Evaluation of duplex guided balloon angioplasty for salvage of failing hemodialysis access

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Background
Duplex ultrasonography plays a vital role in imaging of endovascular procedures of dialysis fistulas. Endovascular procedures coupled with ultrasonography gives a simple and reliable visualization of vessels forming fistula, avoiding the hazards associated with radiological imaging and lowers the financial burden. Trials have started depending on the ultrasonography imaging for intravascular interventions. Adding duplex to these procedures facilitate the accurate sizing of balloons and stents and enables us to objectivThe results ofintervention showed success rate in 18 (90%) patients evidenced by improvedpalpable thrill, residual stenosis less than 30%, restoring the function of AVF inhemodialysis. Local complications were treated conservatively, such as hematomain four (20%) cases and local inflammatory signs in two (10%) cases. None of thepatients lost his access due to intervention, two (10%) cases failed despiteintervention; one case due to thrombosis, a trial of thrombectomy by fogertycatheter was done. The other case failed to mature and maintained smallcaliber. Follow up was done for all cases for at least 3 months to confirmrestoring function of the hemodialysis accesses.ely and quantitatively assess the need and the results of intervention.

Aim
Evaluation of the effectiveness of duplex-guided balloon angioplasty for salvage of failing hemodialysis accesses and maintain their function.

Patients and methods
Twenty patients presented to the vascular surgery unit, in Suez Canal University Hospital between February 2017 and February 2018, eight (40%) presented with failing to mature arteriovenous fistulas (AVF) postcreation by more than 4 weeks,12 (60%) presented with failing AVF after usage in hemodialysis,6F sheath was used, 5-6 mm balloons were appropriate for most of the cases, arterial and venous approaches were used.

Results
The results of intervention showed success rate in 18 (90%) patients evidenced by improved palpable thrill, residual stenosis less than 30%, restoring the function of AVF in hemodialysis. Local complications were treated conservatively, such as hematomain four (20%) cases and local inflammatory signs in two (10%) cases. None of thepatients lost his access due to intervention, two (10%) cases failed despite intervention; one case due to thrombosis, a trial of thrombectomy by fogerty catheter was done. The other case failed to mature and maintained small caliber. Follow up was done for all cases for at least 3 months to confirm restoring function of the hemodialysis accesses.

Conclusion
Duplex-guided balloon angioplasty of nonmaturing and failing AVF is a safe and effective procedure. It is associated with high success rates, low complication rates, and maintained long-term patency of the hemodialysis access.

Keywords:
duplex angioplasty, end-stage renal disease, failing arteriovenous fistulas, nonmaturing arteriovenous fistulas

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Introduction

Hemodialysis is the main primary modality of renal replacement therapy [1]. Successful hemodialysis depends on a patent vascular access to be used for repetitive access to large vessels providing rapid extracorporeal blood flow. Preserving of an established access in a chronic patient remains the Achilles heel of the hemodialysis process [2]. The hemodialysis access may be autogenous arteriovenous

fistulas (AVF), prosthetic arteriovenous grafts (AVGs), or a central venous catheter placed in a large vein. AVFs are the preferred initial hemodialysis access due to their longer patency than AVGs. However, AVGs remain clinically important in patients in whom AVFs are not feasible [3].

Maintaining a patent vascular access remains a major challenge, especially in an aging hemodialysis population. Stenosis and subsequent thrombosis of the hemodialysis access is the most frequent complication encountered in a vascular access surgery [4], especially at the arteriovenous anastomosis or along the venous limb [2]. In the past, when resolving a thrombotic lesion in a stenotic segment fails, the usual response was to insert a temporary catheter and plan for a new access [5].

The number of access sites available for each patient is limited. In addition, failure of stenotic segment affects the quality of life and life expectancy of patients on dialysis, based on Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines. KDOQI recommends early detection and treatment of all hemodynamically impaired vascular access [1], as early re-exploration and management of the vascular access often results in salvage of the access.

Dealing with hemodialysis access complications and restoring its normal function could be done either by classical surgery or endovascular procedures. Open surgery causes significant tissue damage and the treated fragment cannot be temporarily punctured. Endovascular interventions in dealing with dialysis problems can be less invasive, more effective, and less stressful on patients compared with open surgical procedures. In addition, they provide quicker return to daily activities, especially in older, debilitated individuals. However, endovascular procedures also have their limitations. They require exposure to radiograph and administration of contrast medium that may be nephrotoxic or allergic [6].

In the recent years, duplex ultrasonography plays a vital role in imaging of endovascular procedures of dialysis fistulas. Endovascular procedures coupled with ultrasonography gives a simple and reliable visualization of vessels forming fistula, avoids the hazards associated with radiological imaging, and lowers the financial burden.

Benefits associated with ultrasound guidance during intravascular procedures compared to radiological imaging include the following: avoiding nephrotoxic contrast administration, radiograph exposure, and lowering the costs. Elimination of contrast is particularly important in patients with advanced chronic renal failure during a predialysis period and in people with contrast allergies. There are also significant technical advantages including the ability to directly visualize puncture sites, stenosis, thrombus, spasm, and extravasation in real-time. By using duplex one is also able to directly measure the diameter of treated vessels, which facilitates the accurate sizing of balloons and stents. The ability to measure diameter, flow velocity, and volume flow also provides the opportunity to objectively and quantitatively assess the need for and the results of intervention [7].

So, this study aimed at evaluation of the effectiveness of duplex-guided balloon angioplasty for salvage of failing accesses and maintain their function.

Patients and methods

Study setting and population

Our interventional study included all patients with end-stage renal disease on hemodialysis who developed AV fistulae failure or those with nonmaturing hemodialysis access in Suez Canal University Hospital. Criteria of AV fistula failure included; failure of usage in hemodialysis, reduced thrill of the vascular access, decreased dialysis flow rate defined by KDOQI guidelines [1], 'access flow less than 600 ml/min, or less than 1000 ml/min with more than 25% decrease over a four-month period,' stenosis detected by duplex ultrasound (fistula diameter <6 mm), or nonmaturation of an AV fistula after 4 weeks postconstruction due to stenotic lesions. One or more of these findings suggest AV fistula failure. The project was ethically approved by the Institutional Ethical Committee of the Faculty of Medicine, Suez Canal University. Informed consent was obtained from all individual participants included in the study. All patients with decreased arterial pressures (systole <120), infected fistula, aneurysmal dilatation, bleeding AV fistulae, central vein pathology, nonmaturing hemodialysis access that did not complete 4 weeks after creation, having atherosclerotic changes or coagulation disorder were excluded from the study.

Procedures and methods

Detailed history, examination, investigations, and imaging were performed to confirm the diagnosis and exclude patients with exclusion criteria. A radiologist starts by preoperative assessment for detecting stenotic lesions. Preoperative administration of intravenous heparin (50 mg/kg) was done, then the intervention was done under local anesthesia at the puncture site using 2% lidocaine. After gaining vascular access, both

antegrade and retrograde approaches are utilized depending upon the anatomical location of the stenosis. Following introduction of the guidewire (0.035 angled hydrophilic was used) through a needle, a 2-mm skin incision is made using a no. 11 scalpel blade. Subsequently, a vascular sheath (usually 6F that allow introduction of 6-mm balloons) is introduced into the fistula under ultrasound guidance. On the basis of ultrasound image of the stenotic lesion the diameter and length of the balloon is determined (by measuring the vessel diameter adjacent to the stenotic segment and oversizing by 1–1.5 mm. The diameter of balloon most commonly used was 5 mm). During angioplasty balloons were inflated up to 20 atmospheres for 1 min, inflation may be repeated up to three times. If the technique was successful, vascular sheath is removed and proline 4.0 is used to suture the punctured site. A dressing is then placed, vital signs are checked and the patient is discharged. The success of the procedure is assessed based on duplex and clinical determinants. Duplex findings with residual stenosis less than 30% or reduction in flow velocity ratio less than 2 and volume flow more than 300 ml/min were considered successful. Clinically, success of the procedure is suggested by improvement in perceptible murmur over dialysis fistula.

Statistical analysis

The results were analyzed using statistical package for the social sciences, version 20 (IBM Corp., Released 2011, IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY: IBM Corp.). Nonparametric tests were used for analysis; thus group differences were assessed using Kruskal–Wallis and Mann–Whitney *U* test. Likert score averages were given as mean±SD. *P* value less than or equal to 0.05 was set as a criterion for establishing statistical significance.

Results

Descriptive

This prospective study was conducted between February 2017 and February 2018 at Vascular Surgery Unit, Suez Canal University Hospital, Ismailia, Egypt. After obtaining approval from the local ethics committee and informed consent from the patient before intervention, the study included 20 patients, who fulfilled the definition of 'failing to mature' AVF or 'failing AVF.' A total of eight (40%) patients fulfilled the definition of 'failing to mature' AVF and 12 (60%) patients presented with 'failing AVF' (Table 1).

Characteristics of the study population are listed in Table 1. The mean±SD age was 57±14 years There were 14 (70%) male and six (30%) females, five (25%) patients were diabetic, 13 (65%) patients were hypertensive, seven (35%) patients have Ischemic Heart Disease, 10 (50%) patients have hyperlipidemia, and three (15%) patients have chronic liver disease with hepatitis C virus positive.

Table 2 shows data related to AVF. With respect to the types of AVF 11 (55%) patients presented with radiocephalic AVF, five (25%) patients presented with brachiocephalic AVF, four (20%) patients presented with brachiobasilic AVF with superficialization of basilic vein. The duration of time from AVF creation to first intervention range from 2 to 24 months.

Multiple stenotic lesions were present in 12 (60%) individuals. A single stenotic lesion was present in eight (40%). The frequency and the distribution of vascular stenosis were as follows. arterial anastomosis stenosis three (15%); peripheral vein stenosis five (25%); juxta-arterial with peripheral vein stenosis 12 (60%).

Table 1 Background characteristics of the studied sample (*N*=20)

Characteristics	*n* (%)
Sex	
Male	14 (70)
Female	6 (30)
Age (mean±SD) (years)	57±14
Chronic illness	
Diabetes	5 (25)
Hypertension	13 (65)
Hepatitis C	3 (15)
Hyperlipidemia	10 (50)
Cause of nonfunctioning	
Nonmaturity	8 (40)
Stenosis	12 (60)

Table 2 Data related to arteriovenous fistula (*N*=20)

Variables	Frequency (%)
Types of AVF	
Radiocephalic AVF	11 (55)
Brachiocephalic AVF	5 (25)
Brachiobasilic AVF with superficialization of basilic vein	4 (20)
Site of stenosis among the stenotic fistulas	
Juxta-arterial with peripheral vein stenosis	12 (60)
Peripheral vein stenosis	5 (25)
Arterial anastomosis stenosis	3 (15)
Fistula salvage rate	
Successful	18 (90)
Failed	2 (10)
Postintervention complications	
Local hematoma	4 (20)
Signs of inflammation	2 (10)

AVF, arteriovenous fistulas.

Technique Outcomes

Postintervention duplex ultrasound showed that in 18 (90%) patients the angiographic procedure succeeded in increasing the AVF blood flow. In contrast, in two (10%) cases fistulas failed during hemodialysis after intervention due to complete occlusion by thrombus and persistence of AVF 'immature' state, respectively.

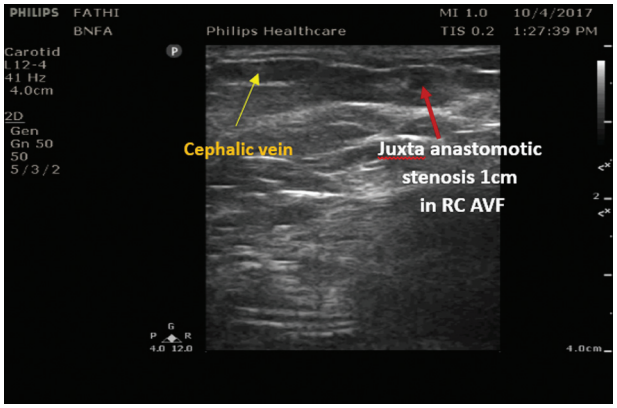
Table 3 shows statistically significant increase in both fistula diameter (P=0.005) and flow rate after (P=0.005) using percutaneous transluminal balloon angioplasty. Figures 1–5 show example of successful intervention for failing to mature fistulae.

Table 3 Variables related to AV fistula before and after using percutaneous transluminal balloon angioplasty intervention (N=20)

Variables	Mean±SD	*P* value
Diameter (mm)		
Preintervention	1.71±0.29	0.005*
Postintervention	3.37±0.43)	
Flow rate (ml/min)		
Preintervention	258±70.30	0.005*
Postintervention	552±48.29	

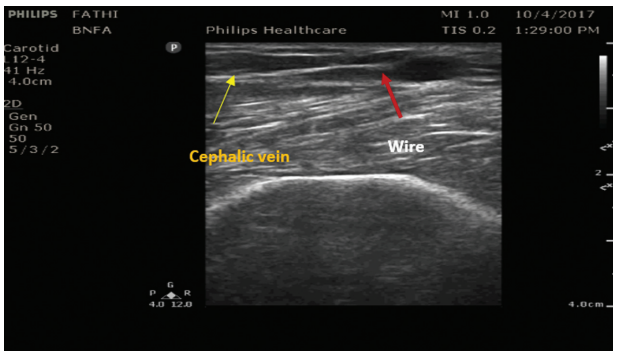
*P values are based on Wilcoxon's rank sum test as appropriate. Statistical significance at P value less than 0.05.

Figure 1



Preoperative duplex ultrasound showed stenotic lesion 1 cm length juxta-anastomosis in the venous limb.

Figure 2



Duplex-guided wire insertion.

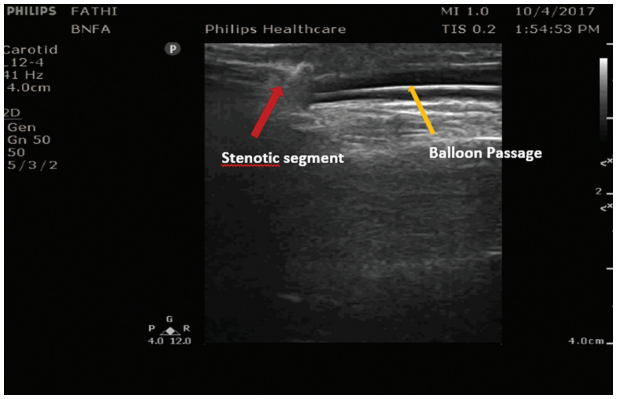
Complications

Four (20%) cases developed local hematoma. In three of them blood dissected into surroundings causing pain and ecchymosis. Hot fomentations successfully treated all of these patients. Two (10%) cases showed signs of inflammation 1 week later and that was controlled by antibiotics and anti-inflammatory medications. No case lost an AVF as a result of the procedure.

Follow up

All 18 patients whose fistulas were salvaged successfully were followed up for a minimum of 3 months. Regular duplex assessment of the salvaged AVF was performed every month to assess patency and flow rate. One patient lost his access as a result of complete occlusion by thrombus after a trial of thrombectomy with fogarty catheter, and another due to persistence of immaturity despite intervention.

Figure 3

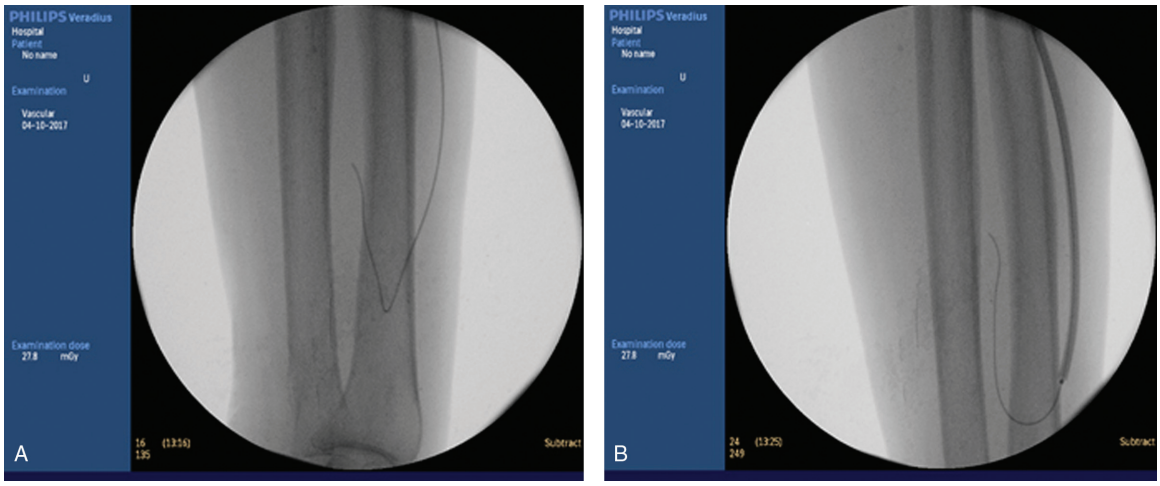


Balloon passage through stenotic lesion.

Figure 4

Post angioplasty assessment.

Figure 5



Fluoroscopic imaging of the procedure.

Discussion

This study was conducted to evaluate the efficacy of duplex-guided percutaneous transluminal angioplasty in salvage of failing to mature or nonfunctioning AVF. The study showed a success rate 80% evidenced by improved palpable thrill, residual stenosis less than 30%, and providing adequate blood flow for hemodialysis. Stenotic lesions of AVF are the most common anatomical causes of thrombosis and account for ~85% of cases of fistula dysfunction [2]. Other causes of thrombosis include hypotension, external compression, hematoma, pseudoaneurysmal formation, trauma, or infection [2]. The pathogenesis of venous stenosis is not fully understood. Stenosis is produced by neointimal proliferation, which has been attributed to the effects of increased venous pressure and turbulent blood flow [8].

To enable the usage of endovascular techniques for immature AVF in predialysis patients and to avoid contrast nephrotoxicity, recent studies are made depending on duplex ultrasound guidance to treat AVF stenosis [4,7,9]. Since the AV accesses are constructed to be superficial, they can be easily assessed with duplex scan imaging, moreover are quite simple to access and manipulate. Since depth and calcification are not an issue, the visualization of the balloons, wires, and sheaths are easier with duplex-guided balloon angioplasty of AVF as compared to the other sites. This extension of using duplex scan imaging to diagnose the problem to actually guiding the intervention represents the only way for patients with renal insufficiency not yet on dialysis in whom dye exposure could be detrimental or those with severe dye allergy.

The most common site of stenosis revealed by this study is juxta-arterial anastomosis followed by peripheral vein stenosis, encountered in about 70% of cases. This may be due to technical manipulation during creation of the access or successive neointimal formation in response to the increased blood flow. Turmel-Rodrigues *et al.* [10] reported the same in his study, two-thirds of stenosis occur distal to the anastomotic area, whereas the remaining third occurs in the venous limb proximal to the anastomosis.

The successful salvage rate in the current study of these nonmaturing and failing fistulas was about 80% that is greater than that of Miquelin *et al.* [11], which showed a salvage rate of 55%. Bhat *et al.* [12] showed slightly higher salvage rate of 88%. Close but slightly lower rate was showed by Falk [13], who stated that his salvage rate was 74%. Fox *et al.* [7] performed 223 cases of duplex-guided hemodialysis access angioplasty with a success rate 98.2% with a result that this procedure could be done as an office-based procedure. Ascher performed 32 office-based ultrasound scan-guided balloon angioplasties of stenosed autologous AVF among 25 patients, all procedures were successfully completed without fluoroscopy and contrast material. There were no systemic complications. One (3%) patient developed an arm hematoma due to focal vein rupture that was controlled by a hand compression for 20 min. An additional patient (3%) had a focal intraluminal dissection not obstructing the flow [9].

Two approaches are used in this study according to the diagnosed lesions. The arterial approach has the advantage of being in the same direction of blood flow, providing access to correct any arterial stenosis. The venous access is also used in peripheral vein stenosis, it has the advantage of less hematoma formation and avoids arterial puncture [9].

The study has some limitations as duplex imaging cannot be extended to the central veins to identify any stenosis or obstruction. If duplex scan imaging suggested a central vein stenosis or physical exam suggested a pulse extending to the shoulder area or superficial veins on the chest wall, fluoroscopy or computed tomography venography (CTV) were used. Only limited number of cases were included in the study; this was mainly because patients presented with delayed completely thrombosed AVF. They did not follow regular examination to detect any abnormalities in the blood flow of the hemodialysis access.

The study proves that duplex-guided percutaneous transluminal angioplasty for salvage of hemodialysis access is a safe procedure with limited complications. All the complications encountered in the study, such as local hematoma formation were treated conservatively. None of the patients included in the study lost his access due to intervention. Although we should admit that intervention was not successful in one case that still did not provide adequate blood flow for hemodialysis, this is mainly attributed to the general condition of the patient as hypotensive blood pressure could not be controlled. Another case revealed rethrombosis during the follow up period, a trial of thrombectomy was done. We must admit that endovascular angioplasty of the nonmaturing and failing AVF does not eliminate the need for additional vascular surgery in some patients. This was evident in our study by the cases that persist in nonmaturity state and restenotic cases that needed trials of thrombectomy; however, we strongly believe that endovascular treatment should be attempted before surgery is considered. This was recommended by Turmel-Rodrigues *et al.* [10] who have demonstrated that endovascular treatment is associated with excellent success rates, low complication rates, and promising long-term patency rates.

Finally, it is important to set strategy to increase AVFs longevity; as this dialysis access might be the last access for dialysis. This strategy must incorporate the efforts of the nephrology team, the vascular surgeons, the dialysis unit staff, and interventional radiology team. At a minimum, this strategy should be directed towards ensuring that every fistula newly created has an opportunity to mature and become a useable access and ensuring that every functioning fistula has the best opportunity for longevity. Duplex-guided percutaneous transluminal angioplasty should be the first option as a safe and effective method in treatment of early-detected AVFs who are failing to mature or there is stenotic lesions impending their appropriate function.

Conclusion and recommendations

Duplex-guided balloon angioplasty of nonmaturing and failing AVF is a safe and effective procedure. It is associated with high success rates, low complication rates, and maintained long-term patency of the hemodialysis access.

Regular survey by duplex for the new hemodialysis access should be done to detect failure to mature fistulas within 1 month to undergo early intervention. Also regular clinical and radiological assessment of functioning hemodialysis access to detect any abnormality or functional deficiency to undergo early intervention. Duplex-guided balloon angioplasty as an emergency procedure should be facilitated and its service should be covered by health insurance. A protocol should be assigned between nephrology team, dialysis unit staff, and vascular surgeons to identify and manage failing hemodialysis access. Training courses should be conducted for the vascular surgeons on the procedures as a safe and effective intervention.

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Nil.

Conflicts of interest

There were no doubt about the efficacy of duplex guided balloon angioplasty in restoring the function of failed hemodialysis access due to stenosis.

References

1 Daugirdas JT, Depner TA, JulaInrig, Mehrotra R, Rocco MV, Suri RS, Weiner DE. KDOQI clinical practice guideline for hemodialysis adequacy: 2015 update. Am J Kidney Dis 2015; 66:884–930.

2 Tang S, Lo CY, Tso WK, Lo WK, Li FK, Chan TM. Percutaneous transluminal angioplasty for stenosis of arteriovenous fistulae: a review of local experience. 2013; 4:36.

3 American Association of Kidney Patients. Understanding your hemodialysis access options. 2011. Available at: https://aakp.org/product/understanding-your-hemodialysis-access-options/. [Last accessed 2018 Mar 24].

4 Gorin DR, Perrino L, Potter DM, Ali TZ. Ultrasound-guided angioplasty of autogenous arteriovenous fistulas in the office setting. J Vasc Surg 2012; 55:1701–1705.

5 Santoro D, Savica V, Bellinghieri G. Vascular access for hemodialysis and cardiovascular complications. Minerva Urol Nefrol 2013; 62:81–85.

6 Bojakowski K, Gora R, Szewczyk D, Andziak P. Ultrasound-guided angioplasty of dialysis fistula – technique description. Pol J Radiol 2013; 78:56–61.

7 Fox D, Amador F, Clarke D, Velez M, Cruz J, Labropoulos N, Ryan M, Gelman L. Duplex guided dialysis access interventions can be performed safely in the office setting: techniques and early results. Eur J Vasc Endovasc Surg 2011; 42:833–841.

8 Campos RP, Do Nascimento MM, Chula DC, Do Nascimento DE, Riella MC. Stenosis in hemodialysis arteriovenous fistula: evaluation and treatment. Hemodial Int 2016; 10:152–161.

9 Ascher E, Hingorani A, Marks N. Duplex-guided balloon angioplasty of failing or nonmaturing arterio-venous fistulae for hemodialysis: a new office-based procedure. J Vasc Surg 2015; 50:594–599.

10 Turmel-Rodrigues L, Pengloan J, Blanchier D, Abaza M, Birmelé B, Haillot O, Blanchard D. Insufficient dialysis shunts: improved long-term patency rates with close hemodynamic monitoring, repeated

percutaneous balloon angioplasty, and stent placement. Radiology 2017; 187:273–278.

11 Miquelin D, Reis L, da Silva A, de Godoy J. Percutaneous transluminal angioplasty in the treatment of stenosis of arteriovenous fistulae for hemodialysis. 2014. Available at: http://www.intarchmed.com/content/1/1/16

12 Bhat R, Mcbride K, Chakraverty S, Vikram R, Severn A. Primary cutting balloon angioplasty for treatment of venous stenoses in native hemodialysis fistulas: long-term results from three centers. Cardiovasc Interv Radiol 2017; 30:1166–1170.

13 Falk A. Maintenance and salvage of arteriovenous fistulas. J Vasc Interv Radiol 2016; 17:807–813.