The role of regular surveillance on maintenance of patency of vascular access

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Received: 12 June 2022
Revised: 07 July 2022
Accepted: 02 August 2022
Published: 05 April 2023

The Egyptian Journal of Surgery 2023, 41:1002–1008

Objectives
Vascular access (VA) dysfunction, typically associated with progressive stenosis with subsequent failure, is a major problem associated with significant morbidity in hemodialysis (HD) patients and increased health care expenditure. The study aim was to report VA patency outcomes after intervention for flow dysfunction detected by duplex ultrasonography (DUS) surveillance associated with the presence of clinical indicator(s).

Patients and methods
This prospective observational study was conducted in a tertiary university hospital (October 2018–October 2020). Patients with end-stage renal disease with newly created VAs underwent routine DUS surveillance every 3 months. Identified cases fulfilling at least one clinical indicator were included and underwent pre-emptive interventions. Thrombosed VA and asymptomatic lesions were excluded. Surveillance was subsequently performed using clinical, DUS and HD criteria to detect a failing/failed access. Patient follow-up and access-related events were analyzed.

Results
The median age of the study group was 51 years, and 59.4% were male. Native VA was the predominant one. The mean access age was 13.9 months. Arm swelling was the major clinical presentation (32.9%). Most lesions were stenotic (86.5%), and juxta-anastomotic (42.9%) was the most common site. Balloon angioplasty +/– venous stent was used in all included patients. Multivariate analysis revealed that decreased access age, occlusive, multiple lesions, and lesion length more than5 cm were significant predictors of primary patency loss.

Conclusion
This study highlights the role of regular surveillance to stay ahead of the anticipated access dysfunction and to intervene in a timely manner. Integrated and efficient team work between HD providers and the vascular surgeons is crucial.

Keywords:
surveillance, vascular access, vascular access dysfunction

Egyptian J Surgery 2023, 41:1002–1008

1110-1121

Introduction

Hemodialysis (HD) is the most preferred modality for patients with end-stage renal disease, a continuously growing population worldwide [1,2]. This confirms that a suitable long-lasting vascular access (VA) is crucial for their treatment. The most commonly used types of permanent VA are arteriovenous fistula (AVF) and arteriovenous grafts (AVGs) [3]. VA flow dysfunction is one of the most important causes of morbidity and mortality, with increased health care costs among HD patients [4]. The annual cost of VA creation and maintenance is more than one billion dollars per year [5]. There have been recent advances in understanding the pathogenesis of VA flow dysfunction. Historically, neointimal hyperplasia was considered a major cause of venous stenosis, leading to VA flow dysfunction. The contribution of intimal hyperplasia (IH) to AVF dysfunction still remains controversial [6]. Evidence has revealed strong association of access dysfunction with HD patient's prognosis [7]. This knowledge has resulted in novel management for VA flow dysfunction and its potential complications. Therefore, the aim of the current study was to report VA patency outcomes after intervention for flow dysfunction detected by regular duplex ultrasonography (DUS) surveillance associated with the presence of clinical indicator(s).

Patients and methods

This prospective observational study was approved by our Institutional Review Board and conducted between October 2018 to October 2020 in a high-volume,

tertiary referral university hospital. All patients with end-stage renal disease with newly created AVF/AVG underwent routine DUS surveillance every 3 months, using Philips HD5 (Philips Healthcare, Eindhoven, the Netherlands) fitted with 3–12-MHz linear array transducer, to detect cases associated with flow dysfunction as diagnosed by the presence of more than or equal to 50% reduction in the luminal diameter of the feeding artery or outflow vein, identify its location and extent, assess the feeding artery, and plan for the puncture site for possible intervention.

Identified cases fulfilling at least one clinical indicator [8] were included in the study and underwent pre-emptive either surgical or endovascular intervention, according to lesion location and/or surgeon preference. Cases with thrombosed VA and those with stenosis but not associated with clinical indicators (asymptomatic lesions) were excluded from the study. All eligible patients were fully informed about the nature of the study, as well as the alternative treatment modalities available, and they were provided informed consent forms once agreed to participate in the study.

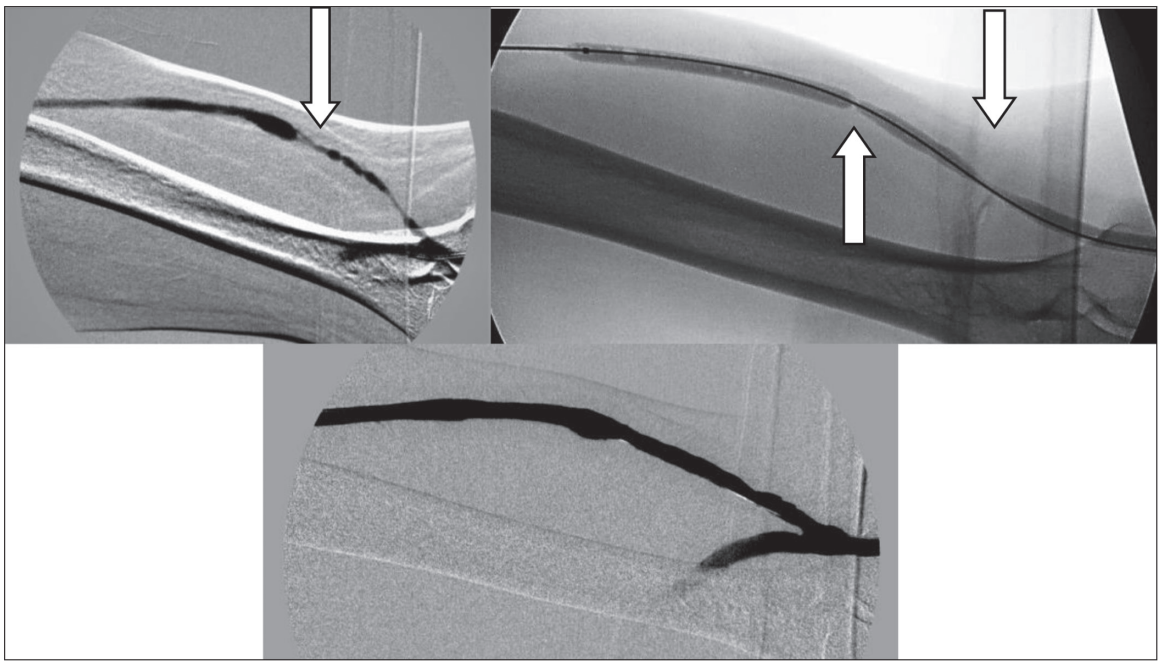
Endovascular procedure: all procedures were performed in a hybrid operative room, equipped with a mobile C-arm fluoroscopy device (Philips Pulsera; Philips Healthcare), under local anesthesia (2% lidocaine) with optional monitored conscious sedation (midazolam and fentanyl). Usually 3000–5000 IU of heparin was delivered intravenously at the beginning of the procedure to guard against thrombotic events.

After gaining percutaneous access to the AVF, diagnostic fistulography of the entire access circuit to the level of the right atrium was performed, through a 6 Fr, 11-cm-long introducer sheath (Prelude, Merit Medical Systems Inc., South Jordan, Utah, USA), to confirm the diagnosis, and identify the location and length of stenosis. Stenotic lesions were negotiated using angled tip 0.035' hydrophilic guide wires (Glidewire; Terumo Medical Corp., Somerset, New Jersey, USA) or .018' guide wires (V-18 Control Wire, Boston Scientific, Marlborough, Massachusetts, USA). Then, angioplasty was performed using 3–12 mm diameter, 4–8-cm-long high-pressure balloons (Dorado; Bard Peripheral Vascular Inc., Tempe, Arizona, USA; Mustang, Boston Scientific). The size of the balloon was selected according to the reference diameter of the most proximal nonaneurysmal vein segment. The balloon inflation time was 3–5 min and in cases of rupture or elastic recoil, inflation was extended for 5–10 min. Postangioplasty completion angiography was obtained in two views as near to orthogonal as possible to assess the technical success of the procedure and exclude possible complications (Figs 1–3). The procedure was concluded with removal of the sheath, and hemostasis was achieved with the use of a purse-string suture. HD was resumed 1 day after the procedure.

Follow-up

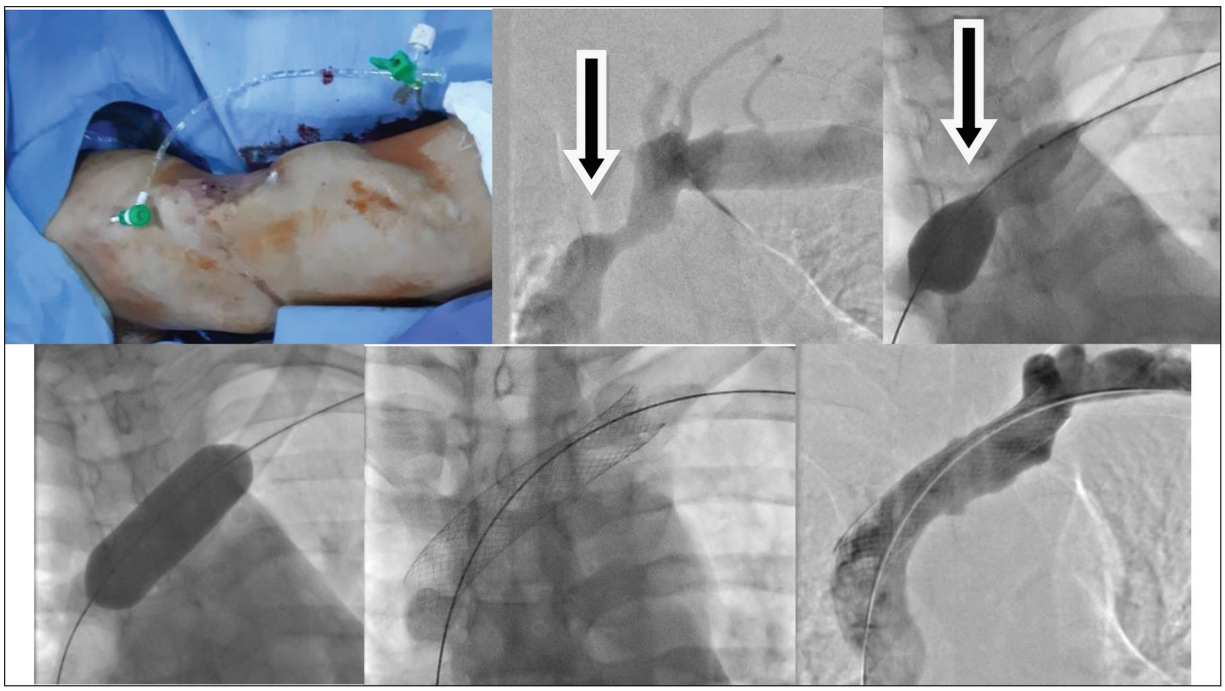
Monitoring and surveillance were subsequently performed using clinical and HD criteria, respectively, to detect a failing/failed access. Each patient's HD records were reviewed, and all access-related events

Figure 1



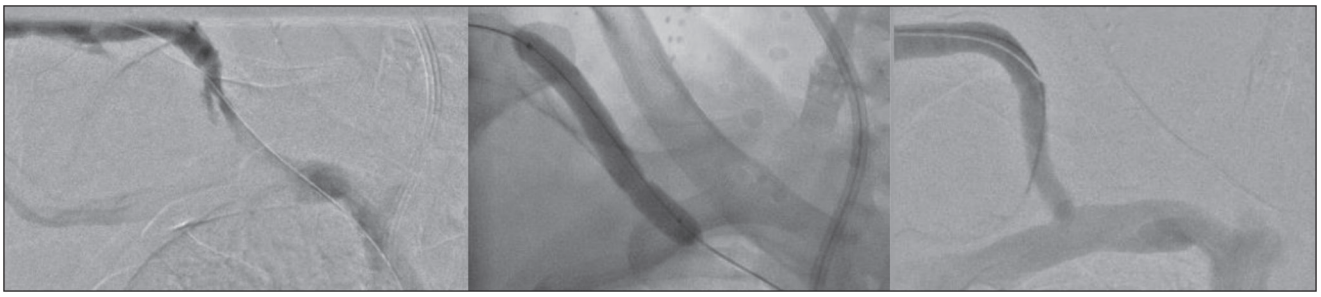
Transradial balloon angioplasty of post-anastomotic multiple lesions of basilic vein transposition AV access. AV, arteriovenous.

Figure 2



Transfistula vein balloon angioplasty and venous stenting (18×9 mm Wallstent) of left innominate vein recurrent significant lesion with perfect inline flow.

Figure 3



Diagnostic venogram showing significant lesion at the cephalic arch treated with balloon angioplasty with no residual lesion after completion venogram.

were documented. Follow-up information for each patient was collected at 1, 3, 6, and 12 months after the treatment procedure.

Study outcome measures

(a) Technical success was defined as patent access with less than 30% residual stenosis at the end of the procedure. (b) Primary patency was defined as the interval following the first surgical/endovascular intervention until any intervention designed to maintain or to restore patency, access abandonment, or the time of measurement of patency. (c) Assisted primary patency was defined as the interval following the first surgical/endovascular intervention until access abandonment or the time of measurement of patency including intervening manipulations (surgical or endovascular) designed to maintain patency [9].

Statistical analysis

Statistical analysis was performed using SPSS 25.0 (SPSS Inc., Chicago, Illinois, USA) and MedCalc 16.8 (MedCalc Software, Ostend, Belgium). Continuous variables were expressed as mean±SD and/or median and interquartile range, and categorical variables as frequency and percentage. Patency rates were analyzed using Kaplan–Meier survival curve, reported as proportion±SE, and intergroup differences were compared using the log-rank test. Multivariate analysis using Cox proportional-hazards regression model with stepwise approach was generated to assess the influence of various demographic, access, and lesion characteristics on primary patency, with results presented as hazard ratio (HR) and 95% confidence interval (CI). A *P* value less than 0.05 was considered statistically significant.

Results

During the study period, 250 patients underwent creation of new AVF/AVG in the study institution. Stenotic lesions in the absence of clinical indicators were identified in 80 patients, and those were excluded from the present study. A total of 170 patients had stenotic lesions associated with clinical indicator(s), and those constituted the study cohort.

The median age of the study group was 51 years, and 59.4% (101/170) were male. Diabetes was detected in 47.1% (80/170). Brachiocephalic and basilic vein transposition AVFs were predominant in 44.1 and 27.6%, respectively, whereas AVGs were reported in 13.5% (23/170). The mean±SD access age was 13.9 ± 8.3 months (Table 1). Different clinical presentations were recorded; the majority was arm swelling (32.9%), difficult cannulation (27%), and decreased thrill (17.6%). Lesion characteristic is examined in Table 2. Underlying single lesion was detected in most patients (77.1%, 131/170), whereas multiple lesions were detected in 22.9% (39/170). The majority of detected lesions were juxta-anastomotic (42.9%, 73/170), and at the cephalic arch (22.9%, 39/170), whereas central vein lesion was detected in 17 cases. Most of lesions were stenotic in nature (86.5%). The total lesion length was categorized into less than 2 cm 25 (14.7%), 2–5 cm 104 (61.2%), and more than 5 cm 41 (24.1%) (Table 2). Our study's postoperative technical success was 100% (170/170). Early thrombosis (first postoperative day) was found in five patients, and they were abandoned. The 3-, 6-, and 12-month primary patencies were 85.3, 75.4, and 58.3%, respectively. Assisted primary patency rates reported at 3, 6, and 12 months were 92.4, 86.8, and 78.0%, respectively (Fig. 4).

Table 1 Patient demographics and access characteristics

Variables	Value (*N*=170)
Age (years)	
Mean±SD	48.9 ± 12.1
Range	19–73
Median (IQR)	51 (16)
Sex [*n* (%)]	
Male	101 (59.4)
Female	69 (40.6)
Diabetes mellitus [*n* (%)]	80 (47.1)
Hypertension [*n* (%)]	68 (40)
Access type [*n* (%)]	
Brescia-Cimino (radiocephalic) fistula	25 (14.7)
Brachiocephalic AVF	75 (44.1)
Basilic vein transposition AVF	47 (27.6)
Prosthetic AVF	23 (13.5)
Access side [*n* (%)]	
Right	55 (32.4)
Left	115 (67.6)
Access age (months)	
Mean±SD	13.9 ± 8.3
Range	3–40
Median (IQR)	11 (10)

AVF, arteriovenous fistula; IQR, interquartile range.

Table 2 Lesion characteristics

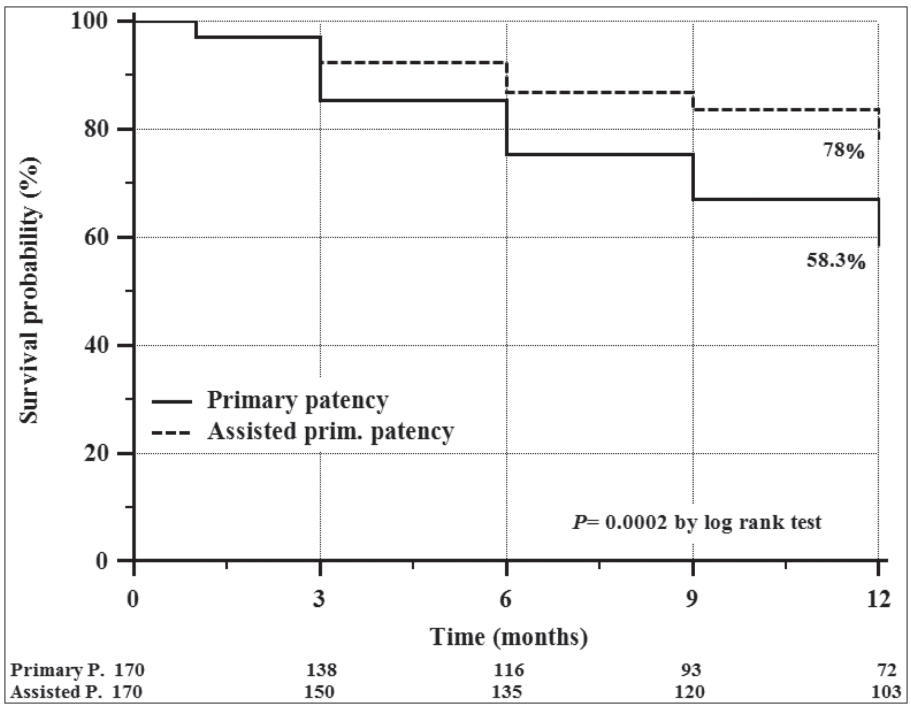
Variables	Value (*N*=170)
Presentation [*n* (%)]	
Difficult cannulation	46 (27)
Decreased thrill	30 (17.6)
Prolonged bleeding from puncture site	16 (9.4)
Arm swelling	56 (32.9)
Dilated chest collaterals/neck veins	22 (12.9)
Lesion number [*n* (%)]	
Single	131 (77.1)
Multiple	39 (22.9)
Lesion location [*n* (%)]	
Anastomotic	21 (12.4)
Juxta-anastomotic	73 (42.9)
Mid-vein/graft segment	51 (30)
Cephalic arch	39 (22.9)
Central veins	17 (10)
Feeding artery	8 (4.7)
Lesion nature [*n* (%)]	
Stenosis	147 (86.5)
Occlusion	23 (13.5)
Total lesion length [*n* (%)]	
<2 cm	25 (14.7)
2–5 cm	104 (61.2)
>5 cm	41 (24.1)

Univariate analysis for predictors of loss of primary patency was reported in Table 3. Multivariate analysis using Cox proportional hazard regression model revealed that decreased access age (HR, 0.93; 95% CI, 0.89–0.97; *P*=0.0014), presence of occlusive lesions (HR, 1.96; 95% CI, 1.10–3.48; *P*=0.02), and total lesion length more than 5 cm (HR, 2.47; 95% CI, 1.38–4.43; *P*=0.0026) were the only significant independent predictors of loss of primary patency (Table 3). A total of 30 patients were censored owing to loss to follow-up (*n*=15), death (*n*=8.), and renal transplantation (*n*=7). Moreover, 25 VAs were complicated by either thrombosis (*n*=13), infection (*n*=7), or pseudoaneurysm (*n*=5).

Discussion

The literature has reported several studies that documented significant adverse patient health effects, decreased quality of life, and increased health care costs from access dysfunction, underdialysis, and access thrombosis. Access flow dysfunction is a major problem that is typically associated with underlying stenosis and/or thrombosis [4,10]. The main aim for performing routine VA monitoring and surveillance is

Figure 4



Kaplan–Meier showing primary and assisted primary patency.

to detect and correct the stenosis to provide efficient dialysis, reduce the risk of thrombosis, and improve access function. Ignoring the access until it fails is not an acceptable issue.

Poor blood flow is usually caused by progressive stenosis of the arterial inflow or venous outflow, and it eventually increases the risk of clotting. The flow disturbances and hemodynamic changes associated with VA may initiate an IH response. The IH occurs mostly at the outflow anastomosis of AVG and anywhere along the outflow vein in a native VA. It can as well involve the ipsilateral central veins, even in the absence of previous indwelling catheters [11,12].

In agreement with the KDOQI guidelines [13], we used a routine monitoring, consisting of VA physical examination with surveillance using DUS as necessary, to detect clinical indicators of VA flow dysfunction. The use of physical examination and DUS is an accepted and evidence-based practice for the assessment and monitoring of access flow dysfunction. It is easily available, requires minimal training, is cost-efficient, and takes minimal equipment and time [14,15]. Moreover, routine VA surveillance by measuring access blood flow (Qa), pressure monitoring, or imaging for stenosis, which is additional to regular clinical monitoring, is not recommended by the KDOQI group [13]. Consequently, intervention was indicated in the study cohort when flow dysfunction existed based on both physical examination and DUS.

Surveillance procedures, including access flow (Qa) measurement by a variety of specialized methods and the use of dynamic and static venous pressure, have been studied to detect stenosis before the development of a clinical indicator [16–18]. The access flow and pressure may be influenced by many factors other than the presence of stenosis, including the location and degree of the stenosis, hemodynamic variations over the course of dialysis (e.g. timing and blood pressure), cannulation technique, and AV access characteristic [18,19]. Thus, it requires repeated measurements to confirm abnormal surveillance results. Moreover, VA with multiple stenoses, not reliably detected with a single surveillance tool, may influence its diagnostic role [20]. The AVG and the AVF can have different pathophysiology for development of stenosis, which may occur at different rates, locations, and hemodynamic consequences based on their configurations [21]. In addition, the expertise and reliability of the operator obtaining the measurement may contribute to abnormal surveillance indicators. As a result, the use of surveillance methods alone is not accurate to interfere in VA dysfunction, and it should be used as a supplementary to clinical monitoring. Moreover, for AVF/AVG, the available data do not demonstrate improved patency with surveillance and subsequent pre-emptive intervention with no clinical indicators, compared with routine clinical examination [13,18,20].

The presence of positive clinical indicators and underlying access significant stenosis may increase the

risk of thrombosis and VA loss. Consequently, KDOQI considers it reasonable for those patients to undergo pre-emptive surgical or endovascular intervention of their access to improve access patency [13]. Accordingly, in our study, we only interfered in 170 HD patients with clinically relevant access dysfunction. Immediate dialysis was delivered to all patients without the need for a temporary central venous catheter. Our 3-, 6-, and 12-month primary patencies were 85.3, 75.4, and 58.3%, respectively (Fig. 3). Heye *et al.* [22] reported a primary patency of 48.5% at 1 year, 31.4% at 2 years, and 22.5% at 3 years. Aktas *et al.* [23] were able to report substantially higher primary patencies of 84.7, 62.2, and 23.7% at 1, 2, and 3 years, respectively. Sugimoto *et al.* [24] reported 1-year primary patency of 47.3% of successful procedures. Asif *et al.* [25] reported 6-month patency of 75% and 12-month patency of 51%. Our patencies compare favorably with the reported studies.

Asymptomatic patients in the study cohort underwent close follow-up without pre-emptive intervention. Clinically, it is hard to anticipate which anatomic abnormality will progress into a significant functional clinical abnormality, and treatment of clinically asymptomatic stenosis may lead to unnecessary and, subsequently, further interventions to maintain patency with no evidence of improvement [26].

Several studies and meta-analyses have increased our awareness of multiple clinical, anatomical, or biochemical factors that may affect fistula patency. For example, in a meta-analysis by Neuen *et al.* [27], they found out that fistulas that were 4 cm, patients with diabetes mellitus, residual stenosis more than 50%, and patient age more than 75 years were all independently associated with shorter primary patency. In a study by Malka *et al.* [28], occluded fistulas as compared with stenosed fistulas, and fistulas needing a second re-intervention were associated with poor patency rates. Given the number of interventions necessary to maintain some AVFs and AVGs, at some point, it may be prudent to abandon the failing access and to pursue a new HD access in some patients. A study by Aktas *et al.* [23] showed that early dysfunction and lowered primary patency were positively correlated with the presence of factors such as increased patient age, diabetes mellitus, longer lesion length, early recurrence, and residual stenosis. Sugimoto *et al.* [24] also showed that older age, presence of diabetes, longer lesions, and multiple lesions contributed to decrease in the primary patency. Previous studies and analyses show that older age, occluded fistulas, younger fistulas, presence of diabetes and risk factors of atherosclerosis, longer and multiple lesions, early recurrence, and significant residual stenosis do not harbor well for the patency. As compared with the available evidence, a multivariate analysis of our study variables revealed that decreased access age (HR, 0.93; 95% CI, 0.89–0.97; *P*=0.0014), the presence of occlusive lesions (HR, 1.96; 95% CI, 1.10–3.48; *P*=0.02), and total lesion length more than 5 cm (HR, 2.47; 95% CI, 1.38–4.43; *P*=0.0026) were only significant independent predictors of loss of primary patency (Table 3).

The limitation of our study included monitoring and surveillance using physical examination and DUS data without access blood flow (Qa) and pressure monitoring measures. These methods may be influenced by many factors and require repeated measurements that use high specialized tools. In addition, the available evidence documented a high diagnostic accuracy of clinical indicators and invaluable DUS data for detecting access dysfunction [13].

Conclusion

This study highlights the role of monitoring and surveillance to stay ahead of the anticipated progressive access dysfunction and to intervene in a timely manner so that underdialysis and access clotting do not occur.

Table 3 Univariate and multivariate analysis of demographics, access, and lesion characteristics for predictors of primary patency loss

Variables	Univariate analysis		Multivariate analysis	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Age	0.99 (0.98–1.02)	0.74		
Male sex	0.85 (0.53–1.38)	0.52		
Diabetes	0.95 (0.59–1.53)	0.82		
Hypertension	0.67 (0.39–1.12)	0.13		
Left-sided access	0.80 (0.49–1.33)	0.39		
Access age	0.92 (0.88–0.96)	**0.0001**	0.93 (0.89–0.97)	**0.0014**
Multiple lesions	4.27 (2.62–6.95)	**<0.0001**	1.79 (0.98–3.25)	0.06
Occlusive lesions	3.02 (1.71–5.31)	**0.0001**	1.96 (1.10–3.48)	**0.02**
Lesion length >5 cm	3.85 (2.38–6.23)	**<0.0001**	2.47 (1.38–4.43)	**0.0026**
Angioplasty±stenting	1.37 (0.63–2.99)	0.43		

CI, confidence interval; HR, hazard ratio. The bold numbers indicate the clinically significant values.

It has to be a part of an integrated and efficient team work between the patient's dialysis providers and the vascular surgeons.

Acknowledgements

Author contributions: Conception and design of the study: Ahmed K.S. Ahmed and Haitham Ali. Acquisition of data: Ahmed M. Rashed. Analysis and interpretation of data: Ahmed K.S. Ahmed, Mohamed Shahat, and Haitham Ali. Drafting of the article: Ahmed K.S. Ahmed, Mohamed Shahat, and Ahmed M. Rashed. Critical revision of the article: Ahmed K.S. Ahmed and Haitham Ali. Final approval of the article: Ahmed K.S. Ahmed and Haitham Ali. Overall responsibility: Ahmed K.S. Ahmed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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