, l'intervento con cui il chirurgo ha maggiore confidenza.

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