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Research article

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Endovascular treatment of nonfunctional vascular access through retrograde arterial access: A single-center experience with midterm follow-up

Umut Oguslu, Burçak Gümüş

Okan University Hospital, Department of Radiology, Istanbul, Turkey

ORCID ID of the author(s)
UO: 0000-0001-7985-0734
BG: 0000-0002-3933-7263

Corresponding Author
Umut Oguslu
Aydinli Cad. No: 2 Okan Universitesi Hastanesi Icmeler, Tuzla, Istanbul, Turkey
E-mail: umutoguslu@gmail.com

Ethics Committee Approval
The study was approved by the Institutional Review Board (IRB) of Okan University Hospital (Number: 56665618-204.01.07).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Nonfunctional vascular access is treated through venous or brachial artery access traditionally. However, each route has its drawbacks. This study aimed to evaluate the feasibility, safety, and effectiveness of retrograde arterial access (RAA) in the treatment of nonfunctional vascular access with mid-term results.

Methods: Patients with nonfunctional vascular access who were treated through RAA between January 2019 and December 2020 were included in this cohort study. Patient demographics, lesion characteristics, procedural details, technical and clinical outcomes were noted.

Results: Thirty-six interventions were performed on 30 patients. Twenty-nine occlusions and seven long segment stenoses were treated. The radial artery was accessed in 34 cases, the interosseous and ulnar arteries were accessed in one case each. The technical and clinical success rates were 100% and 97.2%, respectively (35/36). Venous rupture was encountered in three patients. No puncture-site complication was observed. The mean follow-up time was 14.3 (range: 6-24) months. None of the patients showed signs of hand ischemia and the accessed arteries were patent at Color Doppler Ultrasound examinations. Post-intervention primary patency rates were 100%, 73.3%, 47.5% at 1, 6 and 12 months, respectively. Post-intervention secondary patency rates were 100%, 93.3%, 84.8% at 1, 6 and 12 months, respectively.

Conclusion: RAA is effective and safe in the treatment of nonfunctional vascular access with comparable outcomes to traditional routes. The low access-site complication rates make this access site an attractive salvage route when traditional approaches are not feasible.

Keywords: Retrograde arterial access, Vascular access, Transradial access, Interventional radiology, Arteriovenous fistula

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Introduction

Permanent vascular access is needed to maintain adequate hemodialysis for patients with end-stage kidney disease (ESKD). National Kidney Foundation Dialysis Outcomes Quality Initiative (NKF-KDOQI) 2019 guidelines suggest an autogenous arteriovenous fistula (AVF) placement as the first-line option of vascular access, followed by prosthetic arteriovenous grafts (AVG) in preference to central venous catheters due to lower infection rates, if it is consistent with the patient's ESKD Life Plan [1, 2].

Percutaneous transluminal angioplasty was widely used as the first-line treatment of nonfunctional hemodialysis access [1, 3]. The traditionally used technique is percutaneous direct antegrade/retrograde venous access [4]. Brachial artery access was proposed for when the venous route is not feasible [3]. However, each route has its advantages and drawbacks [5]. Retrograde arterial access (RAA) through the radial artery is widely accepted as the primary access for coronary interventions due to its minimally invasive nature, and low access site complication rates [6, 7]. Also, transulnar access (TUA) was found to be safe when transradial access (TRA) cannot be used [8]. Experience in the non-coronary intervention era is still growing [9-11]. However, there is still limited data on the use of RAA in vascular access interventions.

The objective of this study was to report the feasibility, safety, effectiveness, and mid-term follow-up results of the endovascular treatment of nonfunctional vascular access through RAA.

Materials and methods

Study design and patient population

This cohort study was designed as a retrospective file review and the protocol was approved by the institutional ethics committee of Okan University Hospital (No:56665618-204.01.07). The medical records of 212 patients with ESKD who underwent endovascular treatment of nonfunctional AVG and AVF between January 2019-December 2020 were reviewed. Patients fulfilling the following criteria who were treated with retrograde arterial access were included: (1) Long segment stenotic/occluded downstream vein of AVF/AVG that precluded venous access (2) Multi-level lesions (3) A negative Allen's test. The exclusion criteria were as follows: (1) Severely calcified arteries (2) Infected AVFs/AVGs (3) End-to-end radial-cephalic anastomosis (4) History of severe contrast media allergy. All patients gave written consent before the initial treatment; however, informed consent was waived.

The radial artery was preferred when (1) the radial-cephalic fistula anastomosis was located >2 cm proximal to the styloid process, (2) the radial artery diameter was >2 mm, (3) the Allen test was negative. TRA was contraindicated when (1) the radial artery had a high origin that is proximal to the brachial-cephalic/basilic fistula location, (2) a severe, circumferential calcification, (3) occluded radial artery. When TRA was not technically feasible, the interosseous artery or the ulnar artery was used as an alternative access site per the operators' discretion.

Endovascular treatment

Vascular access was obtained with a micropuncture set (Mini Access Kits, Merit MAK™, Merit Medical South Jordan, Utah, USA). The artery was punctured under sonographic guidance with a 21G needle. 0.018" guidewire was inserted and a 4F introducer sheath was advanced. The system was upsized to a 6F sheath (Glidesheath Slender, Terumo, Tokyo, Japan) over a 0.035" guidewire. The sheath was flushed with a combination of nitroglycerin (100 mcg) and verapamil hydrochloride (2.5 mg) every 15-20 minutes to avoid vasospasm. A bolus dose of 5000 IU, followed by an infusion of 1000 IU/h unfractionated heparin were administered to maintain the activated coagulation time (ACT) between 250–300 s.

Stenotic/occluded segments were passed with a combination of 0.018" guidewire (Boston Scientific, Marlborough, MA, USA), or a 0.035" hydrophilic guidewire (Radiofocus®, Terumo Medical Corporation, Tokyo, Japan), and 4-5F vertebral catheters (Cordis, Hialeah, Florida, USA). Balloon angioplasty was performed with 6-10 mm-diameter balloon catheters (Sterling, Boston Scientific, Marlborough, MA, USA). Self-expandable stents (Innova™, Boston Scientific Corp, Natick, MA, USA) were used under the following circumstances: (1) A residual stenosis of more than 30% (2) Persistent leaks after balloon angioplasty.

In patients with acutely thrombosed AVFs/AVGs, first, the intravenous cannulas were inserted in the thrombosed segments, and a total dose of 2-4mg tissue plasminogen activator (tPA) alteplase (Actilyse®, Boehringer-Ingelheim, Ingelheim am Rhein, Germany) diluted in 20cc saline was administered at a rate of 1-2 mg/h. Subsequently, aspiration thrombectomy was performed with 6F catheters and the balloon was inflated at a low pressure to macerate the thrombi. Once blood flow was reestablished, a diagnostic angiogram was obtained to elicit the culprit lesion. The stenotic segments were treated with balloon angioplasty (Figure 1).

Hemostasis was achieved with manual compression or a radial compression device (TR band, Terumo Medical Corporation, Tokyo, Japan).

Outcomes

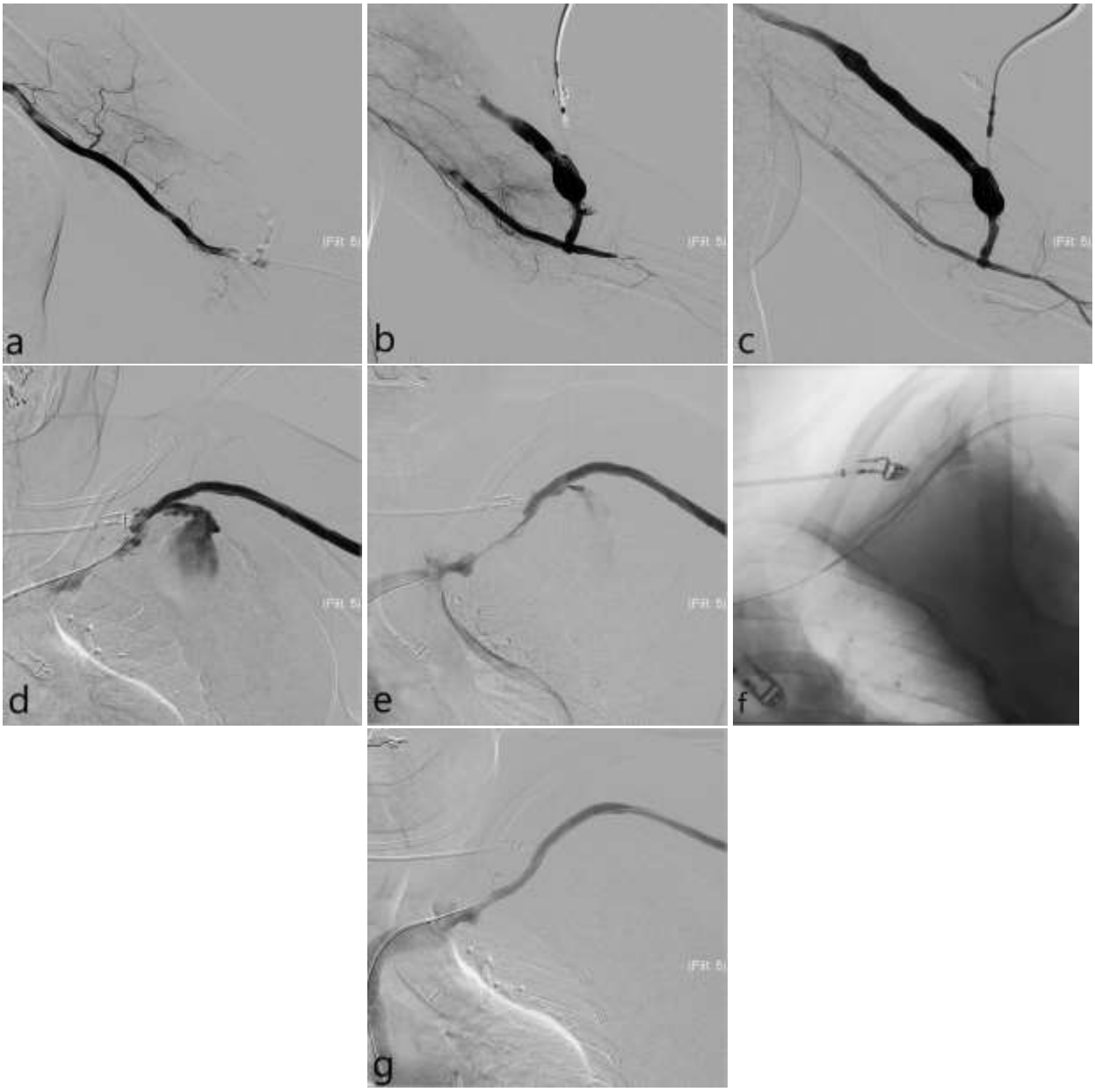
Complications and outcomes were classified according to the guidelines of the Society of Interventional Radiology [12] and recommended standards defined by Sidawy et al [13]. Technical success was defined as less than 30% residual stenosis at the endpoint of the intervention. Clinical success was defined as at least one successful dialysis session following endovascular treatment.

Post-intervention primary patency was defined as the interval after endovascular treatment until thrombosis or the need for reintervention due to unsuccessful hemodialysis. Post-intervention secondary patency was defined as the interval after endovascular intervention until access abandonment or thrombosis.

Follow-up

All interventions were outpatient procedures. After the first successful dialysis session, an initial follow-up examination was scheduled at the first week, 1, 3, 6, 12 months, and annually thereafter. AV access and the radial artery were evaluated with clinical examination and color Doppler ultrasound (CDUS). All

Figure 1: A 49-year-old female presented with a sudden loss of thrill. (a) Diagnostic angiogram demonstrates complete occlusion of the brachial-cephalic fistula. (b) Control fistulogram following 2 mg tPA infusion shows partial recanalization. (c, d) Subsequent balloon angioplasty, fistulography demonstrates complete restoration of flow. Residual stenosis, venous rupture, and contrast extravasation at cephalic arc are observed. (e, f) Leak persisted after stent placement and a telescoping construct was formed with second stent deployment. (g) Completion angiography shows restoration of the flow and complete cessation of the leak.



patients were followed at their respective hemodialysis unit or via telephone interviews. The patients were referred for further evaluation when signs of vascular access dysfunction were detected.

Statistical analysis

A power analysis was performed with G*Power version 3.1.9.2 to determine the sample size. A minimum number of 26 samples was calculated to reach a power level of 0.8.

The frequency distribution of qualitative variables and the mean and standard deviation of continuous variables were reported as descriptive statistics. The number of endovascular interventions per patient was found. Kaplan–Meier analyses were used to estimate cumulative patency rates. All analyses were performed using IBM SPSS Statistics version 23 software (SPSS Statistics v23, IBM Corporation, Somers, New York).

Results

Thirty-six RAA procedures were performed on 30 patients. Eight were male and the mean age was 62.5 (range: 26-79) years. Patient demographics, and vascular access characteristics are presented in Table 1. Among all, 26.7% (8/30) of the patients were diabetic, and 33.3% (10/30) had a history of coronary artery disease. None of the patients were current smokers. All patients had mature AVF/AVG before nonfunction. Twenty-six patients had autogenous vascular access, while four patients had non-autogenous vascular access with a prosthetic graft.

Lesion characteristics, procedural details, and the outcomes are presented in Table 2. The treatment indication was long-segment stenosis in seven cases and long segment occlusion of AV access in 29 cases. In the occlusion group, the culprit lesion was perianastomotic stenosis in 16 cases, cephalic arch stenosis in 4 cases, brachiocephalic vein stenosis in 5 cases, intent stenosis in 2, and hypertrophic valve in one case. In one case, the etiology of the thrombosis could not be elicited. One

patient had multilevel lesions, long segment occlusion of the AVG and downstream vein, and concomitant short segment stenosis of the central veins. Treatment was attempted within 48 hours of acute occlusion in all cases.

Table 1: Patient demographics and vascular access characteristics

Variable	Number or mean	% or range
Age	62.5	26-79
Sex		
Male	8	36.4
Female	22	63.6
Treated limb		
Right	12	40
Left	18	60
Comorbidities		
Diabetes mellitus	8	26.7
Cardiovascular event	10	33.3
Hypertension	14	46.7
Type of vascular access		
Autogenous	26	86.7
Prosthetic	4	13.3
Vascular access location		
Brachial-cephalic	14	46.8
Brachial-basilic	12	39.9
Radial-cephalic	4	13.3
Previous endovascular intervention	4	13.3

Table 2: Lesion characteristics, procedure details, outcomes

Variables	Number or mean	% or range
Lesion type		
Stenosis	7	19.4
Occlusion	29	80.6
Lesion length (cm)	30.3	7-46
Access site		
Radial	34	94.4
Ulnar	1	2.8
Interosseous	1	2.8
Complications		
Major	0	0
Minor	3	8.3
Technical success	36	100
Clinical success	35	97.2

The radial artery was accessed in thirty-four procedures. One patient with a history of coronary intervention presented with a completely occluded autogenous brachial-cephalic forearm fistula. The radial artery was occluded at CDUS examination. In this case, endovascular treatment was performed via interosseous artery access. One patient presented with rethrombosis of the AVG. CDUS showed an irregular and thickened wall of the radial artery owing to the previous intervention, but no significant stenosis was detected. The ulnar artery was used as the access site.

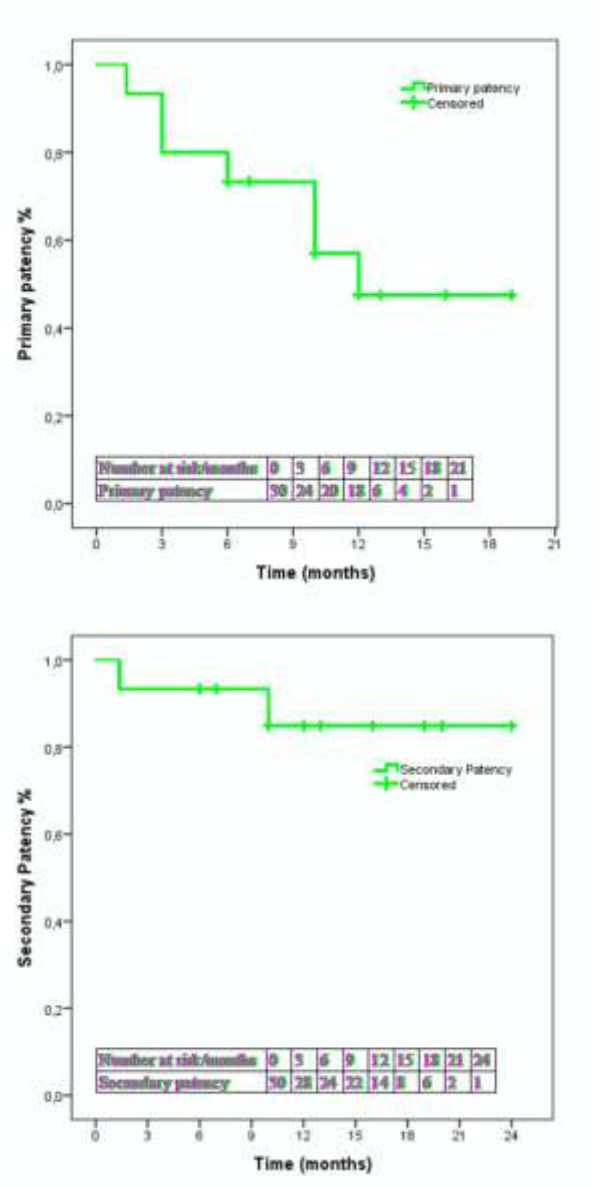
Retrograde arterial catheterization was performed successfully in all procedures. After angiography, residual stenosis was <30% in all lesions, corresponding to a technical success rate of 100%. In 35/36 cases (97.2%), patients underwent at least one successful dialysis session after the treatment. One patient developed rethrombosis two days after the treatment. Physical examination revealed extensive arm edema and RDUS showed acute thrombosis in the outflow vein. After consulting with the nephrologist and vascular surgeon, dialysis access was abandoned, and a tunneled central venous catheter was placed through the right internal jugular vein. Eventually, new vascular access was created by placing a prosthetic brachial-basilic straight graft.

No major complication was observed during the hospital stay. Venous rupture occurred in three patients (3/36 [8.3%]) after balloon dilation. The rupture site was the perianastomotic vein in two patients, which was treated with prolonged balloon inflation with low pressure and manual compression. Venous rupture at the cephalic arch site with subsequent expansive chest wall hematoma was encountered in the other case. Extravasation persisted even after three prolonged balloon inflations for three minutes. A combination of bare stent placement and prolonged balloon inflation was used but failed to halt bleeding. Eventually, a second bare stent was placed within the first stent to form telescoping stenting. Extravasation ceased immediately. The patient recovered well and underwent successful dialysis sessions.

Distal embolism into the arterial circulation was not encountered in any of the patients. All three distal access arteries were patent in all patients after the procedure and at follow-up on CDUS examination. None of the patients developed significant (>70%) stenosis or signs of hand ischemia.

The mean follow-up was 14.3 (range 6-24) months. The post-intervention primary patency rates were 100%, 73.3%, 47.5% at 1, 6 and 12 months, respectively. A mean of 1.6 interventions was performed per patient to maintain adequate dialysis during the follow-up period. The post-intervention secondary patency rates were 100%, 93.3%, 84.8% at 1, 6 and 12 months, respectively (Figure 2).

Figure 2: (a, b) Kaplan-Meier curves showing estimated primary and secondary functional patency rates



Discussion

Our retrospective patient series showed excellent technical success rates (100%) with high clinical success (35/36 [97.2%]) in the treatment of nonfunctional AV access through retrograde arterial access in patients in whom traditional routes were not feasible. A relatively high complication rate (3/36 [8.3%]) was encountered, which was managed by endovascular means, and no access site complication was observed.

Traditionally, vascular access lesions are treated through direct venous access with a retrograde or antegrade fashion. Though most lesions are treated successfully, this route has some distinct disadvantages. A second sheath is needed when multilevel lesions are detected. When AV access is occluded, retrograde injection of the contrast media through the venous access might not reveal the anastomosis site and afferent artery structure. Retrograde injection of contrast media might result in the dislodging of the thrombi into the arterial branches. The brachial artery has been used as an alternate route to overcome this issue, but puncture site complication rates are reported as up to 12% [3, 7]. Achieving hemostasis after brachial sheath removal can be troublesome, especially in obese patients, and inadvertent manual compression of the access site may lead up to rethrombosis of the AV access.

RAA offers several advantages to overcome these drawbacks. It is possible to visualize the entire conduit clearly, while contrast media is injected close to the anastomosis site with an antegrade fashion. The venous route has potential kinks and steep angulations, and the brachial route has a U-turn at the anastomosis site. In contrast, RAA has a straighter course that gives increased torque ability to the wire tip and increases support in advancing devices. One sheath is enough to treat multi-level lesions of the outflow vein and central veins [14]. Achieving hemostasis is relatively safer, and access site-related complications (prolonged bleeding time, hemorrhage, vasospasm) do not cause compromised blood flow in vascular access, which reduces the risk of early rethrombosis [5, 15]. In complex cases, in which the proximal radial artery is anastomosed to the perforator of the median antecubital vein (Gracz fistulae), catheterizing the anastomosis site through the retrograde venous route might be quite challenging [16]. RAA will facilitate the guidewire to directly pass through the anastomosis that will shorten the procedure time and forestall unsuccessful guidewire manipulations.

There are also drawbacks to RAA. First, although, most lesions can be treated with ≤6F sheaths safely, larger sheaths are needed when central venous lesions coexist, which will increase the risk of post-intervention access artery occlusion [17]. However, if a satisfactory collateral flow in the hand is confirmed with both the Allen test and a CDUS examination, the repercussion of this result is negligible [18]. Second, a high origin of the radial artery from either the brachial or axillary artery has a prevalence of up to 7% [19]. When the brachial artery is used as an inflow artery of the conduit, careful CDUS examination is crucial to exclude this variation to avoid unnecessary punctures. When a high origin of the radial artery variation is encountered, brachial or interosseous/ulnar artery might be the preferred access site. Third, if the conduit is created with a prosthetic brachial-antecubital forearm loop graft, catheterization of the anastomosis site and advancing balloon catheters over the guide wires might be problematic owing to the steep angulation. Fourth, the prevalence and severity of vascular calcification are higher in dialysis patients than in the other groups, which makes radial and other hand arteries more challenging [20]. In these cases, the crisscross technique or antegrade brachial artery access could be a better option.

A few studies are investigating the feasibility, safety, and effectiveness of RAA in the treatment of nonfunctional AV access [5, 14, 21-26]. Most studies include autogenous radial-cephalic direct wrist access. Wang et al. treated 69 lesions (65 stenoses, 4 total occlusions) in 49 patients with radial-cephalic fistulae. Forty-two (60.9%) patients had perianastomotic outflow vein stenosis. They reported a technical success of 91.3% (63 of 69 lesions) and clinical success of 96% (48 of 50 lesions) [21]. Le et al. performed 50 therapeutic procedures through TRA. They achieved a technical success rate of 88% and a clinical success rate of 84%. They also reported the functional patency rates of 88.5%, 84.2%, and 83.0% at 1, 6, and 12 months, respectively [22].

In the current study, we achieved a technical success rate of 100%, and a clinical success rate of 97.2%, which is corroborated with previous reports using either traditional routes or TRA [3, 4]. Our primary and secondary patency results were also comparable with early studies and NKF-KDOQI recommendations [4, 27, 28]. The complication rate (3/36 [8.3%]) was higher than previous reports [29]. Venous rupture was encountered in three patients with totally occluded AV access. The use of tPA in addition to high dose heparin might explain the high rate of bleeding complication.

Post-intervention radial artery occlusion was reported within a wide range, between 0.8-38% [30]. Chen et al. treated 131 patients with dysfunctional Brescia-Cimino fistula. A 6F sheath was placed through TRA. Sixteen patients had multiple radial artery punctures for reintervention during follow-up. They reported weak radial artery pulse in two patients, but no occlusion was observed [15]. Lin et al. [25] performed 165 interventions in 101 patients (69 AVG, 32 AVF). They reported distal embolism in three patients, which were treated by surgical interventions. Severe vasospasm was encountered in two patients, in whom additional access was required to perform endovascular treatment. Using higher doses of heparin and shorter compression times reduces the risk of radial artery occlusion after intervention [31, 32].

In our study, accessed arteries were patent at CDUS examinations performed before discharge and follow-up visits. No major complication was observed at the puncture site. One patient presented with rethrombosis of the AV access six months after the initial intervention. The radial artery wall was thickened and irregular. The lumen was patent, and flow dynamics were within normal limits. Treatment was performed through TUA without any access site complications.

Limitations

The limitations of our study include the sparse number of patients, and its retrospective nature, which made randomizing impossible. In addition, the number of patients in whom the ulnar artery and interosseous artery were used for access was limited, and they were utilized only when transradial access was not

eligible. RAA was preferred over antegrade brachial artery access at the operators' discretion, which may cause selection bias. RAA was the only route used for treatment; therefore, comparing it with venous and/or brachial artery routes was not possible. Long-term results are needed.

Conclusion

Our study demonstrated that RAA is feasible, safe, and effective in the treatment of nonfunctional AV access with high technical and clinical success rates. Low access site complication rates make this access site an attractive salvage route when traditional routes are not feasible.

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