Significance of arteriovenous ratio index on predicting the primary functional maturation of autogenous arteriovenous fistula

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Received: 15 January 2023
Revised: 30 January 2023
Accepted: 30 January 2023
Published: 9 June 2023

The Egyptian Journal of Surgery 2023, 42:114–124

Background
The incidence of end-stage renal disease is progressively increasing, with more than a fifth of cases progressing to dialysis yearly. According to the newest The Kidney Disease Outcome Quality Initiative (KDOQI) and The National Kidney Foundation (NFK), they consider autologous arteriovenous fistulas (AVFs) as a primary method of choice in hemodialysis patients. To this date, different studies have evaluated the impact of several different variables on the primary functional maturation (FM) of AVFs. One of the preoperative investigations used is ultrasound mapping on vessels. Even so, the vessels meet the minimal threshold diameter for surgical AVF creation, but still, there is high rate of AVF maturation failure. This suggests a need to reassess the preoperative ultrasound criteria used to optimize AVF maturation.
Aim
The aim of this study is to demonstrate that the suggested measurement technique of arteriovenous ratio (AVR) index obtained from inflow (arterial diameter) to that of outflow (venous diameter) is an independent predictor of primary FM of AVFs. This study implies that minimal diameter difference between inflow and outflow remains crucial for optimal hemodynamics of AVFs irrespective of other variables.
Patients and methods
This a prospective observational cohort study that was conducted at Ain Shams University hospitals on 120 patients presented with end-stage renal failure between November 2020 and March 2022, which were submitted for AVF.
Results
This study shows that the AVR index has significant importance in FM of AVF. As shown, AVR index of 1.01–1.06 and 1.06–1.14 has maturation rate of 100%. While as the AVR index increases or decreases away from AVR index subgroups of 1.01–1.06 and 1.06–1.14, the rate of FM decreases subsequently reaching to only 57.9% in AVR index 0–0.79 and 55.6% in AVR index 1.51–2.63.
Conclusion
The outcome of this study demonstrates that the suggested novel measurement technique (AVR index) is an independent predictor of FM in AVFs. This study implies that minimal diameter (i.e. inflow artery diameter to outflow cephalic vein diameter) mismatch, irrespective of other variables, remains crucial for optimal hemodynamics of AVFs and their primary FM.

Keywords:
artery diameter, arteriovenous fistulas, arteriovenous ratio index, end-stage renal disease, hemodialysis, primary functional maturation, vein diameter

Egyptian J Surgery 42:114–124

1110-1121

Introduction

Because end-stage renal disease (ESRD) is becoming more common, there are more patients in the world who need hemodialysis [1]. Patients' vascular access is their 'lifeline' to hemodialysis, therefore, functional maturation (FM) of the arteriovenous fistulas (AVF) is essential for hemodialysis care [2]. For those individuals, autogenous AVFs are the primary option for vascular access, especially as they provide improved results and follow-up [3].

Overall, 28–53% of AVFs have been reported to fail to develop sufficiently for dialysis. AVFs are associated with high non-FM rates due to multiple factors such as age, vessel diameter, patient demographics, hematologic factors, biochemical markers, comorbidities, method and angle of anastomosis, and pressure and flow studies are involved [4].

Preoperative and postoperative ultrasound measurements have been used to predict FM of

AVFs in several centers, using brachial or radial artery, or vein inner diameter measurements, and blood flow measurements in varying locations of these arteries or the AVF veins. Recent evidence has shown that vessel diameters, irrespective of all factors, are independently associated with primary FM of AVFs [5].

Fistulas at the anatomic snuff box had smaller vessels than the necessary diameters for AVF development; nevertheless, brachiocephalic (BC) AVFs have considerably bigger vasculature, and we could still see considerable early hyperplasia and FM failure. Additionally, a smaller wrist may have a smaller vein and artery that could not meet the ideal requirements for AVF and be refused as a result. This raises the clinically relevant question of whether an arteriovenous ratio (AVR) index acquired from the input (radial artery diameter) to that of the outflow (cephalic vein diameter) may be more pertinent in fistula development and its subsequent impact on velocity, pressure, and FM. This ratio may also provide light on the cumulative effect of unstudied real-time pressure, velocity, and remodeling (wall shear stress (WSS), hyperplasia) changes over the development phase [6].

Aim

The aim of this study is to demonstrate that the suggested measurement technique of AVR index obtained from inflow (arterial diameter) to that of outflow (venous diameter) is an independent predictor of primary FM of AVFs. This study implies that minimal diameter difference between inflow and outflow remains crucial for optimal hemodynamics of AVFs, irrespective of other variables.

Patients and methods

This a prospective observational cohort study of 120 patients presented with ESRD between November 2020 and March 2022 in Ain Shams University hospitals, who were submitted for AVF. This research was performed at the Department of General Surgery, Ain Shams University Hospitals. Ethical Committee approval and written, informed consent were obtained from all participants.

Inclusion criteria: ages from 18 to 70, ESRD, and both sexes.

(1) Exclusion criteria: extremes of ages, peripheral vascular diseases, central venous occlusion, sclerosed or thrombosed superficial and deep veins of upper limbs, patients with heart failure, patients with veins under 2-mm diameter, and patients who underwent primary assisted maturation within the follow-up period.
(2) The study participants signed a written consent and were informed about the protocol and the necessity of regular follow-up for the completion of the study. Patients underwent full detailed history taking and clinical assessment and preoperative laboratory and radiological investigation were done before the AVF creation. Patients underwent follow-up at the outpatient clinic and did duplex ultrasound after 8 weeks to access AVF maturation.

Preoperative ultrasound: it is performed through the B-mode and Doppler mode with linear probe (frequency >7 MHz for B-mode and >5 MHz for Doppler mode with arm position 45–60° and the patient is in supine position in a warm room to avoid vasoconstriction). The measurements were performed 1 week before the operation (in the clinic) and immediately preoperatively (in the operating room) under tourniquets and in the same environmental settings. The means of measurements were taken into account for the entire length of the vessels (three different points) and an average was taken.

Standard and definitions: to avoid heterogeneity and to create a uniform approach, the following were applied.

(1) FM was defined against the rule of 6 s assessed clinically and with duplex ultrasound at 8 weeks after AVF formation, with a depth of not more than 0.5–0.6 cm from the skin, a diameter (main body of fistula) of 6 mm or more preoperative, flow rate of 600 ml/min or more and a length of 6 cm or more, and for successful two-needle cannulation and dialysis [7].
(2) The formula used to calculate flow volumes is area×mean velocity×60, where area is cross-sectional area of the blood vessel in square centimeters (as the vessel is cylindrical, its cross-sectional area is calculated as the square of the radius×3.14), mean velocity (in cm/s) is measured from the Doppler trace recorded at the site of measuring area, and 60 is number of seconds in a minute [8].
(3) The formula used to calculate AVR index is arterial (inflow) diameter divided by the venous (outflow) diameter [6].
(4) The vein was considered suitable if the result of the 'tap test' (application of a tourniquet proximally and percussion of the vein with fingers for vibration across the course of the vein) was positive and consistent throughout the vein.

(5) The radial artery was used and assessed further with ultrasound only if the result of Allen test was normal (positive), indicating adequate blood flow in the ulnar artery and palmar arch.
(6) The arteries were also assessed for hemodynamic studies (flow and stenosis) and not used for if there was peripheral arterial disease.
(7) Brachiobasilic AVF is preformed at the first and second stage during the same secession.
(8) Local anesthesia was 2% lignocaine on the preoperatively marked area (straight incision between vein and artery) to avoid damaging the vein during its infiltration. However, some cases required regional or general anesthesia (e.g. two-staged brachiobasilic AVFs) under an experienced anesthetist.

Statistical analysis

The collected data were revised, coded, tabulated, and introduced to a PC using Statistical Package for Social Science (IBM SPSS statistics for windows, Version 26.0. Armonk, NY: IBM Corp). Data were presented and suitable analysis was done according to the type of data obtained for each parameter.

Descriptive statistics

(1) Mean, SD, and range for parametric numerical data, while median and interquartile range for nonparametric numerical data.
(2) Frequency and percentage of nonnumerical data.

Analytical statistics

(1) Student *t* test was used to assess the statistical significance of the difference between two study group means.
(2) Mann–Whitney test (*U* test) was used to assess the statistical significance of the difference of a nonparametric variable between two study groups.
(3) χ^2 test was used to examine the relationship between two qualitative variables.
(4) Fisher's exact test was used to examine the relationship between two qualitative variables when the expected count is less than 5 in more than 20% of cells.
(5) The receiver-operating characteristic (ROC) curve provides a useful way to evaluate the sensitivity and specificity for quantitative diagnostic measures that categorize cases into one of two groups.

P value: level of significance:

(1) *P* value more than 0.05: nonsignificant.
(2) *P* value less than 0.05: significant.

Results

The demographic sample used was 120 patients from Ain Shams University hospitals, where the mean age was 54.3 years of which 49.2% were male and 50.8% were female patients. Patients had mean height 1.66 m, weight 73.87 kg, and BMI 26.98. About 25% of patients studied were smokers and mostly male patients. Also, the patients in the study group used had 81.7% hypertensive, 48.3% were diabetic, 20.8% were ischemic heart disease, and 23.3% had hyperlipidemia, this is shown in Tables 1 and 2.

Moreover, as shown in Table 3, in the study group used, 70.8% had left access that is more preferred in the right upper limb-dominant patients. About 30% of the upper limb access done were distal [radiocephalic (RC)] and 70% percent were proximal AVFs of which 65 cases of BC AVF and 19 cases of brachiobasilic AVF.

As regards the arteries, the mean arterial velocity and mean diameter for brachial was 65.9 cm/s and 3.49 mm. While the mean arterial velocity and mean diameter for radial was 46.17 cm/s and 2.76 mm. As regards, mean vein diameter (under tourniquet) for basilic veins 3.36 mm, while cephalic (distal proximal) was 3.08 mm, shown in Tables 4–7.

Table 1 Sociodemographic data for the study group

	Mean/*n* (SD/%)	Median (IQR)	Range
Age	54.32 (12.73)	56 (45–65)	18–72
Sex			
Male	59 (49.2)		
Female	61 (50.8)		
Height (m)	1.66 (0.08)	1.67 (1.58–1.71)	1.47–1.85
Weight (kg)	73.87 (9.70)	76 (67–80)	53–97
BMI	26.98 (3.19)	27 (24.3–29.5)	18.3–34.7
Smoker			
No	90 (75.0)		
Yes	30 (25.0)		

IQR, interquartile range.

Table 2 Past medical history for the study group

	Mean/*n* (SD/%)
Diabetes	
No	62 (51.7)
Yes	58 (48.3)
Hypertension	
No	22 (18.3)
Yes	98 (81.7)
Ischemic heart diseases	
No	95 (79.2)
Yes	25 (20.8)

In this study, sociodemographic data and past medical history have no significant importance to FM of AVFs, this is shown in Tables 8 and 9.

Also shown in Table 10, side of access, site of access whether distal (RC) or proximal (brachiobasilic or BC), and type of artery or vein has no significant importance to FM of AVFs.

Moreover, the study shows that brachial artery velocity and diameter and volume blood flow had no significant importance in FM. However, radial artery diameter was significantly important in FM (mean radial artery diameter in nonmature cases was 2.44±0.55 mm and in mature cases was 2.88±0.48 mm). Also, it shows that cephalic vein diameter as a whole is significantly important in FM, while when subgrouped, it showed that only the cephalic in BC AVF is significantly important in FM while not in RC AVFs, this is shown in Tables 11–14.

It is shown in Table 15 that AVF ratio index has significant importance in FM of AVF. As shown, AVF ratio index 1.01–1.06 and 1.06–1.14 has maturation rate of 100%. As the AVF ratio index increases or decreases away from AVF ratio index 1.01–1.06 and 1.06–1.14, the rate of FM decreases subsequently reaching to only 57.9% in AVF ratio index 0–0.79 and 55.6% in AVF ratio index 1.51–2.63.

Shown in Tables 16–19, the cutoff value of brachial and radial arteries is more than 2.8 mm in both arteries. Moreover, the cut-off value of both basilic and cephalic vein diameters is more than 3.3 mm and more than 3 mm, respectively, also shown in Figs 1–4.

Discussion

The AVR index highlights the match or mismatch between the arterial and venous diameters (calibers of inflow and outflow), which has important implications for factors of velocity and pressure in practice. The volumetric property (Q) applicable in such circumstance is obtained by the formula $Q=V\times A$ where V is velocity and A is the surface area of the vessel derived from the actual vessel diameter. Therefore, the inflow Q (brachial or radial artery) can be achieved by (Q inflow=V inflow×A inflow), and outflow Q (cephalic or basilic vein) can be achieved by (Q outflow=V outflow×A outflow).

Table 3 Preoperative data for the study group

	Mean/*n* (SD/%)
SIDE of access	
Right	35 (29.2)
Left	85 (70.8)
Type of access	
Brachiocephalic AVFs	65 (54.2)
Brachiobasilic AVFs	19 (15.8)
Radiocephalic AVFs	36 (30.0)
Artery	
Brachial	84 (70.0)
Radial	36 (30.0)
Vein	
Basilic	19 (15.8)
Cephalic=101	
In proximal AVFs	65 (54.2)
In distal AVFs	36 (30.0)

AVF, arteriovenous fistulas.

Table 4 Preoperative data for the study group

Brachial artery	Mean	SD	Median (IQR)	Range
Preoperative arterial velocity (cm/s)	65.90	6.23	66 (62–69)	50–80
Preoperative arterial diameter (mm)	3.49	0.62	3.6 (3.1–3.9)	2–5
Preoperative arterial volume blood flow (ml/min)	408.25	141.35	415 (309–478)	104–825

IQR, interquartile range.

Table 5 Preoperative data for the study group

Radial artery	Mean	SD	Median (IQR)	Range
Preoperative arterial velocity (cm/s)	46.17	7.64	46.5 (40–50)	30–66
Preoperative arterial diameter (mm)	2.76	0.53	2.75 (2.45–3.05)	1.5–3.5
Preoperative arterial volume blood flow (ml/min)	170.58	72.94	162 (118–213)	55–346

IQR, interquartile range.

Table 6 Preoperative data for the study group

Basilic vein	Mean	SD	Median (IQR)	Range
Preoperative vein diameter (mm)	3.36	0.92	3.3 (2.9–4.1)	2–5

IQR, interquartile range.

Table 7 Preoperative data for the study group

Preoperative cephalic vein diameter in mm	Mean	SD	Median (IQR)	Range
In both proximal and distal AVFs	3.08	0.68	3 (2.6–3.5)	2–4.7
In proximal AVFs	3.21	0.67	3 (2.8–3.7)	2–4.7
In distal AVF	2.83	0.63	2.9 (2.25–3.5)	2–3.7

AVF, arteriovenous fistulas; IQR, interquartile range.

Table 8 Sociodemographic data between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not nature	Mature	Test of significance		
	Mean±SD/*n* (%)	Mean±SD/*n* (%)	Value	*P* value	Significance
Age	53.48±14.5	54.61±12.13	*t*=−0.422	0.674	NS
Sex					
Male	13 (41.94)	46 (51.69)	χ^2=0.874	0.35	NS
Female	18 (58.06)	43 (48.31)			
Height (m)	1.66±0.08	1.65±0.08	*t*=0.239	0.811	NS
Weight (kg)	74±10.4	73.82±9.51	*t*=0.088	0.930	NS
BMI	26.88±3.18	27.01±3.22	*t*=−0.184	0.855	NS
Smoker					
No	26 (83.87)	64 (71.91)	χ^2=1.754	0.185	NS
Yes	5 (16.13)	25 (28.09)			

χ^2, χ^2 test; *t*, Student *t* test of significance.

Table 9 Past medical history between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not mature	Mature	Test of significance		
	n (%)	*n* (%)	Value	*P* value	Significance
Diabetes					
No	18 (58.06)	44 (49.44)	χ^2=0.685	0.408	NS
Yes	13 (41.94)	45 (50.56)			
Hypertension					
No	6 (19.35)	16 (17.98)	χ^2=0.029	0.864	NS
Yes	25 (80.65)	73 (82.02)			
Ischemic heart diseases					
No	25 (80.65)	70 (78.65)			
Yes	6 (19.35)	19 (21.35)	χ^2= 0.055	0.814	NS
Yes	9 (29.03)	18 (20.22)			

χ^2, χ^2 test; *t*, Student *t* test of significance.

Table 10 Operative data between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not mature	Mature	Test of significance		
	n (%) Mean±SD	*n* (%)	Value	*P* value	Significance
Side of access					
Right	9 (29.03)	26 (29.21)	χ^2=0.00	0.985	NS
Left	22 (70.97)	63 (70.79)			
Type of access					
Brachiocephalic	17 (54.84)	48 (53.93)			
Brachiobasilic	4 (12.9)	15 (16.85)	χ^2=0.301	0.86	NS
Radiocephalic	10 (32.26)	26 (29.21)			
Artery					
Brachial	21 (67.74)	63 (70.79)	χ^2=0.101	0.75	NS
Radial	10 (32.26)	26 (29.21)			
Vein					
Basilic	4 (12.9)	15 (16.85)			
Cephalic					
In proximal AVFs	17 (54.84)	48 (53.93)	χ^2=0.301	0.86	NS
In distal AVFs	10 (32.26)	26 (29.21)			
Vein					
Basilic	4 (12.9)	15 (16.85)	χ^2=0.301	0.86	NS

AVF, arteriovenous fistulas; χ^2, χ^2 test.

Table 11 Operative data between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not mature	Mature	Student *t* test		
Brachial artery	Mean±SD	Mean±SD	*t*	*P* value	Significance
Preoperative arterial velocity in (cm/s)	65.81±5.91	65.94±6.38	−0.080	0.936	NS
Preoperative arterial diameter (mm)	3.24±0.77	3.58±0.54	−1.862	0.074	NS
Arterial volume blood flow (ml/min)	407.24±177.85	408.59±128.62	−0.038	0.970	NS

t, Student *t* test of significance.

Table 12 Operative data between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not mature	Mature	Student *t* test		
Radial artery	Mean±SD	Mean±SD	*t*	*P* value	Significance
Preoperative arterial velocity in (cm/s)	46.9±6.24	45.88±8.21	0.352	0.727	NS
Preoperative arterial diameter (mm)	2.44±0.55	2.88±0.48	−2.347	0.025	S
Arterial volume blood flow (ml/min)	136.8±61.01	183.58±74	−1.776	0.085	NS

t, Student *t* test of significance.

Table 13 Operative data between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not mature	Mature	Student *t* test		
Basilic vein	Mean±SD	Mean±SD	*t*	*P* value	Significance
Preoperative vein diameter (mm)	2.8±0.74	3.51±0.93	−1.414	0.175	NS

t, Student *t* test of significance.

Table 14 Operative data between two studied groups

	Functional maturation (postoperative 8 weeks)				
	Not mature	Mature	Student *t* test		
Preoperative cephalic vein diameter (mm)	Mean±SD	Mean±SD	*t*	*P* value	Significance
In both proximal and distal AVFS	2.83±0.68	3.17±0.66	−2.262	0.026	S
In proximal AVFs	2.9±0.63	3.33±0.66	−2.31	0.024	S
In distal AVFs	2.71± 0.77	2.88±0.58	−0.722	0.475	NS

AVF, arteriovenous fistulas; *t*, Student *t* test of significance.

Table 15 Maturation rates against escalating and decreasing arteriovenous ratio index

	Functional maturation (postoperative 8 weeks)			
	Not mature	Mature	Fisher's exact test	
	n (%)	*n* (%)	*P* value	Significance
AVF ratio index				
0–0.79	8 (42.1)	11 (57.9)		
0.8–0.92	7 (36.8)	12 (63.2)		
0.93–1.00	3 (15.8)	16 (84.2)	0.028	S
1.01–1.06	0	11 (100.0)		
AVF ratio index				
1.06–1.14	0	11 (100.0)		
1.15–1.27	3 (15.8)	16 (84.2)	0.04	S
1.28–1.5	6 (35.3)	11 (64.7)		
1.51–2.63	4 (44.4)	5 (55.6)		

AVF, arteriovenous fistulas.

The pressure across each side is represented by *P* (*P* inflow and *P* outflow, respectively). According to the Bernoulli effect, there is an inverse relationship between velocity (*V*) and pressure (*P*), depending on the diameter alterations. Thus, a significant inflow-to-outflow mismatch (AVR) results in decreased velocity but increased pressure and vice versa. However, a closer ratio (1.01–1.14) will result in minimal changes of pressure and velocity.

The results of this study show that the AVR index has significant importance in FM of AVF. As shown, AVR index 1.01–1.06 and 1.06–1.14 has maturation rate of 100%. While as the AVR index increases or decreases away from AVR index 1.01–1.06 and 1.06–1.14, the rate of FM decreases subsequently reaching to only

Table 16 Receiver-operating characteristic curve of brachial artery diameter to predict functional maturation

AUC	95% CI	Significance	Cutoff value	Sensitivity	Specificity	PPV	NPV
0.636	0.524–0.738	0.085	>2.8	93.65	38.1	81.9	66.7

AUC, area under the curve; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Table 17 Receiver-operating characteristic curve of radial artery diameter to predict functional maturation

AUC	95% CI	Significance	Cut-off value	Sensitivity	Specificity	PPV	NPV
0.706	0.531–0.845	0.03	>2.8	57.69	80.0	88.2	42.1

AUC, area under the curve; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Table 18 Receiver-operating characteristic curve of basilic vein diameter to predict functional maturation

AUC	95% CI	Significance	Cut-off value	Sensitivity	Specificity	PPV	NPV
0.717	0.467–0.896	0.105	>3.3	60.0	100.0	100.0	40.0

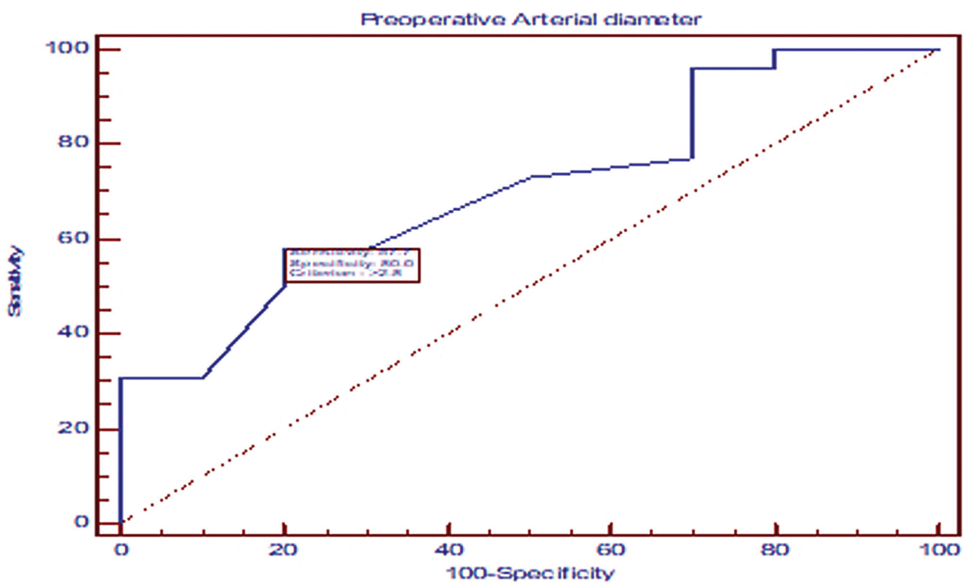
AUC, area under the curve; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Table 19 Receiver-operating characteristic curve of cephalic vein diameter to predict functional maturation

AUC	95% CI	Significance	Cut-off value	Sensitivity	Specificity	PPV	NPV
0.633	0.531–0.727	0.033	>3	54.05	70.37	83.3	35.8

AUC, area under the curve; CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

Figure 1



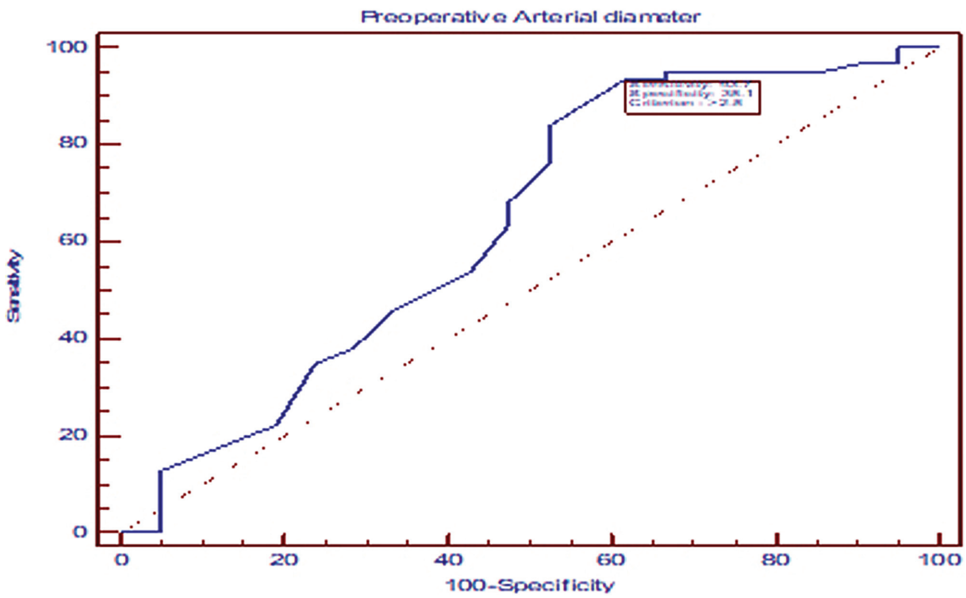
ROC curve of brachial artery diameter to predict functional maturation. ROC, receiver-operating characteristic.

57.9% in AVR index 0–0.79 and 55.6% in AVR index 1.51–2.63.

As regards AVR index, there is also a study done by Kordzadeh *et al.* [6], which was a prospective consecutive single-center cohort study with intention to treat of 324 patients by RC AVFs only (while our study includes all autologous AVFs). This showed among all variables, the AVR index remained the only independent factor associated with FM of RC AVFs where AVR index of 1–1.06 was associated with 100% FM in RC AVFs. Decrease or increase of this index was associated with stepwise reduction in FM of RC AVFs.

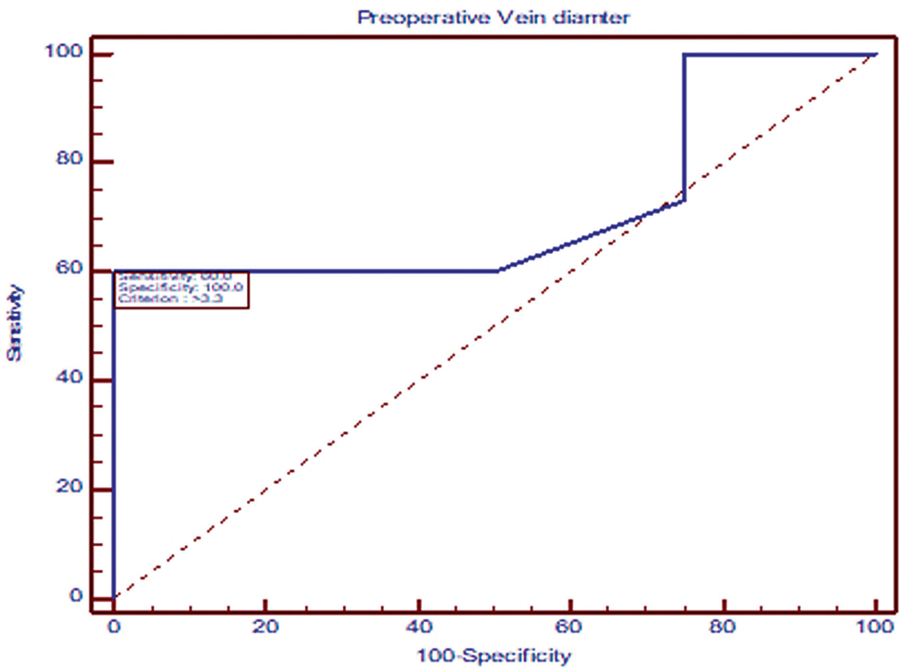
Additionally, Kordzadeh *et al.* [6] study showed that 1.55 mm for the cephalic vein and 1.6 mm for the radial artery are the optimal cutoff diameters for RC AVF

Figure 2



ROC curve of radial artery diameter to predict functional maturation. ROC, receiver-operating characteristic.

Figure 3



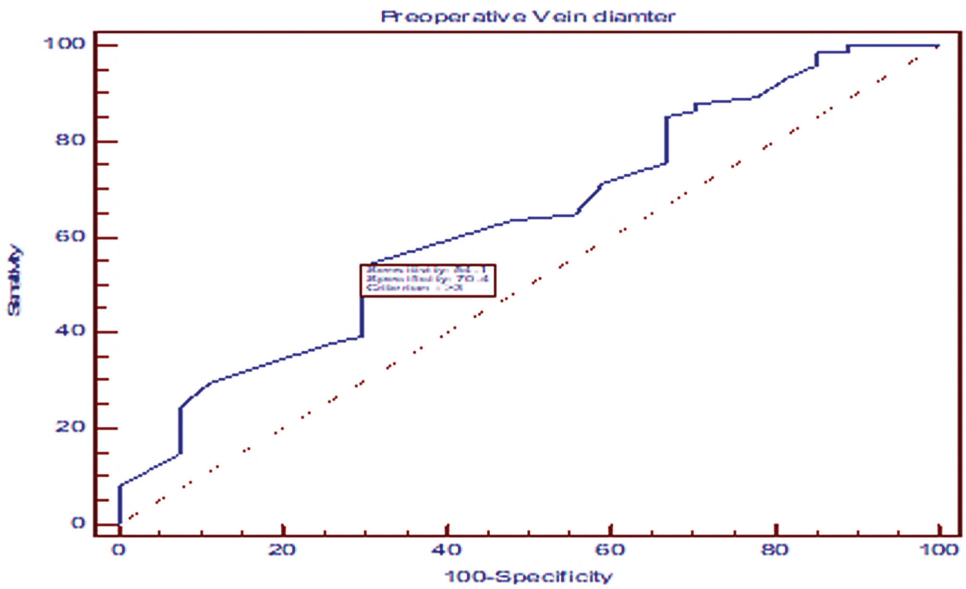
ROC curve of basilic vein diameter to predict functional maturation. ROC, receiver-operating characteristic.

main FM (nonaugmented, internal diameter). This results in an AVR of 1.03 for RC AVF main FM and supports the findings of both studies.

Both experiments demonstrated that the AVR index accurately suggests that a better primary FM may be produced during AVF construction after both vessels' display comparable or close diameter. This might account for the disparity in maturity between small and big arteries.

However, both studies have limitations; as ultrasound assessment is operator-dependent, and for the longitudinal measurement of vessel diameter, the axial resolution of the transducer would remain the most important factor. Therefore, if the axial resolution

Figure 4



ROC curve of cephalic vein diameter to predict functional maturation. ROC, receiver-operating characteristic.

of the 7-MHz transducer can lead to variation of ~0.3 mm, it can be acknowledged that variation in transducer (7 or 10 MHz) could alter the internal vessel diameter measurements. However, this could be far less in the 5-MHz transducer.

Furthermore, Kordzadeh and colleagues study used only RC AVF and not other types of AVFs.

Next, the influence of artery and vein diameters on access outcomes in the literature is highly variable. Although most have documented a strong or independent association between vascular anatomy and outcomes, others have demonstrated minimal association or configuration-dependent findings.

In our study, the side of access, type of access whether distal (RC) or proximal (brachiobasilic or BC), and type of artery or vein has no significant importance to FM of AVFs. Moreover, it shows that brachial artery velocity and diameter and volume blood flow had no significant importance. However, radial artery diameter was significantly important (mean diameter in nonmature cases was 2.44±0.55 mm and in mature cases was 2.88±0.48 mm).

While it showed that cephalic diameter in BC AVFs (mean diameter in nonmature cases was 2.9±0.68 mm and in mature cases was 3.33±0.66 mm) was significantly important, while cephalic diameter in RC AVFs and basilic diameter were not.

Similar study was done by Misskey *et al.* [9], which is a retrospective, single-center cohort study that showed that radial artery diameter less than 2.1 mm and distal cephalic vein diameter less than 3.0 mm were independently associated with reduced autogenous access maturation and patency for RC accesses, with a combination of both being most predictive. However, neither proximal cephalic vein nor brachial artery diameter was found to be predictive of BC access maturation and patency, which is similar to our study showing that brachial artery diameter had no significant importance, while radial artery diameter had significant importance. However, this study shows that proximal cephalic vein diameter has no significant importance, while distal cephalic vein diameter is significantly important, which is opposite to the results of our study.

A limitation of Misskey and colleagues is it did not assess basilic vein and brachiobasilic AVFs. Also, this study did not assess FM but primary and secondary patency.

Furthermore, Misskey and colleagues study highlighted a difference in vein and artery diameter according to sex where men had a larger tourniquet-derived cephalic vein for RC accesses than women did, however, there were no differences for BC access. Also, the mean artery diameter was larger for men than for women, with radial and brachial artery diameters. Moreover, Misskey and colleagues study highlighted that vein diameter was inversely proportional to age. However, similar to our study, both age and sex had no significance importance to FM of AVFs in Misskey *et al.* [9] study.

Another study done by Kordzadeh *et al.* [10] shows that the most significant factors associated with autogenous RC AVF primary FM are the anatomical factors of cephalic vein and radial artery internal diameter. This is the largest prospective consecutive cohort study on a RC AVF (confined to wrist RC AVFs) and no other variables (patient demographics, laterality, anesthesia type, and comorbidities) were found to be predictors of primary FM. The study demonstrates that once the cutoff of more than 1.5 mm in the cephalic vein and 1.6 mm in the radial artery diameter is met, a primary FM of more than 85% can be anticipated. Furthermore, there appears to be a fourfold increase in primary FM with increase in the cephalic vein diameter (>1.5) and an increase in FM by 715-fold with increase in the diameter of the radial artery (>1.6), emphasizing the importance of inflow in primary RC AVF FM.

Another study by Farrington *et al.* [11] showed that the contribution of venous diameter to AVF maturation evident on univariable analysis disappeared on multivariable analysis, whereas the arterial diameter remained a key predictor of both unassisted and overall AVF maturation. This finding contradicts conventional wisdom, which regards the preoperative venous diameter as the most influential factor for AVF maturation.

All of the earlier research described in this debate, however, had some significant drawbacks. First, due to the high likelihood that patients chosen for autogenous access would have favorable anatomy, there is a strong selection bias that might lead to overstating of reported results. Second, there is a difference between vein diameters if tourniquets are used or not (as tourniquets raise the diameter up to 30%). Last but not least, there is substantial variation in the reporting of vein diameter among studies, not to mention that ultrasonography is operator-dependent. Although some employ a minimum vein diameter in the outflow tract, a sizable portion uses perianastomotic values, which results in the variation in sizes.

Also, Farrington *et al.* [11] showed, in the multivariable model, preoperative systolic blood pressure was predictive of AVF maturation where a higher systolic blood pressure was associated with both unassisted and overall maturation, while our study showed no significance importance for blood pressure in FM of AVFs.

The latter finding is consistent with a previous study by Feldman *et al.* [12], which showed that mean arterial pressure of 85 mmHg or higher immediately prior to AVF creation was associated with higher rates of maturation.

AVFs are classically created with a goal depth of 6 mm or less below the skin. This can be a challenge in patients with higher BMI and relatively more subcutaneous tissue. These patients may require secondary procedures to make their AVF more accessible for cannulation. The need to superficialize an AVF is associated with an increase in time to functional maturity as well as additional risk of surgery and higher incidence of preceding hemodialysis catheter use. These points are worthy of consideration during the informed consent process. Soft tissue compression of venous outflow, increased risk of thrombosis, and leptin-mediated intimal hyperplasia and medial thickening have been cited as reasons for decreased maturation and patency, and less frequent use of AVF in obese individuals. However, our study showed no significant importance as regards BMI and diabetes mellitus with FM of AVFs, which is contradicted by Wilopo *et al.* [13] study on 80 patients where multivariate analysis shows that only BMI, peripheral arterial disease (PAD), and preoperative vein diameter more than 2 mm are associated with AVF maturation, while diabetes mellitus in bivariate analysis (not multivariate) was associated with lower rate of AVF maturation.

Also, Wilopo and colleagues showed that severe obesity was connected to a decrease in fistula maturation. Obese class-III patients showed a 6% lower maturation rate than normal-weight individuals.

When compared with patients of normal weight, obese class-III patients had an 8, 10, and 7% decrease in primary, primary-assisted, and secondary patency, respectively [13].

Conclusion

The outcome of this study demonstrates that the suggested novel measurement technique (AVR) is an independent predictor of FM in AVFs. This study implies that minimal diameter (i.e. inflow artery dimeter to outflow vein diameter) mismatch (AVR, 1–1.06), irrespective of other variables, remains crucial for optimal hemodynamics (pressure and velocity) of AVFs and their primary FM. This has been attributed to the minimal hemodynamic changes of pressure and velocity diminishing significant WSS and rapid intimal hyperplasia.

The final question is why the AVFs still fail to mature once all factors have been identified and perioperative protocols have been adhered to. The answer might be found once other unknown but recently highlighted factors in other areas of vascular surgery can be assessed. This includes the role of local and systemic inflammation, wound-healing process, neutrophil-to-lymphocyte ratio, and other possible serological markers.

Limitations

This study has assessed only FM. Primary and secondary failures are not evaluated because it requires long-term follow-up, as the present study is a short-duration follow-up study. Other factors that affect the success of AVF, like the surgeon's performance, postoperative ultrasound, and PAD, were not studied. Moreover, our study included a limited number of patients.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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