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Research Article

Effects of Diabetes, Hypertension and Cardiovascular Disease on Arteriovenous Fistula Outcomes in Hemodialysis Patients

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ABSTRACT

Background: The creation of a functional arteriovenous fistula remains the preferred form of vascular access for hemodialysis, yet maturation failure continues to pose a major clinical challenge. Although diabetes, hypertension, and cardiovascular disease are widely presumed to impair vascular remodeling, emerging evidence suggests that their impact may be less significant when vessel anatomy is adequate. This study evaluates the influence of these comorbidities on fistula maturation while accounting for preoperative vascular characteristics and standardized surgical technique. **Methods:** A prospective observational study was conducted involving patients undergoing radiocephalic or brachiocephalic AVF creation. Detailed demographic data, comorbidity profiles, and preoperative vascular measurements were recorded. Doppler ultrasonography was used to assess vessel diameter prior to surgery. All patients were followed for a minimum of three months, and functional maturation was defined as successful use of the AVF for six consecutive hemodialysis sessions. Outcomes were compared between patients with and without diabetes, hypertension, ischemic heart disease, and peripheral vascular disease. **Results:** Among the enrolled patients, overall AVF maturation was achieved in the majority, with no statistically significant differences observed between comorbidity groups. Diabetic and hypertensive patients demonstrated maturation rates comparable to those without these conditions, and neither ischemic heart disease nor peripheral vascular disease negatively influenced early functional outcomes. The strongest predictor of successful maturation was preoperative cephalic vein diameter, while arterial diameter, surgical technique, and comorbidities showed no measurable impact. **Conclusion:** Comorbidities traditionally considered detrimental to vascular health did not adversely affect AVF maturation when vessel anatomy was

adequate and perioperative evaluation was standardized. These findings reinforce the primacy of preoperative vascular suitability in access planning and support an anatomy-focused, rather than comorbidity-restrictive, approach to AVF creation.

Keywords: Arteriovenous fistula; Hemodialysis access; Diabetes mellitus; Hypertension; Cardiovascular disease; Vessel diameter; Fistula maturation; Preoperative ultrasonography; Vascular remodeling; Patency outcomes

INTRODUCTION

Chronic kidney disease continues to rise globally, with a substantial proportion of patients progressing to end-stage renal disease requiring long-term hemodialysis. For these individuals, vascular access is not only a procedural requirement but a determinant of survival, quality of life, and healthcare burden. Native arteriovenous fistulas (AVFs) remain the preferred access due to their superior patency, lower infection rates and reduced intervention needs compared with grafts and central venous catheters [1]. Despite this advantage, early AVF failure and non-maturation remain persistent clinical challenges, affecting nearly 30–40% of newly created fistulas. Understanding predictors of maturation is thus essential for optimizing access planning and improving long-term dialysis outcomes.

Among the diverse factors influencing AVF success, patient comorbiditiesespecially diabetes mellitus, hypertension and cardiovascular diseaseare of particular importance because they are highly prevalent in the hemodialysis population and have well-documented effects on vascular biology. Diabetes contributes to medial calcification, endothelial dysfunction, impaired nitric oxide bioavailability and a pro-thrombotic vascular environment, all of which can impede venous remodeling after fistula creation [2]. Hypertension induces arterial stiffness, smooth-muscle hypertrophy and microvascular rarefaction, factors that may alter the hemodynamic profile required for successful AVF maturation [3]. Cardiovascular disease, including ischemic heart disease and peripheral vascular disease, reflects systemic atherosclerotic burden and may influence inflow capacity, distal perfusion and the ability of the fistula to sustain adequate blood flow [4].

Though biologically plausible, clinical evidence regarding the independent effect of these comorbidities on AVF outcomes remains inconsistent. Several contemporary studies demonstrate higher rates of early thrombosis, assisted maturation and intervention among patients with diabetes or ischemic heart disease [5]. However, other prospective analyses argue that when preoperative vessel diameter and anatomical suitability are taken into account, the influence of systemic disease diminishes markedly, and comorbidities do not independently predict maturation failure [6]. These conflicting results may stem from heterogeneity in study designs, inconsistent definitions of AVF maturation, variable use of Doppler ultrasound mapping, and differences in fistula location (forearm vs upper arm).

Preoperative duplex ultrasound has become central to modern vascular-access planning because venous diameter, distensibility and arterial adequacy are among the strongest predictors of AVF success. Vessel caliber appears to be a key intermediary variable linking comorbidities to fistula outcome. Patients with diabetes, for example, often exhibit thicker intima, reduced venous distensibility and a greater burden of microvascular diseaseall factors associated with delayed or failed maturation [7]. Similarly, cardiovascular disease may limit the physiologic capacity needed to support fistula flow, leading to elevated risk of non-maturation and ischemic complications in the early postoperative period [8].

Routine vascular mapping has been shown to mitigate some of these risks by identifying suitable vessels even in patients with multiple comorbidities. Evidence suggests that selecting veins above defined

diameter thresholds improves maturation probability, particularly in diabetic and hypertensive patients in whom vessel caliber is often borderline [9]. These observations reinforce the importance of integrating both anatomical and clinical factors when planning AVF creation.

Meanwhile, the increasing application of machine learning and predictive modeling to vascular-access assessment further strengthens the recognition that vessel quality, rather than comorbidity burden alone, may be the dominant determinant of maturation. Recent models incorporating ultrasound data, vascular elasticity indices and comorbidity profiles have demonstrated high accuracy in predicting early AVF outcomes [10]. Such tools have the potential to refine patient selection, anticipate complications, and personalize access strategies in complex patients.

Against this backdrop, the present study examines the effects of diabetes mellitus, hypertension and cardiovascular disease on AVF maturation and early patency within a prospectively followed cohort, while accounting for vessel diameter, AVF type and surgical technique. By integrating detailed comorbidity profiling with preoperative ultrasonographic assessment, this study aims to clarify whether these systemic conditions independently impair AVF outcomes or whether their impact is primarily mediated through anatomical variables such as vein diameter and arterial adequacy. Understanding this distinction is critical, as it directly informs access planning, patient counseling and strategies to improve the reliability of AVF maturation in high-risk populations.

Objectives

The primary objective of this study is to evaluate how key comorbiditiesspecifically diabetes mellitus, hypertension, and cardiovascular disease (including ischemic heart disease and peripheral vascular disease)influence the functional maturation and early failure of arteriovenous fistulas (AVFs) in patients undergoing hemodialysis. Since these systemic conditions are known to affect vascular biology, endothelial function, and arterial and venous compliance, this investigation aims to determine whether they play a significant role in predicting successful AVF usability or contribute to early thrombosis, non-maturation, or access-related complications.

A secondary objective is to compare AVF outcomes between patients with and without these comorbidities to assess whether the presence of metabolic or cardiovascular disease should influence preoperative planning and fistula site selection. By analyzing maturation rates, complication patterns, and functional usability across comorbidity groups, the study seeks to clarify whether diabetes, hypertension, or cardiovascular disease represent independent predictors of AVF outcomes or whether their effects are mitigated when adequate vessel diameter and anatomical suitability are present.

METHODOLOGY

Study Design

This study was conducted as a prospective observational analysis evaluating the effects of diabetes mellitus, hypertension, and cardiovascular disease on the maturation and early functional outcomes of arteriovenous fistulas in hemodialysis patients at Stanley medical college Chennai between 2021 to 2022. The methodology adhered to STROBE criteria for observational studies, ensuring transparent reporting of participant selection, data collection, variables, and outcomes. All eligible patients undergoing native radiocephalic or brachiocephalic AVF creation were enrolled and followed for a minimum period of three months to assess functional maturation.

Study Setting and Population

The study was carried out in a tertiary care hospital with a dedicated vascular access program. All patients meeting the clinical indication for hemodialysis access creation and satisfying inclusion and exclusion criteria were considered for participation.

Demographic variables, comorbidities, and vascular characteristics were recorded preoperatively. Patients were assigned to subgroups based on the presence or absence of diabetes, hypertension, ischemic heart disease, and peripheral vascular disease, enabling comparative evaluation of AVF outcomes.

Preoperative Evaluation

All participants underwent standardized preoperative Doppler ultrasonography to assess cephalic vein and arterial diameters, venous compressibility, and anatomic suitability for AVF creation. Patient comorbidities were documented from clinical records, including prior dialysis access, duration of disease, and cardiovascular history. Preoperative evaluation also included physical examination of vascular status, assessment for limb edema, and documentation of arterial pulses.

Surgical Procedure

Arteriovenous fistulas were created using standardized operative protocols. Radiocephalic AVFs were constructed at the wrist when suitable anatomy was present, while brachiocephalic AVFs were created at the antecubital region when forearm vessels were inadequate. Both end-to-side and side-to-side anastomotic techniques were employed based on intraoperative vessel characteristics and surgeon judgment. Systemic heparinization, vessel mobilization, and anastomotic construction followed uniform operative steps to minimize procedural variability.

Postoperative Follow-up

Participants were evaluated at regular intervals during the three-month postoperative period to determine functional maturation. Maturation was defined as the successful use of the AVF for six consecutive hemodialysis sessions. Physical examination findings, thrill and bruit characteristics, and dialysis records were used to confirm suitability. Complications such as thrombosis, infection, aneurysm formation, limb edema, distal ischemia, and rupture were documented.

Study Variables

Primary variables included diabetes mellitus, hypertension, ischemic heart disease, and peripheral vascular disease. Outcome variables included functional maturation, early thrombosis, non-maturation, and complication rates. Secondary variables included age, sex, AVF type, anastomotic technique, vein and artery diameters, and prior dialysis access.

Data Collection and Management

Data were collected prospectively using structured case-report forms and entered into a secure digital database. Preoperative measurements, operative details, and follow-up outcomes were validated by cross-referencing clinical notes, ultrasonography reports, and dialysis records. All data were anonymized before analysis.

Statistical Analysis

Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized using means and standard deviations. Comparisons between groups with and without comorbidities were performed using chi-square tests for categorical outcomes and independent sample t-tests for continuous variables. A p-value less than 0.05 was interpreted as statistically significant. The association between comorbidities and AVF maturation was analyzed using cross-tabulation to determine potential predictive relationships.

Ethical Considerations

The study was conducted in accordance with institutional ethical guidelines and adhered to principles of patient confidentiality and informed consent. Participants were informed about the study objectives, procedures, and follow-up requirements, and consent was obtained before enrollment.

RESULTS

A total of **120 patients** underwent arteriovenous fistula creation and were

followed for a minimum of three months to assess functional maturation. The study population included both radiocephalic and brachiocephalic fistulas, with demographic and comorbidity profiles recorded preoperatively. Overall functional maturation was achieved in **70.8%** of patients.

Table 1: Patient Demographics and AVF Maturation

Parameter	Mature (n=85)	Immature (n=35)	p-value
Mean Age (years)	50.20 ± 14.31	51.00 ± 15.93	0.788
Sex (Male)	57 (73%)	21 (27%)	0.461
Sex (Female)	28 (66.6%)	14 (33.3%)	—

Baseline demographic characteristics, including age and sex distribution, demonstrated no statistically significant association with AVF maturation. The mean age was similar between matured and non-matured groups, suggesting that chronological age alone does not affect fistula usability. Likewise, male and female patients exhibited comparable maturation rates, with differences falling short of statistical significance. These findings indicate that demographic variables do not independently predict AVF success and reinforce the importance of anatomical and hemodynamic factors over patient age or sex when evaluating suitability for fistula creation.

Table 2: Comorbidities and AVF Maturation

Comorbidity	Mature	Immature	Total	p-value
Diabetes Mellitus	34 (70.8%)	14 (29.1%)	48	1.000
Hypertension	63 (71.6%)	25 (28.4%)	88	0.762
Ischemic Heart Disease	36 (65.4%)	19 (34.5%)	55	0.233
Peripheral Vascular Disease	17 (68%)	8 (32%)	25	0.726
Prior Temporary Dialysis Access	27 (69.2%)	12 (30.8%)	39	0.872

Diabetes, hypertension, ischemic heart disease, peripheral vascular disease, and prior temporary dialysis access did not significantly influence AVF maturation. Maturation rates were comparable between patients with and without these comorbidities, indicating that systemic vascular disease, when moderate and medically optimized, may not impair the physiological remodeling required for fistula maturation. These findings suggest that comorbidities should not serve as exclusion criteria for AVF placement, provided that preoperative vessel diameter and quality are acceptable. The results support the practice of prioritizing anatomical suitability over comorbidity burden during access planning

.

Table 3: Vessel Diameters and AVF Maturation

Parameter	Mature	Immature	Overall Mean	p-value
Cephalic Vein Diameter (mm)	2.804 ± 0.32	2.31 ± 0.354	2.66	0.0001
Artery Diameter (mm)	2.59 ± 0.336	2.53 ± 0.241	2.55	0.358

Cephalic vein diameter emerged as a strong predictor of AVF maturation. The mean vein diameter of matured fistulas was significantly larger than that of non-matured fistulas, confirming that preoperative venous calibre plays a pivotal role in determining remodeling capacity and functional usability. In contrast, arterial diameter did not differ significantly between groups, suggesting that arterial size alone does not limit AVF maturation when anatomically adequate. These results

highlight the central importance of preoperative venous assessmentparticularly in patients with diabetes or cardiovascular diseasein guiding access site selection and optimizing outcomes

.

Table 4: Type of Fistula, Anastomotic Technique, and Maturation

Variable	Mature	Immature	Total	p-value
Radiocephalic AVF	45 (60.8%)	29 (39.1%)	74	0.002
Brachiocephalic AVF	40 (86.9%)	6 (13.1%)	46	—
End-to-Side Anastomosis	71 (72.4%)	27 (27.5%)	98	0.411
Side-to-Side Anastomosis	14 (63.3%)	8 (36.3%)	22	—

Brachiocephalic AVFs demonstrated significantly higher maturation rates compared with radiocephalic AVFs, likely reflecting larger vessel diameter and improved hemodynamic profiles in the upper arm. Meanwhile, the choice of anastomotic techniqueend-to-side or side-to-sideshowed no meaningful difference in maturation outcomes. These findings reinforce the importance of anatomical factors over surgical configuration in determining AVF usability. When patients present with comorbidities such as diabetes or hypertension, preferential selection of brachial-level fistulas may mitigate risks associated with smaller-caliber distal vessels and enhance chances of successful maturation

.

Table 5: Complications Following AVF Creation

Complication	Number	Percentage
Limb Edema	9	7.5%
Wound Infection	7	5.8%
Thrombosis	8	6.6%
Aneurysm	5	4.1%
Symptomatic Distal Ischemia	4	3.3%
AVF Rupture	4	3.3%
Total Complications	37	30.8%

Approximately one-third of patients experienced complications, with limb edema and thrombosis being the most common. Thrombosis was more frequently observed in patients with smaller vessel diameters, reinforcing the role of anatomical suitability in AVF outcomes. No clear association emerged between systemic comorbidities and complication rates. The relatively low incidence of ischemia and aneurysm suggests that appropriate surgical planning and vessel selection can minimize severe complications even in high-risk patients. These findings support the use of AVFs in patients with diabetes or cardiovascular disease, provided that preoperative mapping confirms adequate vascular anatomy.

DISCUSSION

The present study provides a comprehensive evaluation of how prevalent comorbiditiesspecifically diabetes mellitus, hypertension, ischemic heart disease, and peripheral vascular diseaseaffect functional maturation of native arteriovenous fistulas in hemodialysis patients. Despite long-standing assumptions that systemic vascular disease impairs fistula performance, our findings demonstrate that these comorbidities did not exert significant influence on maturation rates when preoperative vessel characteristics were adequate and standardized surgical

techniques were applied. This aligns with the evolving body of contemporary evidence suggesting that vascular anatomy, rather than systemic comorbidity burden, is the dominant determinant of successful AVF maturation.

Diabetes mellitus has historically been associated with microvascular remodeling, endothelial dysfunction, medial calcification, and impaired vasodilatory reserve, all of which theoretically predispose to early AVF failure. However, in our cohort, maturation rates among diabetic patients were comparable to those without diabetes, reinforcing growing evidence that proper vessel mapping may mitigate adverse vascular effects. Recent multicenter analyses have also shown that diabetes alone does not predict fistula failure when preoperative imaging confirms adequate vein diameter and arterial inflow [11]. Similar findings were reported in a 2023 systematic comparison demonstrating that diabetic patients achieve acceptable long-term patency when treated with meticulous surgical technique and early surveillance programs [12]. These contemporary results collectively suggest that chronological vessel changes associated with diabetes may be less impactful than previously believed, particularly when vascular anatomy is optimized preoperatively.

Hypertension, another common comorbidity in hemodialysis populations, is frequently implicated in arterial wall stiffness, remodeling, and increased pulse pressurefactors that could potentially reduce the capacity of an AVF to remodel and mature. In our study, however, hypertension was not associated with reduced maturation rates. This may reflect the growing recognition that controlled hypertension does not necessarily impair arterial elasticity to an extent that compromises AVF outcomes. Advanced imaging studies have demonstrated that hypertensive patients with preserved arterial distensibility exhibit similar maturation trajectories to normotensive individuals [13]. Additionally, contemporary vascular biology research suggests that the hemodynamic stimulus introduced by AVF creation may override baseline hypertensive arterial changes, allowing for adaptive outward remodeling even in patients with long-standing hypertension [14].

Ischemic heart disease represents systemic atherosclerotic burden, and by extension, raises concerns regarding reduced arterial inflow capacity and impaired microvascular responsiveness. However, our results demonstrated no significant association between IHD and AVF maturation. These findings correspond with recent prospective data showing that coronary artery disease severity does not correlate reliably with peripheral arterial adaptability or fistula outcomes [15]. It is increasingly understood that coronary artery disease and peripheral arterial disease progress along partially independent biological pathways. Studies using high-resolution arterial biomechanics modeling have shown that forearm and upper-arm vascular beds maintain compensatory vasodilatory mechanisms even in the presence of systemic atherosclerosis [16]. This may explain why individuals with IHD in our cohort demonstrated preserved maturation potential when vessel diameter and quality were adequate.

Peripheral vascular disease, unlike other comorbidities, directly affects limb arterial perfusion and could be expected to impact AVF maturation more overtly. Nevertheless, the presence of PVD in our study did not predict fistula failure. Although this appears counterintuitive, similar findings have been reported in high-resolution duplex mapping cohorts, where localized stenoses or diminished distal perfusion did not necessarily impede AVF remodeling when the anastomotic artery and draining vein were unaffected [17]. Furthermore, modern vascular ultrasound enables precise identification of segments suitable for AVF creation despite the presence of broader

limb vascular disease. Studies examining intraluminal shear stress patterns have demonstrated that even in patients with clinically significant PVD, proximal arterial segments may retain adequate flow reserve to support AVF maturation [18]. Thus, the clinical impact of PVD appears to depend less on diagnosis alone and more on the specific anatomic region selected for fistula construction.

An important implication of our findings is the apparent primacy of vessel anatomy over systemic comorbidity profiles. Multiple recent publications highlight the weight of preoperative vascular diameter, venous distensibility, and arterial elasticity compared to comorbidities in predicting AVF outcomes [19]. Diabetic, hypertensive, and cardiovascular disease patients often present with increased vessel wall thickness; however, when the luminal diameter is sufficient, physiological remodeling appears capable of compensating for structural alterations. This is supported by contemporary data emphasizing the prognostic accuracy of ultrasound-derived vein diameter thresholds over clinical comorbidity variables [20]. Our findings reaffirm that early AVF failure is more closely linked to anatomical limitationsparticularly small cephalic vein diameterthan to metabolic or cardiovascular risk factors.

The absence of comorbidity-related differences in our cohort may also reflect improvements in preoperative imaging and surgical planning. Modern ultrasound mapping provides detailed insight into vessel diameter, distensibility, and depth, enabling individualized surgical site selection. Recent technological advancements, including 3D vascular mapping and intraoperative flow assessment, have substantially improved the accuracy of predicting AVF maturation potential [21]. Our results are consistent with the premise that when vascular anatomy is carefully evaluated and utilized to guide access placement, comorbidities become secondary considerations. Moreover, standardized postoperative follow-up protocols and timely intervention for non-maturing fistulas may help equalize outcomes across patients with varying comorbidity burdens.

Although comorbidities did not predict fistula outcomes in our study, it is important to acknowledge that the biological mechanisms underlying AVF maturation remain complex. Diabetes and hypertension have been shown to influence endothelial nitric oxide availability, smooth muscle cell proliferation, and arterial wall compliance. Cardiovascular disease influences systemic inflammatory pathways that may also contribute to stenosis formation. High-quality mechanistic studies continue to reveal that systemic disease states interact with local vascular remodeling in nuanced ways [22]. Yet, these pathophysiological processes may not translate to measurable differences in clinical maturation outcomes when surgical techniques and imaging selection are optimized.

The findings of this study align with recent research advocating a paradigm shift toward anatomy-driven decision-making in vascular access surgery. Several predictive models incorporating vascular imaging data outperform comorbidity-based risk stratification systems for identifying patients at risk of AVF failure [23]. Emerging machine-learning algorithms further integrate flow dynamics, vessel morphology, and intraoperative factors to refine predictive accuracy, minimizing reliance on traditional comorbidity indicators [24]. A recent systematic evaluation further strengthened this shift by demonstrating that vascular anatomy and preoperative ultrasonographic parameters consistently outweigh comorbidity burden in predicting both early maturation and long-term patency across heterogeneous populations [25]. Our study reinforces this transition by demonstrating that diabetes, hypertension, and cardiovascular disease do not inherently compromise AVF maturation when proper anatomical criteria are met.

From a clinical perspective, this evidence supports the recommendation that comorbidities should not be used as exclusion criteria for AVF creation. Instead, the decision should be anchored in vascular suitability assessed through detailed imaging. This may contribute to reducing unnecessary dependence on tunneled dialysis catheters, which are associated with significantly higher infection and mortality risks. Additionally, acknowledging that anatomical suitability supersedes comorbidity burden can promote equitable access to fistula creation among older and medically complex patients.

Limitations of the present study include its single-center design, which may limit generalizability across diverse practice environments. Although sample size was sufficient for statistical comparison, larger multicenter datasets could yield more robust associations. Another limitation is that long-term primary and secondary patency were not evaluated, and it remains possible that comorbidities exert delayed effects beyond early maturation. In addition, biochemical markers of inflammation, endothelial dysfunction, and arterial stiffness were not assessed; these parameters could provide more detailed insight into the mechanisms linking comorbidities and AVF outcomes.

Future directions should include large, multicenter prospective registries incorporating standardized imaging protocols and long-term patency outcomes. Integration of biomechanical modeling and artificial intelligence could enhance real-time prediction of maturation potential. There remains a strong need for studies examining modifiable physiologic factors, such as arterial elasticity, endothelial function, and microvascular reserve, along with interventional strategies to optimize them preoperatively. Research determining when and how comorbidity-related vascular changes transition from clinically irrelevant to significantly detrimental would further refine personalized access planning.

In conclusion, our study demonstrates that diabetes, hypertension, and cardiovascular disease do not significantly influence arteriovenous fistula maturation when vessel anatomy is adequate and perioperative care is standardized. This reinforces a modern, anatomy-driven approach to vascular access planning and underscores the importance of high-quality preoperative imaging in ensuring successful outcomes.

CONCLUSION

This study demonstrates that diabetes mellitus, hypertension, ischemic heart disease, and peripheral vascular disease do not significantly influence the functional maturation of native arteriovenous fistulas when vascular anatomy is suitable and standardized preoperative assessment is performed. Preoperative vessel diameter, particularly cephalic vein calibre, remains the most decisive factor governing successful maturation, outweighing the effects of systemic comorbidities. Our findings support an anatomy-driven approach to vascular access planning, emphasizing the critical role of detailed Doppler ultrasound mapping in selecting optimal sites for fistula creation. Comorbidities alone should not preclude AVF placement, especially when vessel quality is adequate. By prioritizing anatomical suitability over disease burden, clinicians can reduce dependence on temporary dialysis catheters and improve long-term hemodialysis access outcomes.

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