

Endovascular Treatment of Failing Arterio-Venous Fistula for Hemodialysis

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ABSTRACT

Background: Percutaneous trans-luminal angioplasty has become an established treatment of dysfunctional arterio-venous fistula. The outcome of such intervention is significantly influenced by the site of the lesion.

Aim of the study: To analyze the impact of the site of the treated lesion(s) on the immediate and delayed outcomes of endovascular salvage of dysfunctional AVFs in terms of technical success and 3, 6 months patency rates.

Patients and methods: This study was carried out from February 2016 to February 2018. It included 60 hemodialysis patients who had dysfunctional native AVFs that were subjected to endovascular salvage.

Results: AVFs dysfunction was caused by an underlying single lesion in 50 cases while multiple lesions were found in 10 cases. The commonest site of occlusion was central veins (23.3%) while the least common site was the proximal arterial segment (1.7%). Technical success achieved in 88.3% patients. Recanalization was best achieved through trans- radial in the major-

ity of cases. Balloon angioplasty alone successfully re-canalized 41 AVFs, while stenting was needed in 8 patients and 4 cases aided by thrombectomy. Of them 3 AVFs only were abandoned on top of procedure complications. The overall primary patency rates of 50 AVFs were 82% and 58% at 3 and 6 months respectively.

Conclusion: PTA is simple, less invasive, shorter procedure, enables immediate dialysis without the need for CVC, reduces the risk of infection, and saves the patient's veins. The site of the lesion has an impact on the outcome of endovascular salvage of dysfunctional AVF with variable immediate success and later patency rates.

Keywords: Endovascular; Native AVF; Dysfunction; Salvage

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ABBREVIATIONS

PTA: Percutaneous Trans-luminal Angioplasty; AVF: Arterio-Venous Fistula; HD: Hemodialysis; ESRD: End-Stage Renal Disease; PSVR: Peak Systolic Velocity Ratio; NIH: Neointimal Hyperplasia

INTRODUCTION

Hemodialysis (HD) for patients with End-Stage Renal Disease (ESRD) requires a well-functioning vascular access. Native AVF has been the dialysis access of choice when suitable vascular anatomy permits as it is a long-term dialysis access that will remain patent over time with a low risk of complications. However, when dysfunction is encountered in them, this represents a major cause of morbidity, mortality and significant HD care-related costs (Sawant A, *et al.*, 2013).

The ideal functional AVF for hemodialysis requires three components: vein diameter of 6 mm, blood flow of 600 ml /min and vein depth of less than 6 mm (Yevzlin A, Asif A, 2009).

Stenosis is a common problem for AVFs and represents the main cause of dysfunction and thrombosis. Access stenosis has been classified based on its location as: juxta-anastomotic (type I), in the puncture sites (type II) and at the outflow into the deep venous system (type III). There are two additional categories of stenosis not involving the access itself, those of the central veins caused by longstanding catheters and those of the arterial inflow (Pirozzi N, *et al.*, 2014).

AVF salvage refers to transforming immature or malfunctioning to functional fistulae, the introduction and evolution of endovascular techniques hold promise to salvage these AVFs that is to transform non-maturing, stenosed, or thrombosed fistulae to functioning fistulae again. Stenotic lesions undergo

balloon angioplasty, accessory veins undergo oblite-ration using coils and thrombosed AVF undergo thrombectomy (Collins AJ, *et al.*, 2015).

AIM OF THE WORK

This study aims to evaluate the impact of the site of the lesion(s) on the immediate and delayed outcomes of endovascular salvage of dysfunctional AVFs in the form of technical success and 3, 6 months patency rates.

PATIENTS AND METHODS

The study was carried out in Cairo university hospital (Kasr Al Aini), Minia university hospital and Al Minufiya university hospital between February 2016 to February 2018 and included 60 patients with failing native AVF treated by endovascular procedures. Patients with native AVF were included if they had failed maturation, flow rate > 600 ml/min, prolonged puncture site bleeding and patients who had manifestations of venous hypertension. Patients with infection, impending rupture, AV graft, contrast allergy and patients who had central venous thrombosis were excluded from this study (Figure 1).

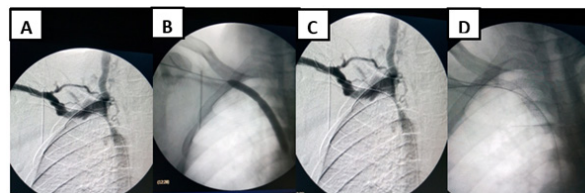


Figure 1: PTA of right brachiocephalic AVF using trans-cephalic access. A) Right innominate vein lesion (red arrow). B) Balloon dilatation. C) Residual stenosis D) Self expandable stent insertion

Clinical examination of fistula

Juxta-anastomotic venous stenosis: bounding pulse is evident at the anastomosis site; the thrill is appreciated mainly in systole instead of being soft and continuous, and felt maximally at the anastomosis site.

Venous stenosis with collapsed segment in between puncture sites and faint thrill.

Central vein stenosis with manifestations of venous hypertension graded from 0 to 3:

- Grade 0: None
- Grade 1: minimal extremity swelling
- Grade 2: moderate extremity swelling
- Grade 3: Severe constant swelling, hyper pigmentation or venous ulceration.

Preoperative investigations

Duplex scan was done in all patients to evaluate the feeding artery and the draining vein, fistula compression by hematoma or seroma, flow rate and Peak systolic velocity (PSV ≥ 375 cm/s) and Peak systolic velocity ratio (PSVR ≥ 3) at and before the location of any narrowed areas. A significant stenosis ($\geq 50\%$ of vein diameter) was suggested.

Lesions sites were stratified into: Proximal arterial lesions, juxta anastomotic arterial lesions, anastomotic lesions, venous juxta-anastomotic lesions (initial 4 cm of the vein adjacent to the anastomosis), puncture sites, junctional segment and central vein (Figure 2).

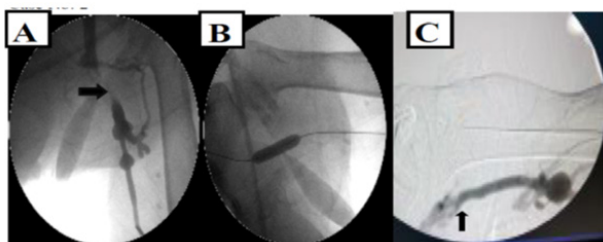


Figure 2: PTA of left brachio-basalic AVF using trans-radial access. A) Junctional stenotic lesion at basilico-axillary region (black arrow). B) Balloon dilatation. C) Successful recanalization of the fistula

Patients counseling and technique details including possible complications and failure rate was explained for every patient and a written consent was taken from each patient and his close relative. All protocols followed the principles outlined in the Declaration of Helsinki. The protocol and informed consent were approved by the Institutional Review Board.

Technique: The procedures were done in angio-suite, under local infiltration anesthesia. General anesthesia was used in children, non-co-operative patients.

Access site:

Radial artery: It used in the majority of cases and had several advantages including easy puncture either percutaneous or by cut down technique, it was enough to treat all the downstream and upstream lesions at the same time, the sheath was kept distal to the fistula site and hence did not interrupt the blood flow of the treated fistula, easy post-operative compression and minimal potential risk of distal embolization to the hand.

Trans-venous access: It was used when venous outflow tract was still patent distal to the anastomosis site especially when there was a limitation to puncture the radial artery. Trans-venous access strictly avoided puncture through a pseudo aneurysm or intimately close to the stenotic segment as this minimizes the room for manipulation. Open surgery was also required when venous thrombectomy found necessary after balloon dilatation of thrombosed venous segment.

Trans brachial: It was less commonly used.

Trans-femoral access: It was needed mainly in patients with flush central venous occlusions especially when an ante-grade wire crossing had failed.

Diagnostic fistulogram

Intra operative venogram was done to visualize the AVF and draining veins after the sheath was flushed with 5000 IU heparin.

Crossing the lesion

A guide wire is then passed through the sheath and is advanced up to the level of the central veins. The guide wire of choice in the majority of cases was a 260 cm 0.035" angled hydrophilic guide wire (Terumo). However, a stiffer (0.018") to get more push ability or a smaller (0.014") wires were used to cross challenging lesions. Wire/catheter complex were then manipulated and advanced under imaging guidance until the lesion site was reached. Satisfactory support for wire manipulation was achieved in most of our cases by using 5F Bernstein or vertebral catheters (Figure 3).

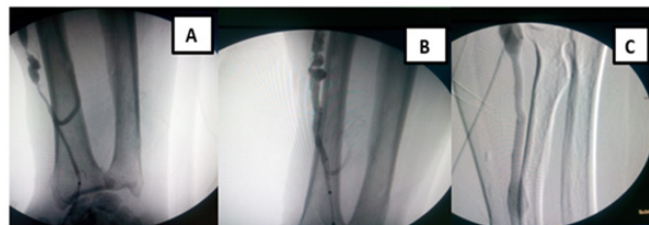


Figure 3: PTA of right radio cephalic AVF using trans-radial access. A) Combined lesions venous juxta anastomotic and needling segment. B) Successful recanalization of the fistula and obscuring the artery after balloon dilatation C) Successful outflow into to cephalic vein

Balloon dilatation

The balloon catheter is passed over the guide wire using 6 mm non-compliant balloon for draining vein and 12-14 mm for central vein, 4-6 mm for juxta-anastomotic lesions, and 4 mm for anastomotic lesions.

Balloon inflation was sustained for 2-3 minutes with a pressure of 12-14 atm., multiple inflations were used for resistant lesions until the stricture was dilated and, in some cases, higher pressure balloon (up to 24 atm.), longer duration, shorter balloon to concentrate the dilatation and smaller non-compliant balloon to create track was used to successfully dilate tight lesions.

Stent insertion

- The stenotic central venous segment was completely effaced by an angioplasty balloon before stent placement. Lesions that cannot be effaced with an angioplasty balloon were not stented.
- The stents used were self-expanding and oversizing by approximately 10%.
- We considered to extend the stent more peripherally rather than centrally and keeping the wire in IVC to achieve more stability and prevent

central slippage.

- After completion of the procedure, a final fistulogram was done through a catheter to determine patency and to exclude any residual stenosis or flow limiting thrombi.

Hybrid procedures

This was essentially needed in dysfunctional AVF due to a heavy thrombus load aiming to combine the procedure with thrombectomy.

- An approximately 3 cm transverse skin incision was made over non-punctured venous segment. A transverse venotomy was made and the distal thrombus was extracted either by simple squeezing, removed with forceps, or by a 5-6 F Fogarty catheter.
- Gentle manipulation and flushing was strictly done to avoid dislodgment of thrombus towards the arterial side.
- Fistulogram was taken in the same manner. If remnant thrombus was found, manual squeezing and passage of thrombectomy catheter were repeated until satisfactory result, the venotomy is then closed with 6/0 polypropylene sutures.

Important definitions in the study

Angiographic success: It is defined as restoration of luminal diameter with less than a 30% residual diameter stenosis.

Technical success: Restoration of a good propagating thrill

Clinical success: The ability to carry out three successful hemodialysis sessions using pump 300 ml/min via the treated fistula.

Follow up

Enoxaparin Sodium once daily S.C and topical hirudin cream three times daily were used routinely in successful cases for 5 days. Patients were advised to use their salvaged fistula for dialysis in the next day after the procedure and rivaroxaban 10 mg as anticoagulant for 3 months.

- Observation of thrill and/or audible bruit, reduction in limb size and disappearance of collaterals.
- Study of complications: Thrombosis, infection, steal phenomena, pseudo aneurysm in the site of puncture.
- Follow up for patency and recurrent stenosis for 3 and 6 months

RESULTS

A total of 60 patients (37 males and 23 females) were included in this study. Mean age was 42.4 ± 15.3 years (range 15-69 years). The most common Co-morbidities were hypertension (33.4%) and diabetes mel-

litus (25%).

The type of dysfunctional AVF was either brachiocephalic, brachio-basalic, radio cephalic or ulnobasalic.

The commonest clinical presentations for dysfunctional AVF were decreased thrill intensity (63.3%) and persistent edema due to venous HTN (21.7%).

The dysfunction of the AVFs was due to underlying single lesion in 50(83.3%) cases while multiple lesions were found in 10(16.7%) cases. The most commonly involved site was central veins (23.3%) as shown in Table 1.

Tran radial access was used in 37 (61.7%), Trans venous in 20 patients (33.3%). Double trans-venous access was needed in 3 patients having total occlusion of their venous outflow tract; one was directed towards the anastomosis and the other was directed towards the central venous outflow. Trans brachial recorded in 9 (15%) cases. Trans-femoral access was needed only in 2 patients with central venous occlusions due to failure of an ante-grade approach.

Anatomic success was achieved in 53 (88.3%) patients balloon angioplasty using non-compliant balloons could successfully recanalize 39 patients. High pressure balloons were mandatory in 2 cases with resilient venous lesions. Eight self-expandable stents were used in those with central venous lesions. Venous thrombectomy was needed in 4 patients as shown in Table 2.

The technique had failed in 7 (11.7%) patients. The causes of failure were total occlusion in 3 cases, persistent false passage (n=1), resistant non-dilatable lesion (n=2) and high origin of radial artery in one patient.

A complication included minor hematoma at puncture site in one patient and was managed conservatively, another 2 expanding hematomas necessitated ligation of the fistula. A circumferentially ruptured balloon material required extraction while performing a successful PTA for radio cephalic AVF. Steal phenomena in brachio-basalic fistula that required ligation. Hemothorax due to rupture of left innominate vein treated with covered stent 14 × 40 mm after sheath exchange (8 French).

The overall 1ry patency rates were 82% and 58% at 3 and 6 months, respectively. In single lesions AVFs, 1ry patency rates were 81.4% and 60.5% at 3 and 6 months respectively; while in multiple lesions' AVFs, the 1ry patency rates were 85.7% and 42.9% respectively as shown in Table 3.

Table 1: Anatomical sites of stenotic lesions

Lesion site	N (%)	Brachiobasilic	brachio cephalic	radio cephalic	Left ulno basalic	WLE/NBI	WLE/NBI	WLE/NBI
		Right	Left	Right	Left	Right	Left	
Proximal artery lesions	1(1.7%)	0	0	0	0	1	0	0
Arterial juxta anastomotic	4(6.7%)	0	0	1	2	1	0	0
Anastomotic lesions	7(11.7%)	0	0	1	2	1	2	1
Venous juxta anastomotic	10(16.7%)	0	2	3	3	1	1	0
Puncture site	10(16.7%)	0	0	5	4	0	1	0
Junctional lesions	4(6.7%)	1	2	0	1	0	0	0
Central venous lesions	14(23.3%)	2	5	2	4	1	0	0
Combined lesions	10(16.7%)	0	1	3	3	1	2	0
Total	60(100%)	3	10	15	19	6	6	1

Table 2: Technical success of the different stenotic lesions

Lesion site	N (%)	Technically successful
Proximal artery lesions	1 (1.7%)	1/1 (100%)
Arterial juxta anastomotic	4 (6.7%)	4/4 (100%)
Anastomotic lesions	7 (11.7%)	6/7 (85.7%)
Venous juxta anastomotic	10 (16.7%)	10/10(100%)
Puncture site	10 (16.7%)	9/10 (90%)
Junctional lesions	4 (6.7%)	4/4 (100%)
Central venous lesions	14 (23.3%)	11/14 (78.6%)
Combined lesions	10 (16.7%)	8/10 (80%)
Total	60 (100%)	53/60 (88.3%)

Table 3: Primary patency rates for 3 and 6 months

Lesion site	Primary patency rate		Total
	3 months	6 months	6 months
Proximal artery lesions	1/1 (100%)		0/1 (0%)
Arterial juxta anastomotic	3/4 (75%)		1/4 (25%)
Anastomotic lesions	5/6 (83.3%)		4/6 (66.7%)
Venous juxta anastomotic	7/9 (77.8%)		6/9 (66.7%)
Puncture site	6/9 (66.7%)		4/9 (44.4%)
Junctional lesions	3/3 (100%)		2/3 (66.7%)
Central venous lesions	10/11 (90.9%)		9/11 81.1%)
Combined lesions	6/7 (85.7%)		3/7 (42.9%)
Total	41/50 (82%)		29/50 (58%)

DISCUSSION

In the near past, the usual decision of failing or recently failed AVF, was plan for a new access and subsequently, the available sites become exhausted and patient life faces a great threat This study included 60 patients male predominance (61.7%) and the most common causes of ESRD and HD were hypertension (33.4%) and diabetes mellitus (25%).

Tran radial access was used in 37 (61.7%), Trans venous in 20 patients (33.3%). Double trans-venous access was needed in 3 patients. Trans brachial recorded in 9 (15%) cases. Trans-femoral access was needed only in 2 patients with central venous occlusions due to failure of an ante-grade approach (Figure 4).

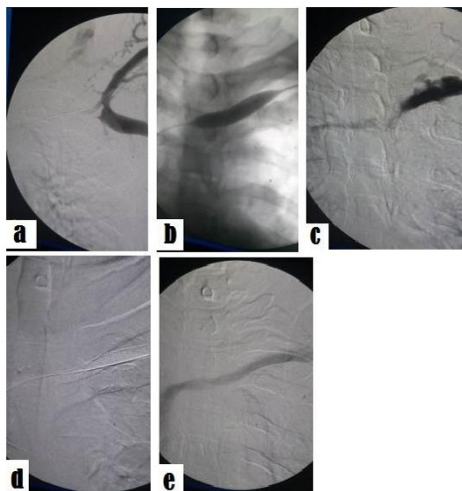


Figure 4: a) Complete occlusion of axillary and SCV, b) Trail of balloon angioplasty of the lesion, c) Suboptimal result, d) Stenosing of the lesion, e) Completion angiogram showing successful passage of contrast through the innominate vein to SVC

Brachial artery puncture was used in minority of cases in this study which was different from Falk A study (Falk A, 2006) that used brachial access in 90% of his patients.

For stenosis located in the artery or at the anastomosis, a retrograde approach was used from the vein in the upper third of the forearm or from the elbow. If this retrograde approach was unsuccessful, the arterial stenosis was treated by ante grade cannulation of the brachial artery at the elbow and selective catheterization of the feeding artery.

The retrograde venous approach has some disadvantages. First, it may be difficult to go into the vein especially in the puncture site as the wire may be hindered by intravenous synechiae. Second, underlying stenosis is difficult to visualize, which may also cause difficulties for the introduction of the sheath. Third, it may be also difficult to cross the anastomosis to the artery due to the sharp angulations. The ante grade brachial artery approach offers some advantages: the puncture is easy and all lesions can be treated via one puncture. However, some drawbacks were encountered including difficult venous lesions manipulation, more incidence of puncture site hematoma and sometimes compromised fistula function due to brachial artery spasm or thrombosis.

Most of the above drawbacks were avoided by the radial artery approach. The radial artery was easy to puncture either percutaneous or by cut down technique.

The cause of AVF dysfunction in this study was either single lesion in 50 (83.3%) or multiple lesions in 10 cases (16.7%). This was near to Nikam MD study in which single lesions represent (66%) and multiple lesions were found in (34%) and this was completely different from Nassar GM (Nassar GM, et al., 2006) who reported multiple lesions in majority (71.4%) of his patients.

In this study the, central venous occlusion was the commonest (23.3%) then venous juxta anastomotic lesions (16.7%) and puncture sites (16.7%) while the least common site was proximal arterial segment (1%). This was different from Nikam MD (Nikam MD, et al., 2015)

who found that anastomotic and juxta- anastomotic lesions were the commonest lesion (51%) followed by isolated downstream vein stenosis in 40% while central vein stenosis was found in 4%. Bountouris I (Bountouris I, *et al.*, 2014) reported that the most common stenotic lesions in native AVF were cannulation segments (49%), outflow vein (18%) and central venous lesions (4%).

In this study, standard balloons were used in 39 patients, high pressure balloons were mandatory in 2 cases. Eight stents were used in those with central venous lesions. Venous thrombectomy of heavy thrombus load was needed in 4 patients while in comparison Bountouris I (Bountouris I, *et al.*, 2014) study, balloon angioplasty using standard balloons alone was the primary treatment in most of his cases and only two stents had been used.

Anatomic success was achieved in 53 (88.3%) patients; whether directly through recanalization of the whole fistulous tract or through recanalizing part of it then diverting the blood flow to a patent deeper vein. The percentage of success is close to the study of Heye S (Heye S, *et al.*, 2012) in which success rate was 87.1% and Bhat R (Bhat R, *et al.*, 2007) showed salvage rate 88%. While success rate in our study is greater than that of Miquelin DG (Miquelin DG, *et al.*, 2008) which showed salvage rate 55%.

The technique had failed in 7 (11.7%) patients, and this was comparable to Nassar GM (Nassar GM, *et al.*, 2006) recorded technical failure in 7.6% of his patients.

The rate of technical success in proximal artery lesions was (100%), arterial juxta anastomotic was (100%), anastomotic lesions was (85.7%), venous juxta anastomotic (100%), puncture site (66.7%) junctional lesions (100%), central venous lesion (78.6%) and combined lesions (80%). While in Lotfi and Mostafa rate of technical success in proximal artery lesions was (85.7%), arterial juxta anastomotic was (90%), anastomotic lesions was (90.9%), venous juxta anastomotic (94.7%), puncture site (95%) junctional lesions (93.7%), central venous lesion (81.8%) and combined lesions (82.1%).

Central venous occlusive lesions had the least success rate, so in symptomatic cases, early intervention at the stenosis phase is better than delaying it till total occlusion ensues. This is attributed to coexistence of multiple factors responsible for total occlusion in one hand (including severe fibrosis, and organized thrombosis), and the presence of sizeable extensive collaterals in the other hand (that direct the wire away from the main pathway). In the current study, arterial lesions had a relatively high success rate, but on the contrary, they had the lowest patency rate after 6 months especially when multiple. This success rate can be attributed to both the site of the lesion (being on the high-pressure side of the circuit) and its nature (being mostly soft atherosclerotic plaque). On the other hand, the poor patency rate was attributed to both progressions of atherosclerosis and/or dissection during PTA with resultant NIH and thrombosis thereafter. In addition, it is recommended to minimize the incidence of post PTA dissection by using optimum balloon length required with nominal pressure and long inflation (at least 2 minutes) when dealing with arterial lesions.

Complications were observed on 10% patients, in the form of minor hematoma at the site of puncture that was encountered in one patient and was managed conservatively. Another two expanding hematomas necessitated ligation of the fistula. A circumferentially ruptured balloon material required surgical extraction while performing a successful PTA for radio cephalic AVF. Steal phenomena in brachio-basilic fistula that required fistula ligation. Rupture of left innominate vein recorded during PTA and treated with covered stent and left intercostal tube.

While in the study of Nikam MD (Nikam MD, *et al.*, 2015) complications were observed on 6% of patient, significant complications leading to AVF loss occurred in 2 patients due to vessel rupture in both cases. In Nassar GM (Nassar GM, *et al.*, 2006) study, complications included local hematoma formation in approximately 15% of patients at the access site and most of them were self-limiting. Steal phenomenon in one patient, and required elective ligation.

Fifty three out of 60 AVFs were successfully dilated and 3 of them were abandoned on top of complications, so a total of 50 AVFs were observed for patency. The overall 1ry patency rates were 82% and 58% at 3 and 6 months, respectively. In single lesions' AVFs, 1ry patency rate was 60.5% at 6 months that is higher than in multiple lesions' AVFs, the 1ry patency rate was 42.9%.

Our patency rates is considered quite similar to Nikam MD (Nikam MD, *et al.*, 2015) recorded primary patency rates 76% and 64% at 3 and 6 months respectively and slightly higher than Bountouris I (Bountouris I, *et al.*, 2014) recorded the primary patency of PTA was 61% and 42% at 3 months and 6 months.

CONCLUSION

The site of the lesion has an impact on the outcome of endovascular salvage of dysfunctional AVF with variable immediate success and later patency rates. Using suitable tools and techniques can optimize the results according to each lesion site. The most difficult treated lesions were central venous occlusions but showed the best 6 months patency rates due to stenting, on contrary the easiest lesions to treat were the arterial stenosis sites but showed the lowest 6 months patency rates. Puncture site lesions and combined lesions have the least patency rates. PTA has several advantages as simple, less invasive, shorter procedure, enables immediate dialysis without the need for CVC, reduces the risk of infection, and saves the patient's veins.

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