Clinical and Anatomical Predictors of AVF Success: Multivariate Evaluation of Distal Radiocephalic and Antecubital Brachiocephalic Access

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Abstract- The survival of arterio-venous (AV) fistula and the high rate of hospitalization of these patients (about 20% of the hospitalizations of these patients) are one of the most important challenges of the health system in the management of ESRD patients all over the world. Since AVF failure increases the mortality of patients and causes an increase in treatment costs, determining the optimal site (distal radiocephalic vs. antecubital brachiocephalic) as well as patient factors influencing functional success is crucial. This observational study was conducted on ESRD candidates for hemodialysis who underwent fistula bypass surgery in a tertiary center. Medical records of fifty patients who underwent distal radiocephalic fistula (DRF) creation and fifty who received antecubital brachiocephalic fistulas (ACBF) were reviewed. Demographic characteristics of the patients, such as age, gender, history of diabetes, high blood pressure, and smoking, were recorded. The primary outcome was AVF maturation at 120 days (functional vs. failed). A secondary outcome was early failure, defined as the absence of bruit or thrill within 30 days. 100 patients were examined in two groups (according to the location of the fistula), and the average age was reported as 52.4±12.5. AVF failure was reported in 38% of patients, of which 26% occurred within the first 30 days and 12% occurred within 30 to 120 days. The AVF failure rate was similar between DRF and ACBF groups (*P*:1.00). No statistically significant difference was seen for the failure rate of fistulas based on gender (P value: 0.715). In adjusted analysis, each additional year of age increased the odds of maturation by 4.3% (OR 1.043, 95% CI 1.004–1.083; *P*=0.029), and hypertension was independently associated with higher maturation odds (OR 2.747, 95% CI 1.119–6.746; *P*=0.027). For early failure (<30 days), female patients had 4.7-fold higher odds of failure than males (OR 4.676, 95% CI 1.556–14.048; *P*=0.006), while other covariates showed no significant associations. This study examined the factors that contribute to the failure of arteriovenous fistulas in ESRD patients who are eligible for hemodialysis. The findings demonstrated that various factors, including age and history of hypertension, can affect its success rate. These results are congruent with previous articles and emphasize the importance of choosing the correct type of fistula and careful management of risk factors in improving treatment.

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Introduction

Chronic kidney disease (CKD) and end-stage renal disease (ESRD) represent major global public health issues (1). The rates of ESRD are increasing in both developed and developing countries (2). Over 1.4 million individuals worldwide are undergoing hemodialysis, and this number is increasing by approximately 5% to 10%

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annually (1). The growing population of patients suffering from CKD and ESRD presents a considerable challenge for healthcare systems, resulting in substantial economic costs (3). The incidence of ESRD is accelerating in both developed and developing nations, further emphasizing the global burden of the disease (3).

Ninety percent of people who start treatment for ESRD will finally require hemodialysis, resulting in an estimated 1.2 million people worldwide (4). Hemodialysis requires frequent access to circulation through a fistula, arterial graft, or central venous catheter to ensure adequate blood flow to the hemodialysis machine and the blood filtration process (4). Vascular access failure, however, continues to be the leading cause of complications and hospitalizations among hemodialysis patients globally. Maintaining a long-term, functional blood supply is essential for delivering the required hemodialysis treatments (4). Arteriovenous fistulas (AVFs) are the gold standard for vascular access in hemodialysis patients due to their long-term benefits, including reduced complication rates and improved patient outcomes (5). AVFs are surgically created by connecting an artery to a vein, providing a reliable and durable means for repeated blood access during dialysis (6).

Despite the clear advantages of AVFs over other forms of vascular access, such as central venous catheters and arteriovenous grafts, the maturation process of an AVF remains a significant clinical challenge (7). Unfortunately, no major advances have been made in hemodialysis vascular access over the past three decades, which has led to impaired vascular access, one of the major problems for hemodialysis patients. According to Medicare data, it has been estimated that 20% of all hospitalizations in the hemodialysis population are due to impaired vascular access (8). In 2001, vascular access accounted for 7.5% of the $14 billion that Medicare allocated to the ESRD program (approximately $1 billion per year) (8).

The two primary complications of AVFs are initial failure to mature (non-functionality) and subsequent venous stenosis followed by thrombosis. Data from integrated survival analyses of AVF outcomes suggest primary patency rates of 85% at 1 year and 75% at 2 years; however, the study excluded AVFs that failed to mature sufficiently for hemodialysis. Some centers report primary failure or maturation failure rates as high as 50%, particularly when an aggressive fistula placement policy is employed (9). In some cases, primary patency rates have been reported as low as 43% and 56% for AVF. Additionally, Miller and colleagues reported a higher rate of initial failure for forearm AVFs compared to upper-arm AVFs (59% vs. 34%) (10). This difference was more pronounced in women, diabetic patients, and those over 65 years of age (10).

While some studies have investigated the maturation rates of different AVF sites, results remain inconsistent and inconclusive. The two most commonly used sites for AVF creation are the distal radiocephalic fistula (DRF) at the wrist and the antecubital brachiocephalic fistula (ACBF) at the elbow (11). The DRF is generally preferred due to its easier creation, reduced complication rates, and better aesthetic outcomes. In contrast, the ACBF is often utilized in cases where distal access is unsuitable or in patients with inadequate peripheral veins. Despite their widespread use, it is unclear whether one site leads to better maturation outcomes than the other.

This cross-sectional study aims to examine the correlation between the AVF site (distal radiocephalic vs. antecubital brachiocephalic) and its maturation status (functional vs. failed) in hemodialysis patients who were followed for six months, considering the different vascular diameters, gender, past medical history, and failure rates at each site.

Materials and Methods

Study design and setting

This retrospective observational study reviewed the medical records of ESRD patients who underwent AVF creation in 2022 at Sina Hospital, Tehran. Prior to participation, each patient was thoroughly informed about the potential complications associated with the interventions, and no fees were charged for clinical evaluations or laboratory testing. The Ethics Committee of Tehran University of Medical Sciences approved the study (Approval Code: IR.TUMS.SINAHOSPITAL.REC.1401.094).

Data collection

Patient variables—including age, sex, history of diabetes, hypertension, and smoking status—were systematically recorded. Data collection from patient records—via their medical files, structured questionnaires, and laboratory test reports—was performed in strict adherence to ethical standards, ensuring both integrity and confidentiality. Informed consent was obtained from all participants.

- *Diabetes* was defined as requiring insulin or oral antidiabetic medications in conjunction with a fasting blood glucose level of ≥126 mg/dL or a random blood glucose level of ≥200 mg/dL.

- *Hypertension* was defined as a systolic blood pressure >140 mmHg, a diastolic blood pressure >90 mmHg, or a documented history of antihypertensive therapy.

Sample size calculation

Based on parameters derived from a previous study (12) and with β set at 80% and α at 5%, the sample size was calculated, and determined that 50 patients were required for each group, yielding a total sample size of 100 patients.

Eligibility criteria

All outpatient hemodialysis (non-hospitalized) cases and those older than 8 years old who underwent hemodialysis at least three times per week for a minimum duration of 6 months were included in this study. Patients were excluded if younger than 8 years old, had a life expectancy <6 months, experienced AVF failure during the initial postoperative period due to infectious complications, had a history of steal syndrome or vascular aneurysm, or were using synthetic vascular grafts.

Surgical technique and data collection

Following ethical approval and secured access to patient records, AVF creation was performed in the operating room. For the placement of fistulas, arteriovenous Doppler ultrasound and mapping of two sites are performed by the surgeon. Fistulas with favorable characteristics for distal radiocephalic placement at the wrist were created accordingly, whereas those appropriate for placement in the antecubital region (brachiocephalic AVF) were constructed in that location.

Outcome measures

AVF failure was defined as the absence of both a palpable thrill and an audible bruit in the fistula. Based on maturation status, AVF outcomes were categorized into three groups:

1. **Early failure (within 30 days):** AVFs that never developed a detectable thrill or bruit.
2. **Intermediate Failure (30-120 days):** AVFs that developed a thrill yet remained unsuitable for effective dialysis use.
3. **Successful Maturation (after 120 days):** AVFs that matured to become functional and were successfully utilized for dialysis.

Statistical analysis

Statistical analyses were conducted using SPSS (version 26). To evaluate the normal distribution of the data, the Kolmogorov–Smirnov test was used. Continuous variables are expressed as the mean±standard deviation or median, interquartile range (IQR), whereas categorical variables are reported using percentages and number of events. Group comparisons were conducted using the Chi-square test and t-test, as appropriate. Logistic regression analysis was used to identify potential factors affecting AVF outcomes. A *P* of less than 0.05 was considered statistically significant.

Results

A total of 100 patients, including 39 women and 61 men, were evaluated in the study and were equally divided into two groups: 50 patients underwent DRF creation, and 50 patients underwent ACBF creation. The age range of the participants was 24 to 87 years, with an overall mean age of 52.4 years (±12.5). In the ACBF group, the mean age was 53.1 years (±13.4), compared to 51.8 years (±11.5) in the DRF group; however, this difference was not statistically significant (*P*=0.4). Additionally, there were no statistically significant differences regarding the history of hypertension, diabetes, and smoking between the two groups. None of the participants reported any history of substance abuse or alcohol consumption. Table 1 summarizes the demographic and clinical characteristics of the included patients.

Table 1. Baseline characteristics of the two groups

	DRF (50 patients)	ACBF (50 patients)	*P*
Age, years (mean±SD)	52.1±11.4	53.1±13.4	0.715
Sex, Female N (%)	18 (36%)	19 (38%)	0.836
Hypertension, N (%)	24 (48%)	27 (54%)	0.548
Diabetes, N (%)	21 (42%)	21 (42%)	1.000
Smoking, N (%)	12 (24%)	10 (20%)	0.629

Age and AVF function

Figure 1 illustrates the age distribution across both groups. Notably, across all patients, age was significantly associated with an increased rate of AVF failure at 120 days; however, this relation was statistically significant only in the DRF group (overall *P*=0.019; DRF subgroup *P*=0.004; ACBF *P*=0.429). (Table 2).

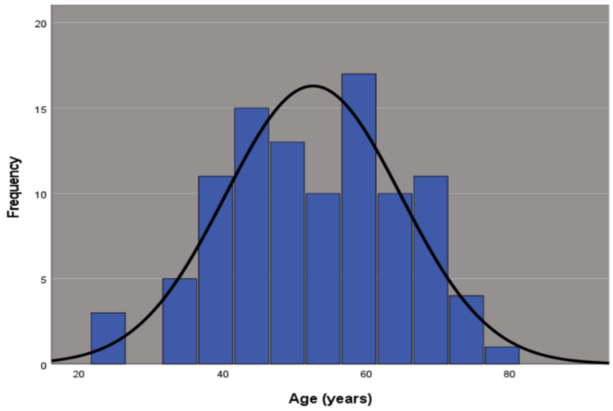

Figure 1. Age distribution of 100 patients undergoing arteriovenous fistula

Table 2. Overall and subgroup analysis regarding the effect of age on AVF function at 120 days

	Number	Matured: age mean ± SD (number)	Failed: age mean ± SD (number)	P
Overall	100	54.9±10.6 (62)	48.7±13.9 (38)	0.019
Distal radiocephalic	50	55.6±10.4 (31)	46.4±10.9 (19)	0.004
Antecubital brachiocephalic	50	54.3±10.8 (31)	50.9±16.2 (19)	0.429

Sex and AVF function

Of the entire cohort, 63 patients were men and 37 were women. Regarding the ACBF group, 56% were male and 44% were female, whereas the DRF group encompassed 32 men (64%) and 18 women (36%). Although the AVF function was not statistically different between men and women in the entire cohort and the ACBF group, women had significantly higher rates of AVF failure at 120 days in the DRF subgroup.

Table 3. Overall and subgroup analysis regarding the effect of sex on AVF function at 120 days

	Sex	N	Matured n (%)	Failed n (%)	P†
Overall	Female	37	20 (54.1%)	17 (45.9%)	0.210
	Male	63	42 (66.7%)	21 (33.3%)	
Distal radiocephalic	Female	18	7 (38.9%)	11 (61.1%)	0.012
	Male	32	24 (75%)	8 (25%)	
Antecubital brachiocephalic	Female	22	13 (68.4%)	6 (31.6%)	0.464
	Male	28	18 (58.1%)	13 (41.9%)	

Diabetes and AVF function

Concerning comorbidities, 42% of the total study population had diabetes. The prevalence was not significantly different between groups, with 21% in both groups. Diabetes did not have a significant association with AVF failure at 120 days across the overall cohort (*P*=0.394), and across subgroup analysis.

Table 4. Overall and subgroup analysis regarding the effect of diabetes on AVF function at 120 days

	Diabetes	N	Matured n (%)	Failed n (%)	P†
Overall	No	58	38 (65.5%)	20 (34.5%)	0.394
	Yes	42	24 (57.1%)	18 (42.9%)	
Distal Radiocephalic	No	29	21 (72.4%)	8 (27.6%)	0.075
	Yes	21	10 (47.6%)	11 (52.4%)	
Antecubital Brachiocephalic	No	29	17 (58.6%)	12 (41.4%)	0.563
	Yes	21	14 (66.7%)	7 (33.3%)	

Smoking and AVF function

Finally, 22% of patients had a history of cigarette smoking, with the same prevalence in both groups. Smoking did not significantly influence AVF outcomes at 120 days in overall and subgroup analyses.

Table 5. Overall and subgroup analysis regarding the effect of smoking on AVF function at 120 days

	Smoking	N	Matured n (%)	Failed n (%)	P†
Overall	No	78	51 (65.4%)	27 (34.6%)	0.189
	Yes	22	11 (50%)	11 (50%)	
Distal radiocephalic	No	38	25 (65.8%)	13 (34.2%)	0.326
	Yes	12	6 (50%)	6 (50%)	
Antecubital brachiocephalic	No	38	26 (65%)	14 (35%)	0.382
	Yes	10	5 (50%)	5 (50%)	

Hypertension and AVF function

Additionally, 51% of all patients had a history of hypertension (54% in the ACBF group vs. 48% in the DRF group), and hypertension was found to significantly affect AVF failure rates at 120 days in the overall population (P=0.027). However, it is noteworthy that, in contrast to the ACBF subgroup, in the DRF subgroup, a history of hypertension was significantly related to AVF maturation (P=0.016).

Table 6. Overall and subgroup analysis regarding the effect of hypertension on AVF function at 120 days

	Hypertension	N	Matured n (%)	Failed n (%)	P†
Overall	No	49	25 (51%)	24 (49%)	0.027
	Yes	51	37 (72.5%)	14 (27.5%)	
Distal radiocephalic	No	26	12 (46.2%)	14 (53.8%)	0.016
	Yes	24	19 (79.2%)	5 (20.8)	
Antecubital brachiocephalic	No	23	13 (56.5%)	10 (43.5%)	0.461
	Yes	27	9 (33.3%)	18 (66.7%)	

AVF site location and fistula function

Clinical outcomes have been evaluated concerning baseline factors, including age, sex, smoking status, hypertension, and diabetes. AVF failure was defined as the absence of a palpable thrill or audible bruit. Overall, 38% of patients experienced AVF failure, with 26% occurring within the first 30 days and 12% occurring between 30 and 120 days postoperatively. Notably, no significant difference between AVF site location and fistula maturation rate was seen.

Table 7. The effect of AVF site location on AVF function at 120 days

	Total number	Matured AVF number (%)	Failed AVF number (%)	P
Overall	100	62	38	
Distal radiocephalic	50	31 (62%)	19 (38%)	1.000
Antecubital brachiocephalic	50	31 (62%)	19 (38%)	

Prognostic factors for AVF function

Multiple logistic regression was employed to determine the prognostic risk factors of AVF failure at 120 days. According to Table 8, in the multivariable logistic regression analysis, only two factors were found to significantly influence the likelihood of arteriovenous fistula maturation. Younger patients were more likely to experience fistula failure compared to older individuals. Each additional year of patient age is associated with a 4.3 % increase in the odds of AVF maturation success. Furthermore, hypertensive patients had approximately 2.7 times the odds of AVF success compared to nonhypertensives.

Table 8. Multiple logistic regression for AVF failure

		Odds ratio	95 % CI	*P*
AVF maturation	Sex (Female vs Male)	0.488	0.189 – 1.257	0.137
	Fistula location (ABCF vs DRF)	1.164	0.480 – 2.821	0.737
	Smoking (Yes vs No)	0.367	0.123 – 1.094	0.072
	Diabetes (Yes vs No)	0.632	0.259 – 1.546	0.315
	Hypertension (Yes vs No)	2.747	1.119 – 6.746	0.027
	Age	1.043	1.004 – 1.083	0.029

Prognostic factors for early AVF function

As a secondary outcome, early failure (within 30 days), AVFs that never developed a detectable thrill or bruit, were seen in 26 patients. According to Table 9, female patients were significantly more likely to experience early AVF failure than males (OR 4.68; 95 % CI 1.56–14.05; *P*=0.006). Other factors did not significantly impact the odds of early AVF failure.

Table 9. Binary logistic regression for early AVF failure to trill

		Odds ratio	95 % CI	*P*
Early AVF failure to trill	Sex (Female vs Male)	4.676	1.556 – 14.048	0.006
	Fistula location (ABCF vs DRF)	2.405	0.870 – 6.646	0.091
	Smoking (Yes vs No)	2.641	0.740 – 9.424	0.135
	Diabetes (Yes vs No)	2.060	0.756 – 5.616	0.158
	Hypertension (Yes vs No)	0.367	0.130 – 1.030	0.057
	Age	0.978	0.938 – 1.02	0.295

Discussion

CKD has emerged as a significant global health issue. Approximately 13.4% of people are affected by CKD, and an estimated 5-7 million people require renal replacement therapy (RRT) for ESRD. However, achieving a mature, usable AVF can be challenging; vascular access is usually mentioned as the “Achilles heel” of modern dialysis because primary failure rates remain significant (13).

This study aimed to evaluate the maturation outcomes of DRF versus ACBF in patients undergoing hemodialysis. Our findings indicate that DRFs had similar maturation rates compared to ACBFs.

Although most of the previous studies declare superiority of distal fistulas, there are some, indicate better outcomes with proximal fistulas (14). Additionally, one retrospective study found the primary patency (functional use without additional intervention) of ACBFs to be significantly higher than that of DRFs (88.7% vs 62.9% in one year) (15). The trade-off is that proximal fistulas, due to their higher flow, may carry an increased risk of complications such as hand ischemia (steal syndrome) or cardiac strain. Nevertheless, the ACBF is often the preferred choice in the upper arm when a wrist fistula is not feasible or has failed (5).

AVF maturation is a complex process influenced by multiple patient-related and technical factors. Numerous studies have investigated predictors of AVF success and failure. Key factors associated with maturation outcomes include:

Age: In the present study, increasing age had a significant protective effect on fistula maturation in the entire cohort and DRF group; however, the impact of increasing age on AVF failure was not statistically significant in the ACBF subgroup. This finding is consistent with the results of another study, which found that increasing age was associated with a reduced risk of fistula failure (16). However, some studies report increased odds of AVF failure in geriatrics, and ABCF was subsequently introduced as a better option for the elderly (17,18). Moreover, age alone is not an absolute contraindication to any type of AVF; other reports suggest that if vascular anatomy is favorable, older patients can still achieve functional fistulas (19).

Vascular Anatomy: One of the determinants of AVF success is the size and quality of the vessels used (20). Adequate vein diameter (≥3 mm) and arterial caliber are strongly linked to successful maturation (21). Novel diagnostic evaluation may improve the understanding of vascular structure for choosing the optimum approach for AVF construction (22-24).

Access Site (Distal vs. Proximal): The location of the fistula plays a pivotal role in AVF failure in our study.

Lower-arm (distal) fistulas are more prone to early failure compared to upper-arm fistulas, largely due to smaller vessels and lower flow (25). Ernandez *et al*., reported 8-fold higher odds of early failure for distal (wrist) AVFs relative to upper-arm AVFs. In their series, distal location was the strongest independent risk factor for non-maturation, emphasizing that site selection should be cautious in borderline cases (26).

Sex: Female gender has been identified as a risk factor for AVF failure in multiple previous studies (27-28). Women generally have smaller-caliber veins and arteries, which may contribute to higher early thrombosis or inadequate maturation (29). Ernandez *et al*., found female patients had a fourfold higher risk of early AVF failure (26).

Diabetes: Diabetes is the leading cause of CKD and ESRD in many countries and is associated with systemic atherosclerosis and vascular endothelial dysfunction (13). These changes can impair AVF outcomes by narrowing vessels and reducing blood flow (13,30).

The impact of diabetes on AVF maturation, however, remains debated. In the present study, diabetes did not significantly increase the rate of fistula failure. Some studies have found diabetes to significantly increase the risk of primary failure (26), while others have shown no independent effect after accounting for other factors (13).

Notably, the study by Ullah *et al*., observed that diabetes was associated with higher failure rates, specifically in brachiocephalic (elbow) fistulas, whereas radiocephalic and brachiobasilic fistula outcomes were similar between diabetic and non-diabetic patients (13). This suggests that diabetes might differentially affect proximal versus distal accesses, possibly due to preferential use of upper-arm fistulas in diabetic patients or differences in vessel pathology. In any case, careful optimization of diabetic patients (e.g., glycemic control, vascular health) and judicious site selection are important to improve AVF success.

Hypertension: Systemic factors like blood pressure can influence fistula flow dynamics. Higher systolic blood pressure has been associated with better maturation in some reports, especially for upper-arm fistulas (31). Consistently, high blood pressure in the present study significantly increased the odds of fistula maturation, which is in line with the results of the study by Bahrami *et al*., (32). They showed that fistula failure occurred less frequently in people with a history of high blood pressure (32). It is noteworthy that we had a similar trend in our DRF subgroup analysis. Furthermore, severe arterial stiffness or peripheral vascular disease can impede flow. Cardiovascular comorbidities (e.g., coronary or peripheral artery disease) often coexist with ESRD and may serve as proxies for poor vascular health, correlating with higher AVF failure rates (33).

Additionally, unhealthy habits such as smoking and physical inactivity can lead to poor vascular quality and, consequently, fistula failure (34). However, smoking did not significantly impact AVF failure rates in our study. These factors can also play a role, but are less clearly defined in the current literature.

Limitations

In addition to well-established risk factors and comorbidities, new inflammatory biomarkers such as the neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) have recently gained attention due to their potential predictive value for vascular complications and systemic inflammation (35-37). Although these parameters were not directly evaluated in the present study, future research may benefit from integrating such inflammatory markers into multivariate predictive models to refine patient risk stratification. Another hot topic of vascular interventions is the integration of artificial intelligence in the management and prediction of clinical outcomes, whose clinical implication needs to be explored comprehensively and precisely (38,39). However, these technologies are still in their early stages and require robust validation in large prospective cohorts.

While our study provides valuable insights into the factors influencing AVF maturation, it has several limitations. The design of the present study was retrospective, which may limit the comprehensiveness and interpretability of the results. It is suggested that by designing prospective studies, a more accurate comparison of different fistula creation methods in ESRD patients would be possible to reduce the fistula failure rate and reduce the treatment costs of patients. Although relying solely on comorbidities provides a feasible approach to predict AVF, future studies should incorporate more novel biomarkers to better clarify the risk factors of AVF. Another limitation is that fistula maturation and failure were assessed solely based on clinical findings (thrill and bruit) without Doppler ultrasound confirmation, which may have introduced diagnostic subjectivity. Finally, the relatively short follow-up period of 120 days may not capture the long-term outcomes of AVF function.

In conclusion, our study supports a comparable maturation rate for DRF and ACBF in a 120-day follow-up. However, successful AVF maturation is multifactorial, involving patient selection, preoperative planning, and surgical execution. Recognizing risk factors (e.g., small vessels, advanced age, female sex, diabetes, distal site) allows clinicians to strategize appropriately. Additionally, given that diabetes and advanced age are important factors for fistula failure, educational programs and ongoing monitoring for diabetic patients and the elderly can be effective in reducing the rate of fistula failure.

The study was conducted in compliance with the ethical standards outlined in the Declaration of Helsinki and its subsequent amendments. The study was approved by the Ethics Committee of Tehran University of Medical Sciences (Approval Code: IR.TUMS.SINAHOSPITAL.REC.1401.094).

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