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Ultrasound guided interventional procedures on arteriovenous fistulae

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Abstract

Autogenous (AVF) and prosthetic (AVG) arteriovenous fistulas are the vascular accesses (VA) of choice for hemodialysis thanks to their improved patency, reduced costs, and lower rate of infections relative to catheters.

In an effort to maximize the number of primary AVF and AVG, shorten maturation times for AVF, and reduce the number of indwelling catheters, several new techniques have been developed within the context of an overall program designed to optimize access care.

This approach includes: (a) Primary Intraoperative Balloon Angioplasty on the vessels selected for AV creation whether small-sized or altered by pre-existing lesions; (b) Percutaneous Transluminal Angioplasty (PTA) on AVF and AVG stenosis, performed under ultrasonographic (UG) or fluoroscopic guide (FG).

We report the experience of two Center in performing the above mentioned procedures on even complex VA. The wise adoption of these techniques may avail to meet the stringent demands for reliable VA placement as defined by KDOQI and, thereby, expand the duration and quality of life for hemodialysis patients.

Keywords

AV fistula, dialysis access, ultrasonography - Doppler evaluation, interventional radiology, techniques and procedures

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Introduction

The vascular access (VA) for dialysis extremely influences the survival of patients requiring chronic renal replacement therapy. Among the failures affecting both the AVF and the AVG, the stenosis represents one of the main cause; in particular, juxta-anastomotic stenoses (JAS) are more frequently located on the venous segment and are characterized by aggressive neointimal hyperplasia.[1,2] K/DOQI guidelines consider reasonable the use of Percutaneous Transluminal Angioplasty (PTA) with PTA balloon as the primary treatment of stenotic lesions of AVF and AVG.[3] PTA is routinely performed exploiting exposure to X-rays and use of contrast medium. The contrast medium may represent an issue in hemodialyzed patient for the possibility of leading to allergic reactions in some patients. A useful alternative to the traditional PTA under angiographic control is the ultrasound-guided angioplasty. In recent years, various papers were published about the use of UG-PTA to treat the stenosis of both AVF and AVG.[4–9] Moreover, some Authors exerted the ultrasonographic guidance to perform intraoperative angioplasty (ITA) during the creation of an AVF.[10–12] Benefits of UG-angioplasty include avoidance of contrast medium and absence of X-ray exposure that may be significant in case of relapses which lead to repeated procedures. In this paper we will report our experience in the use of the UG in carrying out the PTA of AVF and AVG and in performing the ITA.

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Table 1. Series of PTA performed under UG and FG at the Nephrology Unit of "Vito Fazzi" Hospital (Lecce, Puglia, Italy) from January 2014 to November 2019.

	n.	Post-anatomotic stenosis	Outflow stenosis	Artery stenosis	Stent	Serious side effects
FG PTA	303	163 (95%)	111 (100%)	40 (85%)	22	0
UG PTA	114	84 (88%)	30 (100%)	4 (50%)	0	0

The numbers in brackets refer to the success rate of the procedures.

UG-PTA of AVF stenosis

An important contribution to the development of UG PTA comes from the study of Wakabayashi et al., reporting[7] 4869 cases of fistula stenosis treated under UG. Vascular access stenosis involved the outflow-vein belonging to the AVF in 2388 cases (2342 cases of stenosis and 46 cases of obstruction) and the AVG in 2481 cases (2072 cases of stenosis and 409 cases of obstruction). The major lesions in outflow-vein stenoses were located around the anastomosis in 1493 cases and in the intermediate region in 251 cases. US-PTA was used also in 598 brachio-cephalic or subclavian vein stenosis, in which a micro convex-type probe was deployed in order to visualize the lesion through the supraclavicular and the intercostal spaces. Early success was obtained in 4731 of 4869 cases (97.2%). In stenoses cases, early success was achieved in 4288 of 4414 cases (97.1%). In obstruction cases, early success was reached in 443 of 455 cases (97.4%). The primary patency rate was 94.3% at 1 month; in particular, 94.4% in stenosis and 91.9% in obstruction cases. Assistance by intra-operative fluoroscopy or radiography was required in 55 cases, whilst surgical reconstruction was needed in 42 cases and assistance by intra-operative fluoroscopy was obtained in 12 of 15 cases with indwelling stent. Other Authors reported early success in 93% of 228 procedures in 140 patients; side effects occurred in 5.7% of cases.[8]

Between January 2014 and November 2019 in the Nephrology Unity of Vito Fazzi Hospital (Lecce, Puglia, Italy), 418 PTAs were performed in 295 patients for AVF stenosis. The procedures were performed on outpatient basis in all cases. The interventions were carried out through the cannulation of the efferent veins, in a retrograde or anterograde direction depending on the site of the stenosis. Of 418 PTA, 303 were performed under FG and 114 under UG (Table 1). Central venous stenoses are not included in the series. Of the 303 angioplasties performed under UG, in 101 cases the stenosis involved the outflow vein in a portion far from the anastomosis, in 163 cases it was post-anastomotic, in 40 the radial artery was affected in its pre-anastomotic site. The success rate was 100% for the outflow stenoses, 95% for the post-anastomotic ones, and 85% for arterial stenoses. In 22 cases, covered stents were placed within the anastomotic chamber in two cases, involving both the arteria and the vein; in seven cases the selected site for the placement of the stent was post-anastomotic, while in 13 cases it was located on the outflow. Two of the latter were placed on the cephalic arch. All stents were positioned for frequent relapses of stenoses. In the post-anastomotic sites, small size-stents were positioned, maximum length 2.5 cm, in order to save vessels for subsequent new more proximal anastomoses. All stents were placed under FG. Regarding the 14 cases of failure, in four the stenosis was resistant to PTA, in seven other cases it could not be negotiated. In three cases a thrombosis of the access during the PTA occurred and required surgical correction that was successfully performed. Except for the three cases above mentioned, no other serious complications were observed. The three patients were referred for surgical correction that was successfully performed.

Of the 114 cases in which the UG was employed, in four the stenosis involved the radial artery, whilst in 30 interested the outflow portion and in 84 a post-anastomotic stenosis was found (Table 1). The success of UG-PTA was 50% for arterial stenoses, 100% for outflow stenosis, and 88% for post-anastomotic ones. The failures are related to the difficulty in negotiating the stenosis. Of 12 failures, six were referred to the FG, six to the surgical treatment. In some complex cases, characterized by the presence of multiple collateral vessels, the combined use of UG and FG permitted us to successfully complete the procedure.

UG-PTA of AVG stenosis

Despite NFK KDOQI Practice Guidelines for Vascular Access (VA) issued in 2006[13] and wide acceptance of the "Fistula First Breakthrough Initiative" policy regarding the choice of an appropriate VA for hemodialysis, a high percentage of hemodialysis patients that approximates 20% are currently receiving renal replacement therapy treatment through an AVG (Figure 1).

It is estimated that the primary patency rate of an AVG rarely exceeds 58%–63% in the first 6 months following VA placement. This is attributed to an extremely high rate of stenosis resulting from intimal hyperplasia[14] that usually occurs at the graft venous anastomosis (60%), at more centrally located draining veins (37%), in the deep venous system (3%), within the shaft of the graft itself due to repeated needling injury (38%) or occasionally as multicentric stenotic lesions along the entire VA (38%).

Currently, PTA are considered as first line options in attempting the rescue of thrombosed AVG and the maintenance of graft patency.[15] On the other hand, UG-PTA in an

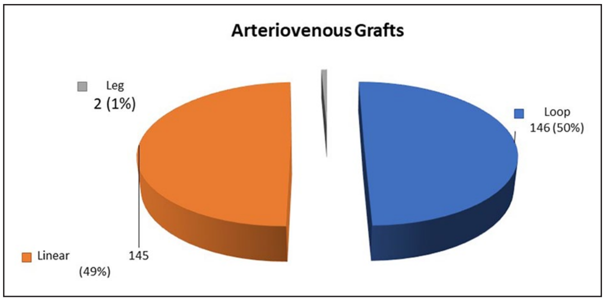

Figure 1. The position of the grafts: one, loop-shaped, in the forearm; one, linear, in the arm; two, in the leg.

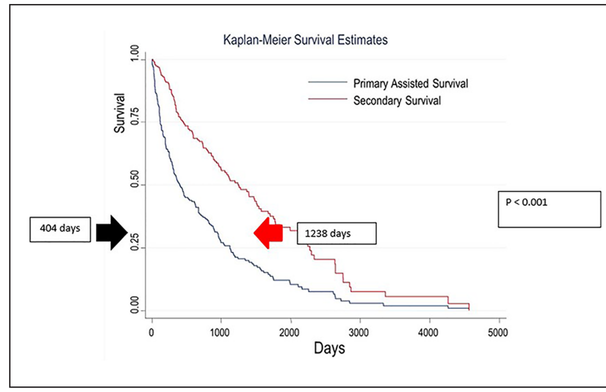

Figure 2. The primary and the secondary assisted survival of the grafts in the follow-up period.

outpatient setting seems to be an alternative approach to the traditional PTA[4] with comparable long term outcomes, according to reported data from small-scale clinical trials.

Between June 2014 and April 2017, in the Nephrology Unit of Manzoni Hospital (Lecco, Lombardia, Italy), a total of 293 consecutive dialysis patients were treated for access dysfunction, 129 male and 164 female patients, of mean age 67 ± 12 years.

The procedures were performed on outpatient basis in all cases. The upper extremity was prepared and draped in the usual sterile manner. All grafts were cannulated under local anesthesia and duplex scan guidance using Philips HD 15 with 5–10 MHz linear probe. Heparin (5000 UI) in saline solution (250 mL) was used during the procedure to wash the introducer. Stenoses were crossed with a 0.035″—curved tip glide wire and were dilated under ultrasound control, using high pressure balloons. The diameter of the balloon was chosen to match the diameter of the normal vessel immediately upstream or downstream.

While the operator supported the ultrasound transducer, the assistant inflated the angioplasty balloon, at least two times for 2 min.

Criteria for dysfunctional graft included decreased flow rate (at least >35%), the peak systolic velocity (more than three times the value in normal vessel) and the grading of stenosis as evaluated during the duplex ultrasound follow up (each patient with a graft undergoes a control monthly). It is known that the usual "corrective" intervention (angioplasty) may itself be harmful.[16,17] Stenotic lesions should not be repaired merely because they are present. If such correction is performed, it is key to demonstrate a functional improvement.

The K/DOQI Guidelines recommend an evaluation for intervention when the blood flow (Q) of the graft is <600 mL/min, or when Q has decreased by more than 25% and falls below 1000 mL/min. When proper statistical methods were applied, Q surveillance was found to be inaccurate predictor of grafts thrombosis.[18] Actually, the measurement of function (Q) is just a surrogate for the measurement of stenosis. If stenosis is significant in inducing a thrombosis, then it is better to directly measure stenosis.[19] So, we adopt a Color-Doppler Ultrasonography (CDU) protocol, in which each patient with a graft is subjected to a CDU control every 20–50 days. During this control, we are able to detect the morphologic data of the graft and of the eventual stenosis; we also measure the peak of systolic velocity (PSV) at artery anastomosis, medium graft and venous anastomosis, and, in case of stenosis, the PSV before and in correspondence of the lesion; we also measure the blood flow always in the same point for each graft, in the brachial artery. All data are recorded in a data base, thus allowing us to study the eventual evolution of the stenosis and to perform a corrective intervention (PTA) only in those cases in which we detect an evolutive stenosis. It was a prospective, single center clinical trial, involving patients with stenotic lesions or thrombosis of AVGs. Referred patients were treated exclusively by UG-PTA and PTT (mechanical thrombolysis) by interventional nephrologists.

Assisted primary and secondary cumulative survival rates were calculated and corresponding patency rates were determined by Kaplan-Meier analysis. The statistical significance was two-tailed, and p-values <0.05 were considered significant.

Technical and clinical success was achieved in all 293 patients. Of a total of 233 PTAs, 130 PTTs were conducted and 102 stents were located, of which 146 in forearm loop grafts, 145 in linear upper arm grafts, and two in lower limb grafts. There were no major complications or need for acute surgical intervention following corrective procedures during the study period. Average assisted primary survival was 404 days, while average secondary access survival was 1238 days ($p=0.01$). Assisted primary patency rates were 52%, 38%, 26%, and 19% at 12, 24, 36, and 48 months, respectively. Secondary patency rates were 79%, 66%, 54%, and 45% at 12, 24, 36, and 48 months, respectively (Figure 2).

In our experience, UG PTA offers a reliable, cost-effective, safe alternative technique in the continuous challenge of treating vascular access dysfunction and improving secondary patency of AVGs for hemodialysis.

UG-primary intraoperative balloon angioplasty during AVF creation

The order of preference for AVF placement in chronic dialysis patients is the wrist (radial-cephalic) primary AVF as first.[3] Despite these indications, in USA and in Europe the number of AVFs in upper arm and related complications, as steal syndrome and overflow syndrome, is constantly increasing.[20] However, early failure (EF) and failure to mature (FTM) are frequently complications of distal AVFs.[21] In the Nephrology Unit of the "Vito Fazzi" Hospital (Lecce, Puglia, Italy), a technique of intraoperative transluminal angioplasty (ITA) has been launched since 2004 in order to reduce the incidence of EF and FTM and to increase the number of vessels suitable to create distal AVF. The ITA was used to dilate arterial stenosis and sclerotic or focally stenotic vein. The procedure was performed during AVF creation, using the arterial or venous incision to introduce the devices for angioplasty.[14] All patients underwent preoperative sonographic mapping. As diagnostic criteria of arterial stenosis we considered the presence of stenosing plaques, detected in B-mode and confirmed by Color Doppler. A low arterial flow during the flush with saline solution was assessed as an indication to ITA. Also the resistance to irrigation of saline solution, due to sclerotic lesions of veins, was deemed to be an indication to ITA. The angioplasty was performed with balloons (SAVVY CORDIS, Johnson & Johnson, Ireland) with a diameter >1 mm compared to the diameter of the vessel to be treated, using a 4-French valved introducer and a 0.018″ guide wire. A long segment of vessel, from the elbow to the site of anastomosis, underwent angioplasty. The size of balloons ranged from 3 to 4 mm, with a medium length of 4–5 cm when we decided to treat only the stenosis and a maximum length of 8–10 cm in the case the vessel needed to be treated for a long segment. The inflation pressure required to dilate the vessels varied from 6 to 10 atm. Ultrasound guidance was used in case of focal stenosis to control the correct position of balloon in the stenosis area and the efficacy of angioplasty.

A previous paper on this topic[12] indicated good results from EF and FTM in a group of patients selected to ITA for artero-venous lesions. The study included 58 distal AFVs performed with ITA compared with 160 AVFs created with standard procedure in the same period. The ITA group included more diabetics (46% vs 10%, $p < 0.001$), more peripheral or central vasculopathy (60% vs 15%, $p < 0.001$) and more severe lower limb ischemia as gangrene or amputation (12% vs 0%, $p < 0.001$). The ITA group showed the same incidence of EF and FTM as that of controls, despite the fact that the two populations displayed a completely different risk of AVF failure. The primary and secondary patency rate at 6, 12, and 24 months were better for control group ($p < 0.01$). The secondary patency rate at 6, 12, and 24 months of ITA group was 85%, 78%, and 78%, values that can be evaluated as satisfactory considering the high risk of AVF failure of the patients. No side effects were recorded. A bias of the paper relies on the different number of cases involved in the two groups. Other Authors have shown that the intraoperative angioplasty may be an option to apply in clinical practice to dilate small veins thus reporting positive results.[22,23] Other experiences exhibited satisfactory data obtained with PTA of the forearm artery and veins in non-maturing autogenous distal AVF for hemodialysis.[24–27] Some of these experiences can be considered comparable to our ITA experience. In fact, the average interval from the surgical creation to the endovascular treatment of the impaired VA was 3.5 ± 1.7 months,[28–29] so it is likely that some arterial lesions existed prior to the creation of AVFs.

Discussion

KDOQI guidelines consider it reasonable to use balloon angioplasty as the primary treatment of AVF and AVG stenotic lesion.[3] Currently, percutaneous endovascular interventions are assessed as first line options in attempting rescue of thrombosed AVG and maintenance of graft patency.[15] However, what seems controversial is the long term efficacy in terms of secondary patency rates and cost effectiveness of such interventions, which are safely and effectively performed in a well-organized Interventional Radiology Room. The need for expensive equipment, highly specialized medical and paramedical staff, the exposure to ionized radiations, the deterioration of patients' quality of life due to repeated hospital visits and the heavy financial burden to health care systems seem to limit the universal applicability of such an approach.

In recent years, some papers were published on the use of ultrasonography during intravascular procedures required to treat the stenosis of both AVF and AVG reporting high success rate.[4–9]

There are some limits connected to UG PTA compared to traditional PTA. First of all, it is not possible to gain a full view of the vascular district, that is limited to the displayed area. Furthermore, fluoroscopy allows a better control of the guides and facilitates the intravascular navigation. In the presence of many collateral venous, in case of very tight stenosis or tortuous vessel course and in case of arterial stenosis, UG- PTA may not be sufficient, thus requiring the aid of the angiography (Figure 3). This aspect is less important in the treatment of an AVG where only one vessel, with no collaterals, is involved and generally the stenosis affects only a post anastomotic venous segment. The best solution could be the availability of an angiograph to be used in selected, difficult cases or in case of complications and therefore it is recommended a valid collaboration with the interventional radiology. Wakabayashi et al.,[7] thanks to his outstanding experience on UG-PTA, performed the procedures in the angiographic room. Another condition in which

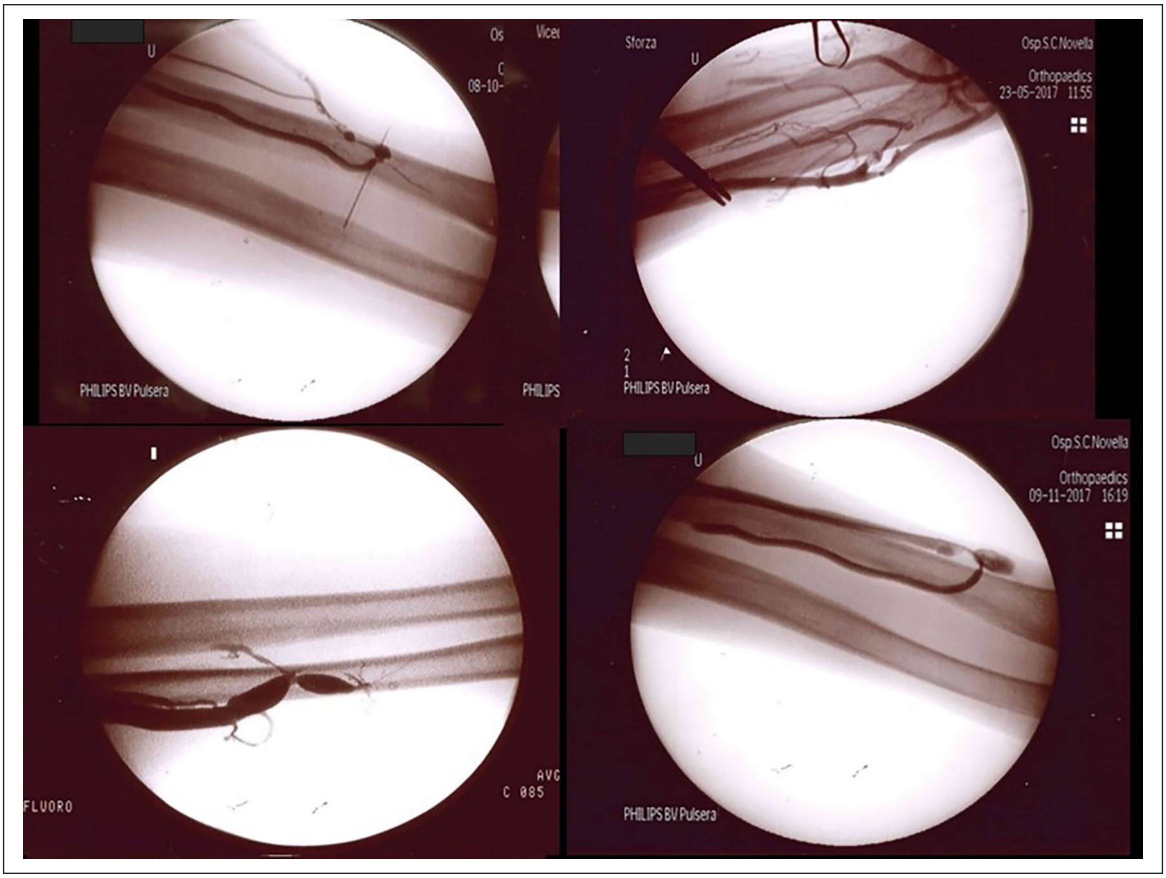

Figure 3. Examples of very tight pre and post anastomotic stenosis.

the use of fluoroscopy seems to be preferred is in the case of stenting. In the experience of both Lecce and Wakabayashi et al.,[7] most of the stents were positioned thanks to fluoroscopic aid. The US guide should be preferred in the case of venous stenoses in which it is easy to place the angioplasty balloon in the site of the stenosis or in case of reported allergy to the contrast medium.

About ITA, the intraoperative use of the Color-doppler tool is easier than that of the fluoroscope. It can be applied in any operating scenario and does not require radiological protection of the operator. However, only few authors have reported the anecdotal use of intraoperative angiography in more complex ITA.[27]

Conclusion

Among the various endovascular procedures aimed at the treatment of malfunctioning AVF or AVG, the UG-PTA, being cost-effective and safe, can represent the first step for the interventional nephrologist who, however, must be skilled in this technique. The UG-PTA is not an alternative technique to traditional endovascular interventional radiology treatments but it is complementary to them; therefore, if it is successful it can avoid them but if it encounters complications it can always refer to them. For this reason, it is almost mandatory that the interventional nephrologist works in close collaboration with the interventional radiologist able to help him in unforeseen and difficult situations. Finally, thanks to ITA it is possible to implement the use of venous vessels that otherwise would not be considered, helping to reduce the sometimes excessive use of CVCs with their associated risks.

Declaration of conflicting interests

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