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Original Research Article

Role of Percutaneous Endovascular Interventions in the Treatment of Failed Hemodialysis Fistula

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ABSTRACT

Background: Arteriovenous fistula is the preferred vascular access for patients requiring long-term hemodialysis because of its superior patency and lower complication rates. However, AVF (Arteriovenous Fistula) dysfunction caused by venous stenosis and thrombosis remains a major cause of access failure, compromising dialysis adequacy. PTA (Percutaneous Transluminal Angioplasty) has emerged as the first-line minimally invasive treatment for restoring fistula patency and prolonging vascular access survival. This study evaluated the procedural efficacy, safety, and short-term clinical outcomes of percutaneous endovascular intervention in failed hemodialysis fistulas.

Methods: A prospective longitudinal observational study was conducted in the Department of Radiodiagnosis, Government Medical College, Kozhikode, from June 2021 to June 2022. Forty patients with dysfunctional AVFs due to outflow vein stenosis who underwent percutaneous angioplasty were included. Clinical examination, Doppler ultrasonography, and angiographic findings were used for diagnosis and procedural planning. Balloon angioplasty was performed through arterial or venous access depending on lesion characteristics. Immediate technical success was defined by restoration of blood flow, successful recanalization, and reappearance of thrill, while clinical success was assessed by adequate dialysis flow and absence of restenosis during a 3-month follow-up. Statistical analysis was performed using SPSS version 22, with $p<0.05$ considered statistically significant.

Results: Among the 40 patients, radiocephalic fistulas constituted 62.5%, and combined fistula and outflow vein stenosis was observed in 97.5% of cases. Long-segment stenosis (90%) and total occlusion (85%) were the predominant lesions. Venous access was used in 75% of procedures, while fistuloplasty with venoplasty was performed in 97.5% of patients. Immediate technical success was achieved in 38 patients (95%), with only two technical failures due to inability to negotiate extensive thrombotic lesions. Minor access-site hematoma occurred in 5% of patients, with no major procedure-related complications. At 3-month follow-up, 36 of the 38 successfully treated patients (94.7%) maintained fistula patency, whereas two patients developed restenosis requiring repeat angioplasty. None of the demographic, clinical, or fistula-related variables demonstrated a statistically significant association with procedural or follow-up outcomes.

Conclusion: Percutaneous transluminal angioplasty is a safe, effective, and minimally invasive treatment for failed hemodialysis AVFs, providing a high immediate technical success rate (95%) and excellent short-term clinical patency with minimal complications. It should be considered the preferred first-line intervention for AVF dysfunction due to stenosis or thrombosis, helping preserve vascular access and improve dialysis outcomes.

Keywords: Arteriovenous Fistula, Hemodialysis, Percutaneous Transluminal Angioplasty, Endovascular Intervention, Vascular Access, Stenosis, Dialysis Access Failure.

INTRODUCTION

Chronic kidney disease is a major global public health challenge, affecting millions of people worldwide and contributing significantly to morbidity, mortality, and healthcare expenditure. As CKD (Chronic Kidney Disease) progresses to ESRD (End-Stage Renal Disease), renal replacement therapy becomes essential for patient survival, with hemodialysis being the most widely utilized treatment modality. Effective hemodialysis depends on reliable vascular access that ensures adequate blood flow for efficient removal of metabolic waste products and excess body fluid.

Among the available vascular access options, the AVF is regarded as the gold standard due to its superior long-term patency, lower infection rates, reduced thrombosis, and fewer complications compared with AVGs (Arteriovenous Grafts) and central venous catheters. Consequently, current clinical guidelines recommend AVF as the preferred vascular access for patients requiring long-term hemodialysis.

Despite these advantages, AVFs are prone to complications that may compromise their function, with stenosis being the most common cause of access dysfunction and eventual failure. Stenosis results primarily from pathological processes such as neointimal hyperplasia, intimal hyperplasia, and venous neointimal fibrous hyperplasia. These changes progressively narrow the vessel lumen, leading to reduced blood flow, inadequate dialysis, increased venous pressures, recurrent thrombosis, and ultimately loss of vascular access if left untreated.

Over the past decade, endovascular interventions have emerged as the preferred minimally invasive approach for the diagnosis and treatment of AVF stenosis. These procedures utilize guidewires, catheters, angioplasty balloons, cutting balloons, drug-coated balloons, and vascular stents to restore vessel patency and improve blood flow. Percutaneous transluminal balloon angioplasty remains the first-line treatment, while adjunctive techniques such as cutting balloon angioplasty and stent placement are reserved for resistant or recurrent stenotic lesions. These interventions have demonstrated favorable technical success rates, prolonged access patency, and improved dialysis adequacy while reducing the need for surgical revision.

Given the increasing prevalence of CKD and the growing dependence on long-term hemodialysis, evaluating the effectiveness of endovascular treatment for AVF stenosis has become increasingly important. A comprehensive assessment of clinical outcomes, procedural success, patency rates, complications, and factors predicting treatment success is essential for optimizing vascular access management, improving patient outcomes, prolonging AVF survival, and enhancing the overall quality of life of patients undergoing maintenance hemodialysis.

Aims and Objectives

The present study aimed to comprehensively evaluate the efficacy of percutaneous endovascular treatment for stenosis and failure of dialysis AVFs in patients undergoing maintenance hemodialysis. Specifically, the study sought to assess the role of percutaneous endovascular interventions in restoring the function of failed dialysis AVFs, identify the various clinical indications for undertaking these procedures, and evaluate their procedural safety and technical efficacy. In addition, the study aimed to determine the short-term clinical outcomes, including AVF patency and functional success, over a 3-month follow-up period among patients undergoing percutaneous endovascular management for failed dialysis AVFs at Government Medical College, Kozhikode.

MATERIALS AND METHODS

Study Design

This was a prospective, single-group longitudinal cohort study conducted over a period of 12 months, from June 2021 to June 2022, in the Department of Radiodiagnosis, Government Medical College, Kozhikode. Eligible patients were enrolled consecutively and followed prospectively to evaluate the procedural safety, efficacy, and short-term clinical outcomes following endovascular intervention.

Inclusion and Exclusion Criteria

The study included all patients with dysfunctional dialysis arteriovenous fistulas who presented with suboptimal dialysis and were scheduled to undergo percutaneous transluminal angioplasty. Eligible participants were those with a clinically dampened thrill over the AV fistula, poor dialysis flow rates, and Doppler ultrasonography demonstrating greater than 50% stenosis of the outflow vein. Patients were excluded if they had newly created (virgin) AV fistulas with poor thrill,

cellulitis involving the dialysis limb, or concomitant venous pseudoaneurysms, as these conditions could interfere with the safety or effectiveness of the endovascular intervention.

Sample Size Calculation

According to a previous study by Beathard GA et al., there was a 94% success rate for fistuloplasty.

The formula used for determining sample size is given below n=4pq/d 2, where P the is percentage of the composite outcome, which is taken as 94%; q is 100- p, d is the precision, which is taken as 10%. The sample size estimated using the above calculation is 23. However, to improve the accuracy of the study, the sample size used was 40.

Data Collection Procedure

After obtaining written informed consent, eligible patients with dysfunctional dialysis arteriovenous fistulas undergoing percutaneous transluminal angioplasty were enrolled in the study. Baseline demographic, clinical, and Doppler ultrasound findings, including the site, extent, and severity of stenosis or thrombosis, were recorded. All procedures were performed by a single experienced interventional radiologist under fluoroscopic guidance using a standardized protocol. Procedural details, including the access route, angiographic findings, balloon angioplasty, intraoperative events, technical success, and procedure-related complications, were documented. Following angioplasty, Doppler ultrasonography was performed to assess restoration of blood flow and fistula patency. Patients received standard postoperative anticoagulation and were followed up at 3 months with clinical evaluation, assessment of dialysis adequacy and fistula thrill, and duplex color Doppler ultrasonography to determine the clinical and radiological outcomes of the intervention.

Statistical Analysis

All collected data were coded, entered into Microsoft Excel, and verified for accuracy before being analyzed using Statistical Package for the Social Sciences (SPSS) software, version 22. Patient demographic characteristics, clinical findings, and procedural variables were analyzed using appropriate descriptive and inferential statistical methods. Categorical variables were summarized as frequencies and percentages. Associations between categorical variables were assessed using the Pearson chi-square test or Fisher's exact test, as appropriate. A *p*-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS

Variable	Category	n	%
Age (in years)	40–50	12	30.0
	50–60	17	42.5
	60–70	11	27.5
Habits	Nil	35	87.5
	Alcohol	3	7.5
	Smoking	2	5.0
Comorbidities	Nil	18	45.0
	DM	6	15.0
	HTN	9	22.5
	DM + HTN	7	17.5

Table 1. Baseline Characteristics of the Study Participants (N = 40)

Table 1 describes the baseline demographic and clinical characteristics of the study participants. Most patients were aged 50–60 years (42.5%), had no addictive habits (87.5%), and 45.0% had no associated comorbidities.

Variable	Category	n	%
Type of AVF	Radiocephalic	25	62.5
	Brachiocephalic	15	37.5
Age of AVF	<1 year	6	15.0
	1–2 years	14	35.0
	2–3 years	9	22.5
	3–4 years	8	20.0
	4–5 years	3	7.5

Table 2. Characteristics of Arteriovenous Fistulas (N = 40)

Table 2 illustrates the characteristics of AV fistulas. Radiocephalic AVFs were the predominant type (62.5%), while AVFs aged 1–2 years constituted the largest proportion (35.0%).

Variable	Category	n	%
Site of Stenosis	AVF + Outflow vein	39	97.5
	Outflow vein alone	1	2.5
Length of Stenosis	Long segment	36	90.0
	Short segment	4	10.0
Grade of Stenosis	High-grade stenosis	6	15.0
	Total occlusion	34	85.0

Table 3. Angiographic Characteristics of Stenosis (N = 40)

Table 3 demonstrates the angiographic findings of AV fistula stenosis. Combined AVF and outflow vein involvement (97.5%), long-segment stenosis (90.0%), and total occlusion (85.0%) were the predominant findings.

Variable	Category	n	%
Access Route	Venous	30	75.0
	Arterial	9	22.5
	Venous + Arterial	1	2.5
Procedure Performed	Fistuloplasty + Venoplasty	39	97.5
	Venoplasty alone	1	2.5

Table 4. Procedural Characteristics (N = 40)

Table 4 shows the procedural characteristics of endovascular intervention. Venous access was the preferred approach (75.0%), and nearly all patients (97.5%) underwent combined fistuloplasty and venoplasty.

Outcome	Category	n	%
Procedural Complications	None	38	95.0
	Hematoma	2	5.0
Immediate Technical Success	Success	38	95.0
	Failure	2	5.0

Table 5. Procedural Outcomes (N = 40)

Table 5 presents the immediate procedural outcomes. Technical success was achieved in 95.0% of patients, while procedure-related complications were uncommon, with hematoma occurring in only 5.0%.

Follow-up Status	n	%
No restenosis	36	94.7
Restenosis	2	5.3

Table 6. Three-Month Follow-up Outcome (N = 38)

Table 6 describes the clinical and radiological outcomes at three months. The majority of patients (94.7%) maintained fistula patency without restenosis, whereas only 5.3% developed restenosis.

Outcome	Significant Variables	p-value
Immediate Technical Success	None	All $p > 0.05$
Three-month Follow-up	None	All $p > 0.05$

Table 7. Association of Study Variables with Clinical Outcomes

Table 7 summarizes the association between study variables and clinical outcomes. Age, habits, comorbidities, AVF type, AVF age, site, length, and grade of stenosis showed no statistically significant association with either immediate technical success or three-month follow-up status ($p > 0.05$).

DISCUSSION

End-stage renal disease is a common condition associated with significant morbidity and mortality. The three most commonly used modalities for long-term hemodialysis access are AVFs, AVGs, and tunneled dialysis catheters. A well-functioning AVF provides adequate dialysis and serves as the lifeline for patients undergoing maintenance hemodialysis. Compared with synthetic grafts, AVFs offer several advantages, including lower infection rates, superior long-term patency, reduced risk of vascular steal syndrome, and decreased morbidity related to surgical intervention during access creation.

AVF dysfunction may be classified as primary, resulting from failure of fistula maturation, or secondary, which occurs due to acute thrombosis of the draining vein or venous outflow stenosis. Stenosis most frequently develops at the juxta-anastomotic region or the outflow vein, accounting for approximately 70–85% of cases, while arterial lesions involving the feeding artery or anastomosis account for the remaining 15–30%.[1] The two most common sites of draining vein stenosis are the juxta-anastomotic region and the venous puncture site.

Several studies have evaluated the effectiveness of percutaneous transluminal angioplasty (PTA) in the management of AVF dysfunction secondary to venous stenosis. Beathard GA et al. reported a technical success rate of 94% with a failure rate of 6% following fistuloplasty.[2] Similarly, others demonstrated immediate technical success rates ranging from 80% to 98% following angioplasty. Kanterman et al**.** observed that repeated balloon dilatation of venous stenosis was associated with progressively declining patency rates.[3] Gillan Irani et al. found no significant difference in anatomical success between drug-eluting balloon PTA and conventional PTA (89.9% vs. 78.3%, respectively**),** while both groups achieved a 100% clinical success rate.[4] Andrew R. Forauer et al. compared balloon inflation times and reported technical success rates of 75% with 1-minute inflation and 89% with 3-minute inflation.[5] Ayse Aktas et al. demonstrated a technical success rate of 96.3% and a clinical success rate of 97.2% following PTA.[6] Likewise, Susana Machado et al. reported immediate success rates of 91% for arteriovenous fistulas and 83% for arteriovenous graft stenosis, with partial success in 11% of procedures and an overall complication rate of 7%.[7]

The present study included 40 patients with dysfunctional hemodialysis fistulas who were referred to the Department of Radiodiagnosis, Government Medical College, Kozhikode, and fulfilled the inclusion criteria. All patients underwent percutaneous transluminal angioplasty. The most common type of vascular access was the radiocephalic AVF (62.5%). Similar to previous reports, the majority of stenotic lesions were located in the juxta-anastomotic region.[8] Venous access was the preferred approach for intervention and was utilized in 75% of the procedures.

Among the 40 patients**,** 38 achieved successful restoration of blood flow with the immediate return of palpable thrill following angioplasty, resulting in an immediate technical and clinical success rate of 95%. In the remaining two patients (5%), the procedure was unsuccessful because the guidewire could not be negotiated across the severely stenotic segment despite repeated attempts.

No major or life-threatening complications were encountered during the study. Only one patient developed a minor non-flow-limiting puncture-site hematoma, which was managed conservatively with compression and resolved completely within three days. These findings are comparable with those reported by previous investigators, confirming that fistuloplasty is a safe and minimally invasive procedure for the treatment of dysfunctional AVFs.[7,9]

Patients were followed for three months after the intervention to evaluate post-procedural patency. Of the patients available for follow-up, 36 maintained fistula patency, whereas two patients developed restenosis, occurring during the first month and third month**,** respectively. In both patients, restenosis occurred at the venous puncture site, resulting in an overall 3-month success rate of 95%**.** These observations are consistent with the findings of Andreu R. et al., who concluded that although PTA provides excellent immediate technical success, it does not eliminate the underlying pathological process responsible for recurrent stenosis.

Limitations

The study has certain limitations, including a relatively small sample size and a limited number of procedures performed. Only symptomatic patients who underwent percutaneous angioplasty were included,

which may limit the generalizability of the findings. Additionally, inflow stenosis and central vein stenosis were excluded from the study. The ongoing COVID-19 pandemic also affected patient recruitment, follow-up, and healthcare-seeking behavior, thereby influencing the overall study population and outcomes.

CONCLUSION

Thrombosis and fistula site stenosis are the leading causes of hemodialysis AVF dysfunction. Percutaneous transluminal angioplasty is a safe, effective, and minimally invasive treatment that restores the diameter of the draining vein, improves dialysis blood flow, and prolongs AVF patency. In this study, the procedure achieved a high immediate technical success rate of 95%. Furthermore, patient demographics, comorbidities, and the degree of stenosis were not significantly associated with procedural outcomes, highlighting the effectiveness of percutaneous angioplasty across symptomatic patients when performed by an experienced operator.

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