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PRIMARY ARTERIOVENOUS FISTULA FAILURE IN PATIENTS ON MAINTENANCE HEMODIALYSIS: PREVALENCE, RISK FACTORS, AND IMPACT ON LONG-TERM OUTCOMES

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Objective: to assess the prevalence of primary arteriovenous fistula (AVF) failure in patients commencing chronic hemodialysis, to evaluate the relationship between primary failure and long-term outcomes, and to identify risk factors for its development. **Materials and methods.** This retrospective cohort study reports the outcomes of 1595 adult patients starting chronic hemodialysis treatment for the first time. **Results.** Primary failure was noted in 369 patients (23.1%), whereas in 1,226 patients (76.9%), the AVF matured normally and was accessible to puncture without additional interventions. Follow-up by a nephrologist, preoperative evaluation by a surgeon, and ultrasound were linked to a lower risk of primary failure: RR = 0.624 [95% CI 0.523; 0.746], $p < 0.001$; 0.648 [0.469; 0.894], $p = 0.005$; and 0.606 [0.471; 0.78], $p < 0.001$ (when ultrasound was performed by or in the presence of a surgeon 0.372 [0.24; 0.577], $p < 0.001$), respectively. The risk of primary failure increased if AVF was created in two weeks and one week before, and during the first and second weeks after hemodialysis initiation. In single-factor analysis, primary failure was linked to a higher risk of all-cause mortality (HR = 1.54 [1.20; 1.97], $p < 0.001$), but not after adjustment for age and comorbidity (HR = 1.11 [0.85; 1.44], $p = 0.761$). Primary failure was associated with poorer secondary patency (HR = 1.79 [1.28; 2.51] $p < 0.001$) and increased need for reconstructive interventions (IRR = 2.199 [1.985; 2.434], $p < 0.001$). **Conclusion.** Risk reduction factors for primary failure include follow-up by a nephrologist, preliminary examination by a surgeon, supplemented by ultrasound scan. Primary failure is not linked to decreased patient survival (after adjustment for comorbid background and age), but to decreased secondary patency of vascular access.

Keywords: arteriovenous fistula, hemodialysis, failure, synthetic vascular graft, primary patency, secondary patency.

INTRODUCTION

Arteriovenous fistula (AVF) is widely considered the optimal type of vascular access for patients on chronic hemodialysis (HD) [1]. For obvious reasons, after AVF creation, time is needed for its maturation, during which volumetric blood flow rate increases in order to ensure a reliable required blood flow into the extracorporeal circuit. In this case, the diameter of the vein and artery increases, the vein wall is transformed, etc. [2] An AVF should typically be ready for successful routine punctures within 4–6 weeks [3] and remain functional for at least 6 months after creation [4]. If it does not mature within this timeframe, it is considered dysfunctional or slow-maturing. Approximately 20% [5] to 30% [6] of patients have primary AVF dysfunction.

Primary dysfunction of an AVF, i.e., issues arising during its maturation process before it can be used for dialysis, often leads to complications like requiring a central venous catheter (CVC) for access, which can result in increased hospital stays and higher treatment costs.

However, the impact of primary dysfunction on long-term outcomes has not been determined. The fact that primary AVF failure is associated with worse long-term outcomes may be due to other reasons, namely the fact that patients with poorer overall health are more likely to experience primary dysfunction, which determines long-term outcome.

Objective: To assess the prevalence of primary AVF failure in patients commencing chronic HD for the first time, to evaluate the relationship between PF and long-term outcomes, and to identify risk factors for its development.

MATERIALS AND METHODS

Study Design

This retrospective cohort study analyzed treatment outcomes in 1,595 patients who underwent AVF creation between June 2018 and February 2024. Inclusion criteria included age over 18 years, initiation of renal replacement therapy (RRT) for the first time, and availability of

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comprehensive medical history (to the required extent) and follow-up data.

Primary dysfunction (failure) was defined as either thrombosis before the first use of the AVF or unsuccessful puncture three months post-creation (delayed maturation).

Our approach prioritized the formation of native AVFs on the lower third of the forearm of the non-dominant upper limb. When native vessels were unsuitable, a synthetic vascular graft (SVG) was used. In the absence of ultrasound data, the access type was selected based on clinical examination. The use of SVG as an alternative to native AVF was intended to improve the likelihood of establishing functional vascular access or shorten maturation time.

The study considered the type of vascular access (native AVF or SVG), the level of creation (lower third of the forearm or other), and the outcomes of only the first intervention for permanent vascular access formation.

Ethical approval was obtained from the independent local ethics committee at Vladimirsky Moscow Regional Research and Clinical Institute under protocol No. 5, dated May 25, 2018.

Data source

The database was compiled using systematized information from the Medical Information System Everest, the Unified Medical Information and Analytical System of the Moscow Oblast, and data from outpatient dialysis centers.

Statistical analysis

Quantile plots and frequency diagrams were used to visually assess whether the quantitative characteristics (and residuals of regression models) followed a normal distribution. Since the distributions showed no significant deviations from normality, data are presented as mean and standard deviation (reported in parentheses). Qualitative variables are described using absolute numbers and percentages.

For comparisons between quantitative variables and binary qualitative factors, Student's or Welch's t-test was applied. When qualitative factors had more than two levels, one-way analysis of variance (ANOVA) was used as an omnibus test, followed by Tukey's criterion for post-hoc pairwise comparisons. For the joint distribution of qualitative variables, Fisher's exact test was applied for 2×2 tables, while the Fisher–Freeman–Halton exact test was used for larger contingency tables. Effect sizes were expressed as risk ratio (RR) and odds ratio (OR) with 95% confidence intervals (95% CI), reported in square brackets.

The association between primary dysfunction and the frequency of CVC use over time was quantified using the incidence rate ratio (IRR), interpreted as relative risk.

Unadjusted patient survival and secondary AVF patency were assessed using the Kaplan–Meier method, with survival curves plotted and asymmetric 95% CI calculated. Differences in survival were evaluated using the log-rank test. Type I right-censoring was applied in survival analysis. Effect size was expressed as hazard ratio (HR) with 95% CI.

Adjusted survival analysis was conducted using the Cox proportional hazards regression model with the adjustedCurves::adjustedsurv() package. The proportional hazards assumption was verified through Schoenfeld residuals analysis, while the linearity between predictors and the log-risk function was examined using martingale residuals. These residual plots were also analyzed for influential observations, supplemented by DFBETAs analysis to identify influential observations. Predictor multicollinearity was assessed using the correlation matrix and variance inflation factor.

Sample size was not pre-calculated but was determined by the available data. Statistical analysis was conducted using R 4.4.1 within the RStudio Desktop 2024.04.2 environment, along with relevant libraries. All tests were two-tailed, and p-values less than 0.05 were considered statistically significant.

RESULTS

Prevalence

Primary failure was observed in 369 patients (23.1% of 1,595), while AVF maturation occurred successfully in 1,226 patients (76.9%) without the need for repeat surgical interventions.

Among patients with primary AVF failure, 127 (34.4% of 369; 8.0% of 1,595) had delayed AVF maturation, while 242 (65.6% of 369; 15.2% of 1,595) developed thrombosis.

A summary of patient characteristics is presented in Table 1.

Despite all efforts, a functional AVF could not be formed in 41 patients (2.6% of 1,595, 11.1% of 369), and there was a conversion of vascular access to CVC (14 patients, 34.1% of 41) or RRT modality from hemodialysis to peritoneal dialysis (27 patients, 65.9% of 41). Among these patients, PF presented as delayed maturation in 7 cases (17.1% of 41) and thrombosis in 34 cases (82.9% of 41). None of these patients underwent a single HD session using AVF.

As shown in Fig. 1, the proportion of patients who required conversion of vascular access or RRT modality remained relatively consistent across all stages. This observation is further supported by the absence of significant differences in the mean number of days between AVF creation and HD initiation among patients who underwent access or modality conversion versus those without dysfunction: –63.5 (52) days (range: –183 to 49) and –67.7 (55.5) days (range: –201 to 125), respectively (P = 0.881).

Additionally, in patients with dysfunction, AVF was generally created closer to the time of HD initiation (–53.4 [53.9] days, range: –194 to 101) compared to those without dysfunction (P < 0.001).

Risk factors

Potential risk factors for primary AVF dysfunction, along with descriptive statistics for the entire cohort, are summarized in Tables 1 and 2. Patients with dysfunction were more likely to be female and had a higher mean age compared to those without dysfunction. Additionally, while small, statistically significant differences were observed in body mass index (BMI), with slightly higher mean values in patients with dysfunction. However, as shown in Table 1, despite formal statistical significance,

Table 1

Potential risk factors for primary AVF failure: demographics and comorbid background. Fisher's exact test (also called the Fisher–Freeman–Halton test) and Student's t-test (Welch's t-test) were used

Characteristics	Total, n = 1595	Primary failure		P value
		Yes, n = 369	No, n = 1226	
Age, years	49.1 (8.6)	54.3 (8.6)	47.5 (8.0)	**<0.001**
Female	720 (45.1%)	204 (55.3%)	516 (42.1%)	**<0.001**
Body mass index, kg/m^2	28.4 (3.7)	28.8 (4.0)	28.3 (3.5)	**0.029**
Persistent hypotension	99 (6.2%)	45 (12.2%)	54 (4.4%)	**<0.001**
Diabetes mellitus	342 (21.4%)	103 (27.9%)	239 (19.5%)	**<0.001**
Polycystic kidney disease	133 (8.3%)	85 (23.0%)	48 (3.9%)	**<0.001**
Systemic processes[1]	53 (3.3%)	41 (11.1%)	12 (1.0%)	**<0.001**
Body weight:				
Malnutrition	11 (0.7%)	3 (0.8%)	8 (0.7%)	
Undernutrition	10 (0.6%)	3 (0.8%)	7 (0.6%)	
Normal	377 (23.6%)	79 (21.4%)	298 (24.3%)	
High nutrition	315 (19.7%)	67 (18.2%)	248 (20.2%)	**0.048**
Grade I obesity	467 (29.3%)	98 (26.6%)	369 (30.1%)	
Grade II obesity	388 (24.3%)	108 (29.3%)	280 (22.8%)	
Grade III obesity	27 (1.7%)	11 (3.0%)	16 (1.3%)	
Nature of deviation of body mass index				
Underweight	21 (1.3%)	6 (1.6%)	15 (1.2%)	
Normal body weight	377 (23.6%)	79 (21.4%)	298 (24.3%)	0.420
Overweight	1197 (75.0%)	284 (77.0%)	913 (74.5%)	

Note: [1] Vasculitis, myeloma, HIV-associated nephropathy, kidney tumors, history of drug abuse/addiction, etc.

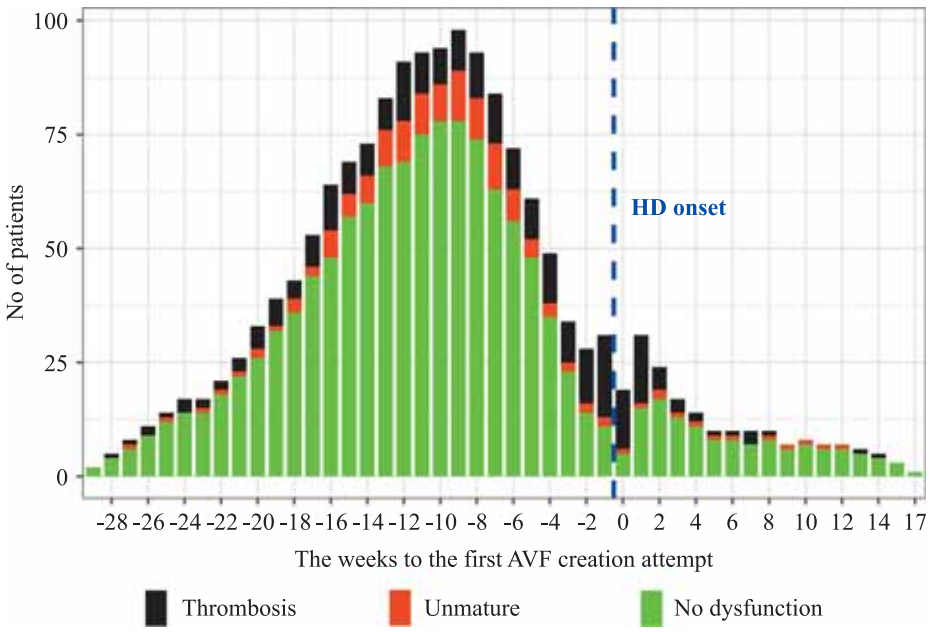

Fig. 1. Frequency of primary AVF failure

the distribution of patients across BMI categories remained relatively uniform.

Although most patients had at least one nephrology consultation six months or more before HD initiation, fewer than 10% were evaluated by a surgeon before AVF creation (excluding the day of the procedure). Preoperative ultrasound was performed in approximately one in five patients, while Doppler ultrasound was conducted in about one in seven. Notably, patients without dysfunction were more likely to have been seen by a nephrologist and/or surgeon before AVF creation and had undergone preoperative ultrasound (with or without Doppler ultrasound); see Table 2.

Among patients who underwent a preoperative surgical evaluation, the interval between consultation and AVF creation, as well as between AVF creation and HD initiation, was shorter in patients with dysfunction compared to those without. Additionally, patients with dysfunction were significantly less likely to have undergone preoperative ultrasound performed by or in the presence of the operating surgeon.

While all quantitative risk factors in Table 1 showed statistically significant associations with primary AVF failure, their clinical relevance varied. For example, the mean age difference between patients with and without dysfunction was 6.8 [95% CI 5.8, 7.7] years, whereas the mean BMI difference was only 0.47 [95% CI 0.02, 0.93] kg/m^2 with higher values in PF patients. Similarly, the mean time between surgical consultation and AVF creation was 10.3 [95%DI –16.4; –4.1] days shorter in patients with dysfunction.

Since these indicators are measured in different units, Fig. 2 presents standardized mean differences to facilitate comparison of their relative impact on primary AVF dysfunction.

When evaluating the association between primary AVF dysfunction and qualitative factors, systemic processes and polycystic kidney disease emerged as the most significant contributors (Table 3). However, no statistically significant association was found between primary AVF dysfunction and abnormal BMI (either decreased or increased relative to normal).

Regarding the impact of preoperative follow-up factors, all analyzed variables were linked to a reduced risk of primary AVF failure (Table 4).

As demonstrated above, the proportion of patients experiencing primary AVF failure increased significantly

Table 2

Potential common risk factors for primary AVF failure: features of preoperative follow-up. Fisher's exact test (also called the Fisher–Freeman–Halton test) and Student's t-test (Welch's t-test) were used

Characteristics	Total, n = 1595	Primary failure		P value
		Yes, n = 369	No, n = 1226	
Follow-up by a nephrologist[1]	1106 (69.3%[3])	216 (58.5%[3])	890 (72.6%[3])	**<0.001**
Follow-up by a surgeon[2]	203 (12.7%[3])	19 (5.1%[3])	184 (15.0%[3])	**0.005**
Time between surgeon's visit and AVF creation, days[4]	28.4 (12.2)	19.6 (11.7)	29.8 (11.6)	**0.001**
Ultrasound before AVF creation	387 (24.3%[3])	60 (16.3%[3])	327 (26.7%[3])	**<0.001**
Doppler ultrasound before AVF creation	264 (16.6%[3])	42 (11.4%[3])	222 (18.1%[3])	**0.002**
Ultrasound performed by or in the presence of an operating surgeon	203 (12.7%[3], 44.4%[5])	19 (5.1%[3], 50.0%[5])	184 (15.0%[3], 72.7%[5])	**<0.001**
Time between AVF creation and the beginning of HD, days	–64.6 (55.3)	–54.5 (53.7)	–67.7 (55.5)	**<0.001**

Note: [1] At least one visit to a nephrologist 6 months or more before starting HD; [2] At least one visit to a surgeon before AVF creation; [3] Percentage of total patient count in this category; [4] Only among patients who were examined by a surgeon prior to AVF creation (not on the day of formation); [5] Percentage of patients who underwent preoperative ultrasound scanning.

Table 3

Strength of association of the risk of primary AVF failure with qualitative attributes: demographics and comorbid background

Characteristics	RR [95% CI]	OR [95% CI]
Female	1.503 [1.255; 1.799]	1.701 [1.346; 2.151]
Persistent hypotension	2.099 [1.657; 2.658]	3.014 [1.992; 4.562]
Diabetes mellitus	1.419 [1.169; 1.722]	1.599 [1.223; 2.09]
Polycystic kidney disease	3.29 [2.79; 3.88]	7.345 [5.039; 10.71]
Systemic processes[1]	3.637 [3.055; 4.33]	12.65 [6.57; 24.34]
Low body mass index[2]	1.363 [0.674; 2.757]	1.529 [0.522; 3.937]
High body mass index[3]	1.132 [0.908; 1.412]	1.172 [0.888; 1.561]

Note: [1] Vasculitis, myeloma, HIV-associated nephropathy, kidney tumors, history of drug abuse/addiction; [2] Relative to normal, P = 0.415; [3] Relative to normal, P = 0.266.

when AVF was created closer to the onset of HD (see Fig. 1).

As shown in Fig. 3, the relative risk of primary dysfunction was statistically significantly increased in the case where AVF was created two and one week before HD onset (RR = 2.44 [95% CI 1.66; 3.59], P < 0.001 and RR = 3.06 [95% CI 2.31; 4.05], P < 0.001, respectively), and in the case of AVF creation during the first and second weeks after HD onset (RR = 2.78 [95% CI 1.93; 4.02], P < 0.001 and RR = 2.47 [95% CI 1.55; 3.96], P = 0.001, respectively).

Impact on long-term outcomes

In the univariate analysis, we identified statistically significant differences in patient survival based on primary AVF failure; see Fig. 4.

The starting time point for survival analysis was the onset of chronic HD.

Censoring criteria: Patients were censored in cases of conversion to another RRT modality or death. Thus, survival among PF-free patients was 95.4% [95% CI 94.1; 96.6], 87.0% [95% CI 84.9; 89.2], 78.4% [95% CI 75.7; 81.3], and among PF patients, 92.7% [95% CI 90.1; 95.4], 80.3% [95% CI 76.1; 84.7], 68.1% [95% CI 62.9; 73.8] at 12, 36, and 60 months, respectively. HR = 1.54 [95% CI 1.20; 1.97], P < 0.001.

As expected, the risk of primary dysfunction was associated with several factors that were also linked to mortality risk. However, after adjusting for comorbidities and age, the association between primary AVF dysfunction and mortality risk was no longer statistically significant (Fig. 5). Adjusted survival among patients without primary dysfunction was 95.0% [95% CI 93.8; 96.2], 85.5% [95% CI 83.4; 87.6], 76.8% [95% CI 74.0; 79.7], and among patients with primary dysfunction was 94.5% [95% CI 93.0; 96.0], 84.1% [95% CI 80.7; 87.5], 74.7% [95% CI 69.9; 79.6] at 12, 36, and 60 months, respectively. HR = 1.11 [95% CI 0.85; 1.44], P = 0.761.

In cases where a functional AVF was achieved in a patient, PF was associated with decreased secondary patency. In patients with primary AVF failure, secondary patency at 12, 36, and 60 months was 91.7% [95% CI

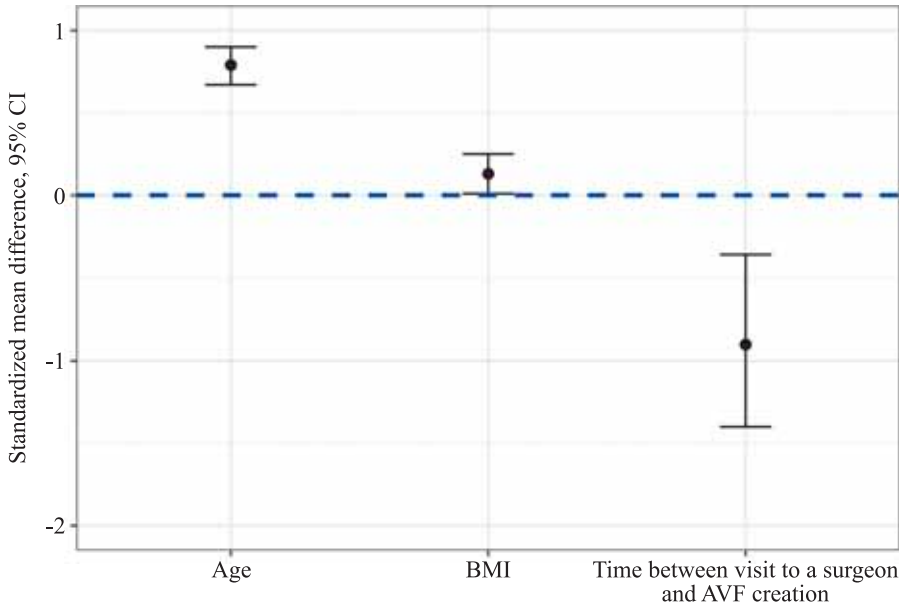

Fig. 2. Standardized difference of quantitative mean scores. Value in patients with primary AVF failure – value in patients without failure

Table 4

Strength of association of the risk of primary AVF failure with qualitative attributes: preoperative follow-up features

Characteristics	RR [95% CI]	OR [95% CI]
Follow-up by a nephrologist[1]	0.624 [0.523; 0.746]	0.533 [0.418; 0.679]
Follow-up by a surgeon[2]	0.648 [0.469; 0.894]	0.582 [0.396; 0.857]
Ultrasound before AVF creation	0.606 [0.471; 0.78]	0.534 [0.394; 0.724]
Doppler ultrasound before AVF creation	0.648 [0.483; 0.868]	0.581 [0.408; 0.826]
Ultrasound performed by or in the presence of an operating surgeon	0.372 [0.24; 0.577]	0.307 [0.189; 0.501]

Note: [1] At least one visit to a nephrologist 6 months or more before starting HD; [2] At least one visit to a surgeon before the day of AVF creation.

88.7; 94.9], 79.7% [95% CI 73.8; 86.1], and 64.7% [95% CI 54.9; 76.2], respectively; in PF-free patients, it was 95.8% [95% CI 94.6; 97.1], 88.4% [95% CI 85.8; 91.1], and 82.9% [95% CI 79.1; 87.0], respectively. Thus, primary AVF failure was associated with a greater than 1.5-fold increase in total loss of function (analyzed period, 60 months after the start of AVF use): HR = 1.79 [95% CI 1.28, 2.51], P < 0.001.

Moreover, primary patency was slightly greater in patients in whom we observed PF: 89.3% [95% CI 85.9; 92.8], 67.5% [95% CI 60.9; 74.8] and 51.4% [95% CI 42.6; 62.1] at 12, 36, and 60 months, respectively; in PF-free patients, 85.9% [95% CI 83.7; 88.2], 60.0% [95% CI 55.8; 64.6] and 44.6% [95% CI 39.1; 50.9], respectively, HR = 0.76 [95% CI 0.60, 0.97], P = 0.029. These paradoxical differences can be explained by the fact that in PF cases, the subsequent vascular access used for HD was typically formed more proximally compared to patients whose initial access matured successfully.

In patients without dysfunction, the first vascular access became functional within the first three months after its formation. The type and localization of these accesses are detailed in Table 5.

Notably, at the time of formation, the distribution of vascular access types and their localization differed significantly between patients with and without PF. Spe-

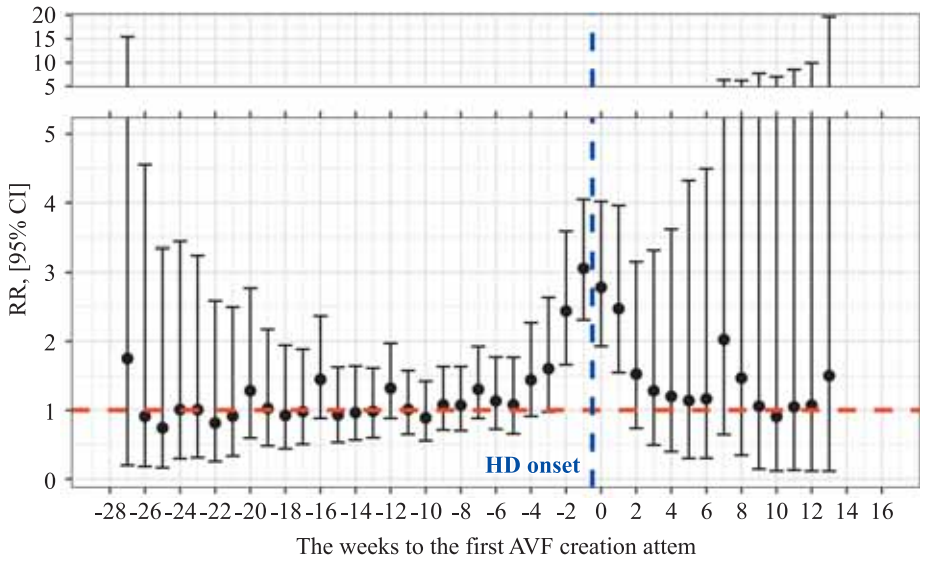

Fig. 3. Relative risk of primary AVF failure depending on the timing of creation and HD onset. When computing estimates, the number of patients at each stage was correlated with the number of patients at earlier (for cases where AVF was created before HD onset) or – later (for cases where AVF was created after HD onset) stages

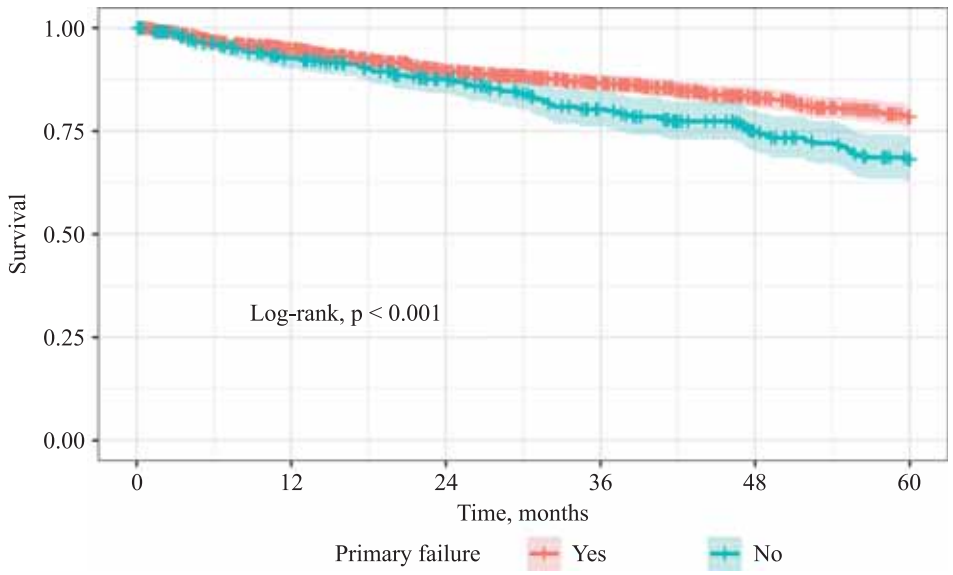

Fig. 4. Unadjusted patient survival (patients who died within 90 days of HD onset were excluded). Kaplan–Meier estimates. Fill indicates 95% CI limits, + – censoring. HD onset served as the baseline time point. In case of HD conversion to other RRT modalities or death, the patient was censored

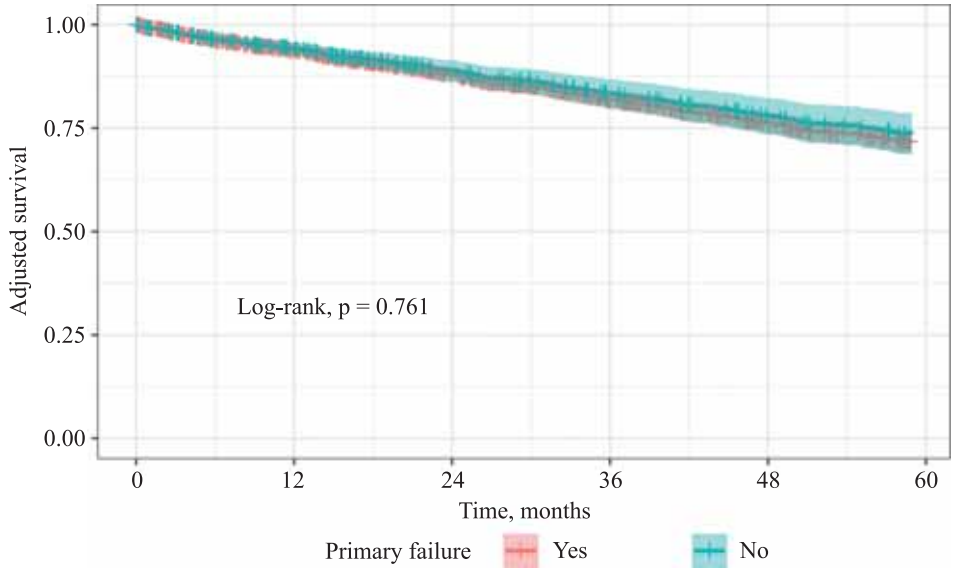

Fig. 5. Comorbidity-adjusted (CCI score) and age-adjusted patient survival at the time of first AVF creation (patients who died within 90 days of HD onset were excluded). Cox proportional hazards regression model. Fill indicates 95% CI limits, + – censoring. HD onset served as the baseline time point. In case of HD conversion to other renal replacement therapy modalities or death, the patient was censored

Table 5

Type and localization of vascular access in the groups at the time of creation and at the time of first puncture

Access type	No primary failure, n = 1226	Primary failure	
		At the time of first creation, n = 328	At the time of first puncture on HD, n = 328
Native AVF, lower third of the forearm	1064 (86.8%)	308 (93.9%)	0
Native AVF of other localization	98 (8.0%)	13 (4.0%)	239 (79.0%)
Synthetic vascular graft	64 (5.2%)	7 (2.1%)	69 (21.0%)

cifically, in PF patients, the proportion of SVG and AVF created outside the lower third of the forearm was approximately half that observed in PF-free patients (P < 0.001).

PF patients underwent one to six reconstructive surgeries. PF was associated with an increased need for reconstructive interventions (excluding the first attempt at AVF creation): IRR = 2.199 [95% CI 1.985; 2.434], P < 0.001 (1.740 [95% CI 1.609; 1.879] per 10 patient-months / 0.791 [95% CI 0.741; 0.845]).

As a result, as shown in Table 5, at the time of the first puncture, 21% of patients had a vascular access formed as an SVG or AVF proximal to the lower third of the forearm (including operations with vein transposition).

Also, primary AVF dysfunction was associated with a significant increase in the need for CVC implantation: IRR = 2.151 [95% CI 1.911; 2.419], P < 0.001 (1.302 [95% CI 1.189; 1.424] per 10 patient-months / 0.606 [95% CI 0.561; 0.652]).

The mean duration of catheterization in PF patients was 13.7 catheter-days [95% CI 12.5; 14.9] per 100 patient-months of follow-up, and in PF-free patients it was 5.2 catheter-days [95% CI 4.8; 5.7] per 100 patient-months of follow-up, IRR = 2.615 [95% CI 2.319; 2.947], P < 0.001. The greater need for CVC use in PF patients naturally resulted in a higher incidence of central vein stenosis (CVS) compared to PF-free patients: HR = 3.706 [95% CI 1.571; 8.739], P = 0.003 (actual incidence of CVS at 60 months 7.3% [95% CI 2.3; 12.0] / 2.1% [95% CI 0.5; 3.7]). In total, CVS developed in 21 patients (11 PF patients and 10 PF-free patients). In case of subclavian, brachiocephalic, or superior vena cava vein lesions, endovascular intervention was performed.

DISCUSSION

Currently, there is no universally accepted timeframe after which a AVF is considered primarily dysfunctional. The European Society for Vascular Surgery (ESVS) Clinical Practice Guidelines [7], recommend assessing AVF readiness for needle puncture 4–6 weeks post-creation. If successful puncture is not possible, further diagnostic and therapeutic interventions should be considered to restore AVF function. The European Society of Nephrology holds a similar opinion [3].

The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF KDOQI) guidelines [4] define primary AVF dysfunction as an access that remains non-functional for dialysis within 6 months of creation, despite radiologic or surgical interventions (endovascular or open surgical procedures).

For this study, we adopted a three-month threshold, as it aligns more closely with domestic clinical practices, particularly regarding preoperative follow-up and patient routing. This timeframe was chosen based on the observation that the mean time between AVF creation and HD onset was just over two months (see Table 2).

Studies assessing the prevalence and risk factors of primary AVF dysfunction, as well as the time required to establish a stable functional access, often focus primarily on delayed maturation, without considering AVF thrombosis.

From our perspective, when planning a patient's long-term vascular access strategy – including the timing and type of initial access formation and possibly even the choice of RRT modality – it is more appropriate to assess PF as a whole, rather than differentiating between thrombosis and delayed maturation.

However, such differentiation remains relevant in the context of evaluating the efficacy of therapeutic or surgical interventions aimed at preventing specific types of PF, a topic that falls outside the scope of this study.

The risk factors for primary AVF dysfunction (PF) presented in Table 3 are well-documented in the literature, reinforcing their significance and aligning with findings from other studies [8–11]. Given that an increased risk of PF is associated with a longer time required to establish a stable vascular access, it is reasonable to suggest that vascular access formation should be planned earlier in patients with these risk factors.

However, in current clinical practice, this is not routinely implemented. Patients with high PF risk typically undergo vascular access formation following the same standard protocol as the general population initiating chronic HD.

In our sample, only 69% of patients had seen a nephrologist at least six months before starting HD and only 13.5% had a preoperative consultation with a surgeon before the day of AVF creation.

This highlights the need for improved CKD screening in high-risk groups and modifications to patient routing protocols to enhance vascular access planning and reduce PF incidence. In addition, as shown in Table 4, preoperative ultrasound performed by or in the presence of the operating surgeon plays a crucial role in improving AVF outcomes.

A previous study with a smaller sample size [12] reported that primary AVF dysfunction was associated with an increased risk of all-cause mortality. However, our analysis yielded a different result: after adjusting for comorbid background (using the Charlson Comorbidity Index) and age, the association became statistically insignificant.

The difference in findings can be attributed to several key factors: the previous study assessed individual comorbid conditions, whereas we employed an integrated assessment of comorbidity; we excluded patients who died within 90 days of HD onset, as mortality during this period is more likely influenced by acute clinical factors unrelated to PF, and this we believe is the major cause of the main difference in findings.

This suggests that while an association between PF and mortality may exist, it is unlikely to be causal – rather, it reflects the complex interplay of multiple health factors affecting patient survival.

The association between PF and both increased primary obstruction (functional vascular access) and decreased secondary obstruction can be attributed to two key factors. First, as shown in Table 5, a significantly higher proportion of PF patients had AVFs created more proximally to the lower third of the forearm (compared to PF-free patients). Proximal AVF location is linked to greater primary patency [5, 13, 14]. However, repeated dysfunctions and reconstructions in these patients exhaust vascular resources, leading to faster complete access failure. Furthermore, primary dysfunction was associated with a significantly increased need for SVG, which may contribute to poorer secondary patency compared to native AVF [15]. While proximal AVFs and SVGs demonstrate a lower incidence of primary dysfunction [16, 17], we recommend considering these options only for patients with risk factors for AVF dysfunction in the lower third of the forearm.

Based on our findings, all patients should undergo a comprehensive preoperative evaluation, including a mandatory surgical consultation before vascular access formation, complemented by ultrasound assessment.

The prevalence of PF in our study (23.1%) aligns with estimates from earlier research [5, 6]. A 2004 meta-analysis [18] reported a PF incidence of 15.3% (95% CI: 12.7–18.3%) with a 95% range of 6–34%, while a 2014 meta-analysis [13] found an incidence of 23% (18–28%). Despite numerous proposed initiatives [19], PF rates have not significantly declined – and may have even slightly increased – over the past two decades.

Most studies identify similar sets of significant risk factors, yet the persistent incidence of PF suggests that improving vascular access outcomes in chronic HD patients requires not just repeated hypothesis testing, but the effective application of existing knowledge, tailored to local clinical practices and systemic organizational changes.

Limitations of the study. This study is retrospective, which comes with inherent methodological limitations.

We did not account for the surgeon's experience or the number of procedures performed per year. However, evidence suggests that surgeon expertise may sig-

nificantly influence vascular access outcomes [20, 21]. In our setting, we believe this factor can be reasonably disregarded, as all participating surgeons had over eight years of experience and performed more than 200 procedures annually.

Additionally, we did not incorporate ultrasound findings in our analysis. This aspect warrants a dedicated investigation, which we plan to publish separately.

CONCLUSION

Factors that reduce PF risk include nephrologist follow-up within six months before HD, preoperative evaluation by a surgeon, and ultrasound examination. While PF is not linked to decreased patient survival after adjusting for comorbid background and age, it is associated with poorer secondary patency of vascular access.

The authors declare no conflict of interest.

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