Research paper

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Ultrasound assessment of upper limb arteriovenous fistulas in hemodialysis patients at the Yaounde University Teaching Hospital

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Keywords
stenosis; fistula; arteriovenous; flow volume

Abstract

Aim: Arteriovenous fistulas are created to serve as a vascular access in hemodialysis patients. Our study assessed the Doppler ultrasound characteristics of upper limb arteriovenous fistulas. **Material and methods:** We carried out a cross-sectional, consecutive sampling study at the Yaoundé University Teaching Hospital. We interviewed consenting patients on maintenance dialysis performed for at least one month via an upper limb arteriovenous fistula, which was subsequently scanned. We compared the proportions and means using chi-squared and ANOVA tests, respectively, with a threshold for significance set at a p value ≥0.05. **Results:** Between 1 July and 31 August 2022, we recruited a total of 41 participants, of whom 56.1% were males. The mean age of the participants was 48.39 years. Radiocephalic (76%) and brachiocephalic (24%) arteriovenous fistulas were the only types present. The mean flow volume in the arteriovenous fistulas was 680.47 (365.98) ml/min, with 34.1% of the fistulas having a low flow volume. Also, 56.1% of the arteriovenous fistulas were stenosed, with the main site of stenosis being the juxta-anastomotic segment of the efferent vein. Aneurysms (53.7%), reverse flow (51.2%), venous luminal flaps (22%), and thrombus (17.1%) were the most common complications identified in the study population, with 78.05% of the arteriovenous fistulas having at least one complication. Factors associated with arteriovenous fistula stenosis included the patient body mass index and the radiocephalic fistula type. Diabetes, aneurysms, and luminal venous flaps were found to be associated with low flow volume. **Conclusions:** The prevalence of vascular modifications and stenosis within functional arteriovenous fistulas was high.

Background

Arteriovenous fistulas (AVFs) are abnormal connections between an artery and a vein. AVFs can be divided into two groups, acquired and congenital. Acquired fistulas can be further subdivided into surgically created, as in for hemodialysis (HD), or secondary to trauma, whether accidental or procedure-related[(1)]. In the context of HD, AFs are created to serve as a vascular access for dialysis. Even though there exist other possibilities for obtaining vascular access for hemodialysis, including Central Venous Catheters (CVCs) and Arteriovenous grafts (AVGs), the AVF has become the preferred route because it is associated with fewer complications than the other access modalities[(2)].

After the creation of autologous AVFs, the blood vessels involved undergo both functional and anatomical and hemodynamic changes (dilatation and vessel remodeling). These changes are necessary to ensure a matured AVF for safe needle cannulation and sufficient blood flow needed for dialysis[(3)]. Amongst these modifications is a significant increase in flow volume in the efferent vein which, for appropriate dialysis, is recommended to be more than 500 ml/min[(4)].

Few studies have been carried out to date to assess the Doppler sonographic characteristics of well-functioning AVFs. A study by Pietura *et al.* evaluated well-functioning mature arteriovenous fistulas and found the prevalence of stenosis to be up to 64%[(5)], which was similar to the 32 cases of stenosis in 40 AVFs identified by Older *et al.*

in their study[6]. The study by Pietura *et al*. also found a mean flow volume in AVFs of 1204.1 ± 554 ml/min[5].

Few sub-Saharan studies evaluating AVFs have been carried out to date; a Cameroonian study by Fokou *et al*. found that out of 518 fistulas created in their study a total of 188 complications occurred in 16% of the AVFs, with aneurysms, failure to mature, and thrombosis being the most frequent[7].

Objectives

The objective of this study was to assess the Doppler ultrasound characteristics of upper limb arteriovenous fistulas. Specifically, we aimed to detect the morphological vascular modifications in arteriovenous fistulas, determine their mean flow volume, and identify the factors associated with low flow volumes.

Methodology

Our cross-sectional study was carried out at major dialysis center in the city of Yaoundé, from 1 July to 31 August 2022. Patients on maintenance dialysis performed for at least a month via upper limb arteriovenous fistulas and consenting to the study were included. We excluded patients with local contraindications for Doppler ultrasound at the AVF site, such as infection or bleeding. We recruited all patients eligible at the institution and consenting to the study within the set time frame.

Data collection

Data was collected via interviews and Doppler ultrasound assessments of the arteriovenous fistulas. The blood vessels were scanned in their longitudinal axis for the measurement of velocity and flow, while the short axis was used to measure diameter. All Doppler measurements were done at an insonation angle of less than or equal to 60°, with the Doppler window parallel to the vessel wall and occupying most of the vessel diameter. Vascular definitions used were those of the American Institute of Ultrasound in Medicine (AUIM).

Definitions

- Arterial stenosis: an artery was considered stenosed when there was a 3 : 1 increase of flow at the reduction of its lumen compared to 2 cm upstream.
- Venous stenosis: a vein was considered stenosed when there was a 2 : 1 increase of flow at the reduction of its lumen compared to 2 cm upstream.
- An absolute peak systolic velocity (PSV) >375 cm/s at a luminal reduction was considered significant.
- Reverse flow: flow towards the anastomosis in artery segment distal to the anastomosis.
- Vessel stenosis: a vessel (arterial or venous) luminal reduction greater than 50%.
- Juxta-anastomotic vein segment: the vein segment before zone of cannulation.
- Aneurysm: a segment of a blood vessel twice larger in diameter compared to adjacent segments.
- Low flow volume: a flow volume of <500 ml/min in the efferent vein.
- Venous thrombosis: the presence of hypo-hyperechoic material in the vessel lumen making in partially to totally incompressible.
- Venous luminal flaps: the presence of luminal projections attached to the vessel wall other valves.
- Venous wall calcifications: hyperechoic venous wall foci, with or without posterior shadowing.

Statistical analysis

Data entry and analysis was done using Statistical Package for Social Sciences (SPSS) version 28 software. Quantitative variables were expressed as means ± standard deviation (SD) when the distribution was considered normal. Pearson's chi-squared test or Fischer's exact test was used for the comparison of proportions, and the ANOVA test was used for the comparison of means. Univariate analysis was used to investigate independent associations to the outcome. A p-value <0.05 was considered statistically significant.

Ethical considerations

This study was carried out after obtaining ethical clearance (Reference number: 288/2022) from the Institutional Ethical Review Board at the Faculty of Medicine and Biomedical Sciences of the University of Yaoundé I. Informed oral consent was obtained from the participants after a detailed oral explanation of the aim of the study and the procedure involved. Patient data was kept strictly confidential.

Results

Demographic characteristics

A total number of 41 participants were enrolled, the majority being male patients, representing 56.1% of the study population. The mean (standard deviation) age of the study population was 48.39 ± 16.56 years. In 78.04% of cases, the fistula scanned was the first on the upper limb and in 21.96% it was the second. We did not have any higher order AVFs.

The main comorbidity found in our study population was hypertension, found in 34 participants, which represented 83% of the study population. Eleven participants suffered from diabetes, and five were persons living with HIV (Tab. 1).

The mean (SD) BMI of the participants was 24.6 (4.21) kg/m^2, with median (IQR) and mean (SD) dialysis vintage of 16.00 (8–32) months and 23.60 (22.40) months. The mean (SD) AVF age of the AVFs evaluated in our study population was 20.25 (18.62) years. Two types of AVFs, radiocephalic and brachiocephalic, were identified in our study population.

Vascular modifications

Evaluating the AVFs, we identified six fistulas which were stenosed with PSV ratio >3, and 18 using the criteria of absolute

Tab. 1. Clinical characteristics of study population

Characteristic		*N* = 41 mean (SD), median	Frequency (%)
Sex: male		23	56.1
Mean age		48.39 (16.56)	
Comorbidities	Hypertension	34	82.9
	Diabetes	11	26.6
	Smoking	3	7.3
	Obesity	3	7.3
	HIV	5	12.2
Number of prior fistulas (0 : 1)		(32 : 9)	78 : 22
Mean weight (SD), kg		69.67 (13.85)	
Mean BMI (SD), kg/m²		24.60 (4.21)	
Median dialysis vintage (IQR), months		16.00 (8–32)	
Mean dialysis vintage (SD), months		23.60 (22.40)	
Mean AVF age (SD), months		20.25 (18.62)	
Fistula type	Radiocephalic	31	75.6
	Brachiocephalic	10	24.4

SD – standard deviation; BMI – body mass index; IQR – interquartile range; AVF – arteriovenous fistula

PSV >375 cm/s (Tab. 2). In the study population, a total of 56.1% of the AVFs were stenosed by either one or more of the definitions. In total, 78.05% of the AVFs had at least one vascular modification.

Tab. 2. Prevalence of vascular modifications

		N = 41, frequency (%)
Stenosed fistulas		23 (56 .1)
Stenosis criteria	Ratio >PSV 3 : 1	6 (14.6)
	PSV >375 cm/s	18 (43.9)
	Ratio >Diameter 2 : 1	3 (7.3)
Aneurysm		22 (53.7)
Reverse flow		21 (51.2)
Venous luminal flaps		9 (22)
Thrombosis		7 (17.1)
Venous wall calcifications		2 (4.9)
Perivascular hematoma		1 (2.4)
AVFs with vascular abnormality		32 (78.05)

PSV – peak systolic velocity

Reverse flow in the artery segment distal to anastomosis, aneurysms (Fig. 1) in the efferent vein, and venous luminal flaps were the most common complications identified in the scanned AVFs. We also had seven cases of non-stenosing thrombi within the efferent veins (Tab. 2).

Hemodynamic characteristics of AVFs

The mean flow volume in the AVFs as seen in Tab. 3 was 680.47 ml/min (Fig. 2), with 34.1% of the fistulas having a low flow volume. Also, the resistivity index in the afferent artery was lower than or equal to 0.5 in 37 out of the 41 fistulas studied.

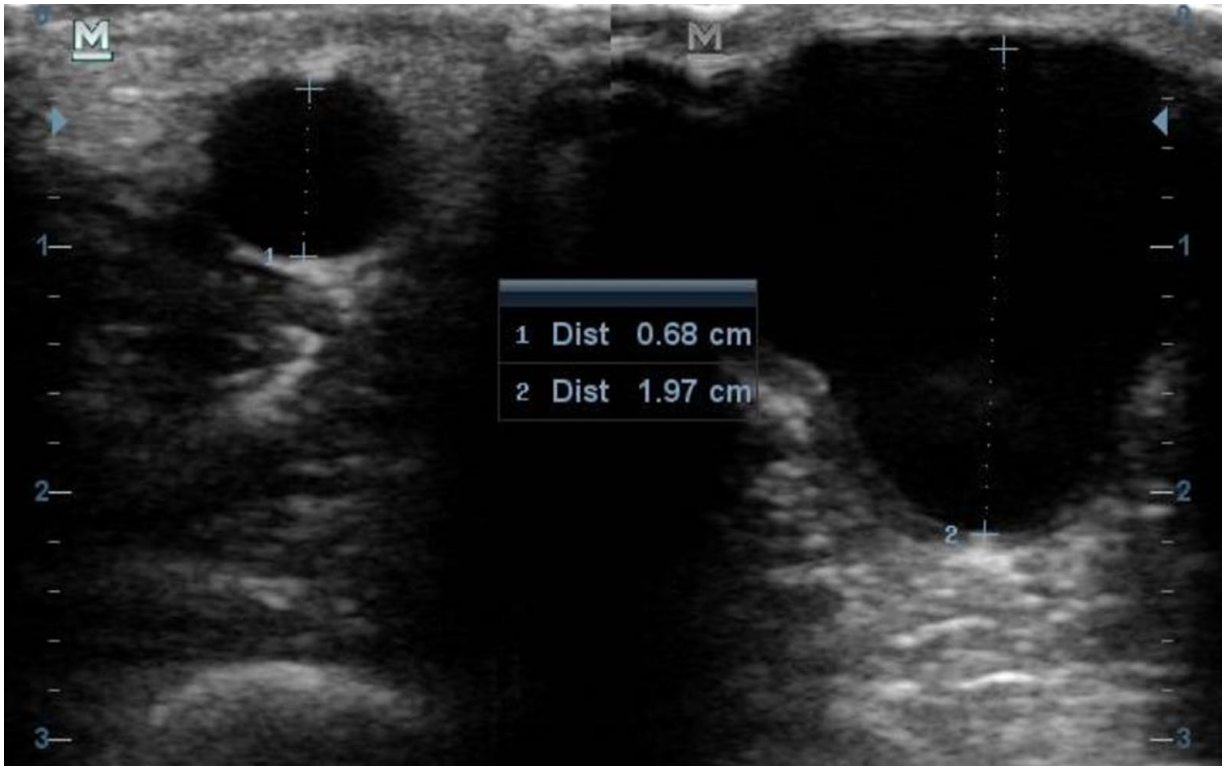

Fig. 1. *Image showing a transverse section through an aneurysm*

Tab. 3. Hemodynamic characteristics

Characteristic	*N* = 41, frequency (%)
Mean artery PSV (SD), cm/s	131.26 (51.98)
Mean RI (SD)	0.43 (0.08)
RI <0.5	37 (90.2%)
Mean anastomosis PSV (SD), cm/s	248.29 (103.81)
Mean flow volume (SD), ml/min	680.47 (365.98)
Low flow volume	14 (34.1%)

PSV – peak systolic velocity; SD – standard deviation; RI – resistivity index

Factors associated with low flow volume

Table 4 shows that among the factors evaluated diabetes, aneurysms, and venous luminal flaps were found to be the determinants of flow volume. Stenosis of the AVF was not associated with the flow volume.

Discussion

Vascular modifications

Aneurysms with a prevalence of 53.7% were the most commonly encountered vascular abnormality. This finding concurred with that reported by Pietura *et al.* who had a rate of 54%, while contrasting with the 27.65% obtained by Fokou *et al*. It is possible that the shorter follow-up time of their cohort might explain the difference. The prevalence of thrombosis in our study was 17.1%, which was not very different from the prevalence reported in the studies by Fokou *et al*. and Pietura *et al*., at 10.63% and 7% respectively[5,7].

Venous luminal flaps were frequent in our study, with a prevalence of 22%. Pietura *et al.* described venous wall irregularities in 20% of the AVFs[5].

Stenosis

We had a high prevalence of stenosis at 56.1%, which is similar to that obtained by Pietura *et al.* at 64%, though different from that reported by Fokou *et al.* (10.63%)[5,7]. The main reason for the differences in prevalence could be the difference in the method of AVF evaluation, which was mainly clinical in their study and sonographic ours. As concerns the site of stenosis, the venous juxta-anastomotic segment (75%) of the efferent vein was shown to be the main site for stenosis, contrary to the study by Pietura *et al.*[5], who observed the anastomosis (57%) as the main site.

Flow volume

Our mean flow volume of 680.47 (365.98) ml/min, obtained by measuring flow in the efferent vein, was similar to that reported by Farrington *et al*. who, by performing measurements at the same site, obtained an average volume flow of 665 ml/min in unassisted mature, assisted mature, or failed-to-mature fistulas[8].

Our mean flow volume was, however, lower than those obtained by Pietura *et al*. and Colombo *et al*. who had the flow volumes of 1204.1 ml/min and 1437 ml/min respectively[5,9]. Both authors

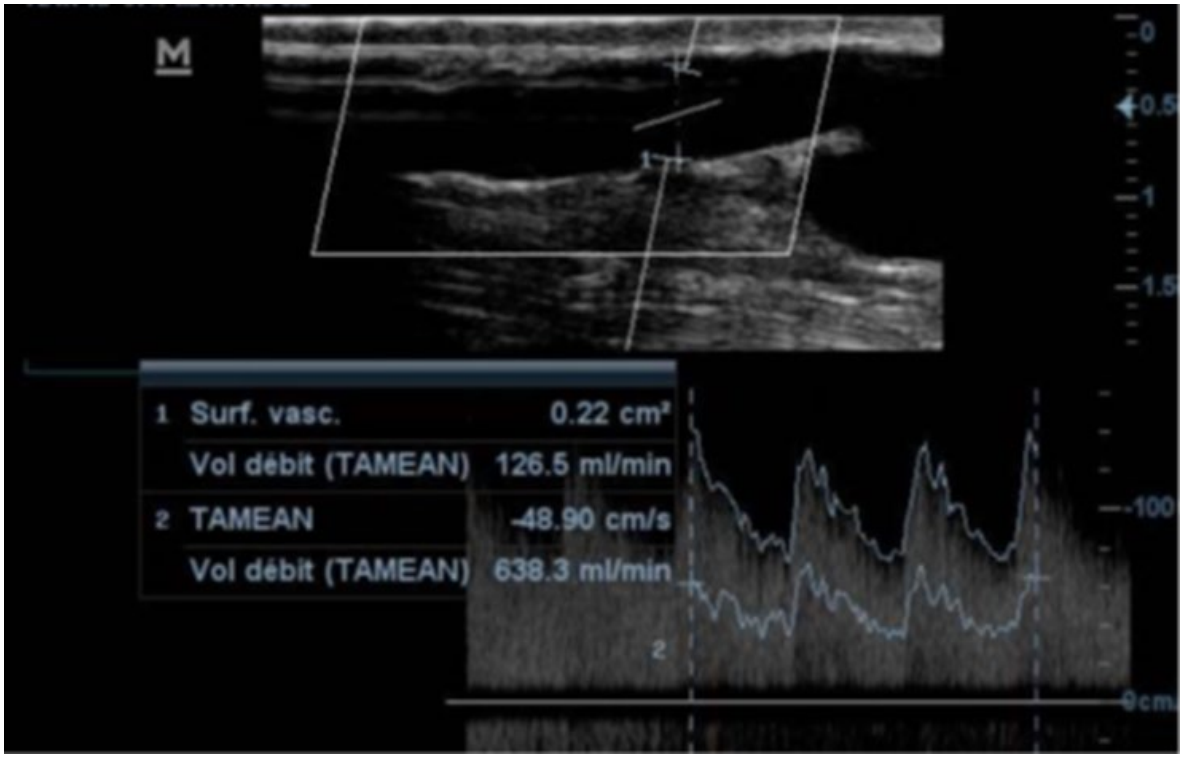

Fig. 2. *Measurement of flow volume within the efferent vein*

Tab. 4. Univariate analysis of factors associated with low flow volume

	Low flow volume		*p*
	Yes (*n* = 14)	No (*n* = 27)	
Male	9 (64.3%)	14 (51.9%)	0.447
Mean age (SD)	55.14 (16.61)	44.89 (15.71)	0.059
Mean BMI (SD)	25.30 (4.15)	24.35 (4.27)	0.468
No prior fistula on limb	12 (85.7%)	20 (74.1%)	0.692
Radiocephalic AVF	11 (78.6%)	20 (74.1%)	1.000
Diabetes	8 (57.1%)	3 (11.1%)	**0.003**
Hypertension	12 (85.7%)	22 (81.5%)	1.000
HIV	0 (0%)	5 (18.5%)	0.146
Mean dialysis vintage (SD), months	19.64 (18.23)	25.67 (24.35)	0.421
Mean AVF age (SD), months	14.08 (9.08)	23.22 (21.30)	0.148
Mean RI (SD)	0.44 (0.08)	0.42 (0.03)	0.557
Reverse flow	5 (35.7%)	14 (51.9%)	0.616
Aneurysm	4 (28.6%)	18 (66.7%)	**0.026**
Venous luminal flaps	0 (0%)	9 (33.3%)	**0.013**
Thrombosis	1 (7.1%)	6 (22.2%)	0.389
Stenosis	9 (64.3%)	14 (51.9%)	0.447

measured their flow volume in the brachial artery, which could explain the difference observed. Importantly, the American Institute of Ultrasound in Medicine recommends scanning the efferent vein for flow volume[4] . Also, the divergent results with those in the study by Pietura *et al*. might be explained by the fact that the authors included only well-functioning fistulas in their study.

Determinants of low flow volume within AVFs

We carried out a univariate analysis to determine the factors associated with low flow rates in AVFs, and identified diabetes ($p = 0.003$), aneurysms ($p = 0.026$), and luminal venous flaps ($p = 0.013$) to be determinants of flow volume. Based on a greater proportion of diabetic patients within the low flow volume group, it could be inferred that diabetes is a factor associated with low flow volumes. This conclusion is similar to that obtained by Tonelli *et al*. who found diabetes to be independently associated with flow volume[10]. On the contrary, we had more aneurysms and luminal venous flaps with appropriate flow volumes, suggesting that their absence is linked to low flow volumes.

Limitations of our study

The major limitation in our study was our small sample size.

Conclusion

There is a high prevalence of vascular modifications and stenosis within well-functioning arteriovenous fistulas. A longitudinal study assessing the long-term impact of stenosis on the patency of the AVFs would be of interest.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: HOA, MM, EG. Writing of manuscript: HOA, AS, MM, YO, EG. Analysis and interpretation of data: HOA. Final acceptation of manuscript: HOA, YO, EG. Collection, recording and/or compilation of data: HOA, AS. Critical review of manuscript: MM, EG.

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