Original Article

Early Prediction of Native Arteriovenous Fistula for Maturation by Doppler Ultrasound Study

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Abstract

Introduction: There are significant chances of maturation failure in arteriovenous fistulas (AVFs) made for vascular access for hemodialysis. AVFs are usually assessed for maturation 6 weeks after the operation. Significant time is lost for performing a salvage radiological procedure or making an alternative AVF, in case the AVF fails to mature. **Materials and Methods:** This prospective observational study was conducted to predict the chances of maturation of AVF by Doppler ultrasound (USG) study. One hundred and thirty-seven patients in whom native AVF was made as a vascular access procedure for hemodialysis were included in the study. In five patients, palpable thrill was absent after 48 h of operation and were excluded from the study. The velocity of the blood, diameter of the vessel, and depth of the vessel from the skin were assessed by USG Doppler 3 weeks after the operation and were correlated with AVF maturation. **Results:** Successful maturation occurred in 114 (86.3%) AVF. The flow rate of the blood and depth of the vein were statistically different in successful and unsuccessful AVF maturation for both the groups of radial artery (RA) and brachial artery (BA) based AVF. For RA AVF, successful maturation was predicted by the flow rate of 539 mL/min (sensitivity 95% and specificity 83%) and 4.2 mm diameter of the vein (sensitivity 93% and specificity 100%). For BA AVF, successful maturation was predicted by the flow rate of 456 mL/min (sensitivity 93% and specificity 100%) and 5.7 mm diameter of the vein (sensitivity 77% and specificity 100%). The measurement of flow and depth at 3 weeks after AVF may predict the maturation of AVF. **Conclusion:** It will be beneficial to do a USG Doppler study 3 weeks after making AVF, as the measurement of flow may predict the maturation of AVF.

Keywords: Arteriovenous fistula, arteriovenous fistula maturation, arteriovenous fistula doppler study

Introduction

Vascular access is crucial for doing hemodialysis (HD) as a renal replacement therapy in patients with end-stage renal disease. Native arteriovenous fistula (AVF) is the best option for vascular access for long-term HD because it has high long-term patency and the least complications.[1] Native AVFs have a high primary failure rate of approximately 23%.[2] A fistula is considered to be matured and successfully used for dialysis if it can be used with two-needle cannulation for two-thirds or more of all dialysis attempts for 1 month and if it delivers the prescribed dialysis within the prescribed time frame. In a patient undergoing thrice weekly dialysis, the duration is 3.5–4.5 h and blood flow rates of 300–450 mL/min.[3] There are no fixed criteria for determining whether an AVF is ready for the commencement of HD. A member of the vascular access team, usually an experienced dialysis technician or nursing personnel involved in dialysis, evaluates the AVF for maturation based on the presence of thrill and venous filling.[1] Ultrasound (USG) is reserved for equivocal examination findings, and it was considered that blood flow of more than 600 mL/min blood flow, vessel diameter of more than 0.6 cm diameter, and <0.6 cm depth from the skin are indicators of successful maturation on ultrasonography.[4] The time taken for the maturation of autologous AVF is about 6–8 weeks.[4] Patent fistulas do not always mature and it is difficult to identify AVFs that fail to mature. Waiting for AVFs to mature for 6 weeks results in a significant loss of time when the AVF fails to mature. Evaluation of AVF before 6 weeks may help in

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Access this article online

Quick Response Code:

Website: www.indjvascsurg.org

DOI: 10.4103/ijves.ijves_45_24

How to cite this article: Gupta S, Saha S, Singh K, Andley M, Anand R, Satija B, *et al*. Early Prediction of Native Arteriovenous Fistula for Maturation by Doppler Ultrasound Study. Indian J Vasc Endovasc Surg 2024;11:169-73.

Received: 14-04-2024 **Revised:** 14-05-2024
Accepted: 15-05-2024 **Published Online:** 11-10-2024

identifying the AVF that may fail to mature, and interventions may be performed earlier for salvage or alternate AVF creation. However, there are conflicting results in the literature. Robbin *et al*. found that AVF blood flow and diameter at 1 day, 2 weeks, and 6 weeks were not independently associated with clinical maturation, and USG findings earlier than 6 weeks are not necessary to predict future clinical maturation.[5] While Ferring *et al*. reported that early postoperative screening of patent AVF at 4 weeks is useful to predict AVF maturity.[6]

The objective of this study was to predict the maturation of native AVF using the USG Doppler study 3 weeks after the operation. This may provide an earlier prediction of the failure to mature.

Materials and Methods

This prospective observational study was conducted at a tertiary care hospital on all patients who were operated for making AVF as a vascular access procedure for HD. Patients with prior failed AVFs were excluded from the study. To determine the fistula site, a preoperative USG Doppler scan of the upper limb was performed in all patients. The cutoff value of the luminal diameter of 2 mm for the artery and 2.5 mm for the vein was used to select the site of AVF.[4] AVF was preferably performed in the nondominant arm, and the site of choice was the radiocephalic, brachiocephalic, and brachiobasilic vessels, in that order.

The operation was performed as a daycare procedure under local anesthesia. Fistulas were made between the end of the vein and the side of the artery using a 6-0 polypropylene suture (Prolene Ethicon Inc.®). Patients were discharged after 6 h of observation. They were called for follow-up after 48 h, 1 week, and 3 weeks. Suture removal was done at 2 weeks. A duplex scan of the fistula site was performed at 3 weeks to assess the flow across the fistula, the diameter of the vein, and the depth of the vein from the skin. The AVF where the thrill was not palpable even after 48 h was not included in the analysis. AVF was deemed successful for dialysis if it could be used with two-needle cannulation for two-thirds or more of all dialysis runs for 1 month and deliver the prescribed dialysis after 6 weeks of creation. The salvage procedure was not carried out. A new AVF was made in case there was a failure to mature till 2–3 months of the creation of AV fistula.

Results

A total of 137 patients underwent surgery, of which five had no thrill at 48 h and were excluded from the analysis. In total, 132 patients were included in this study. The age of the patients in the study ranged from 14 to 75 years, with a mean age of 43.91 ± 13.87 years. Among all the subjects, 81 were males (61.4%) and 51 were females (38.6%). Table 1 lists the sites of AVF creation. Forty-seven (35.6%) were forearm AVF (radiocephalic) and 85 (64.4%) were cubital fossa AVF (brachiocephalic AVF-73; brachiobasilic AVF-4, and brachioantecubital AVF-8). In 114 (86.3%) patients, the AVF matured, while in 18 (13.6%) patients, maturation failed. The baseline features of the two groups are shown in Table 1.

Postoperative USG Doppler evaluation of AVF was performed 3 weeks later to assess the flow, diameter, and depth of the vein. The mean Doppler flow in individuals attaining AVF maturation was 679.78 ± 163.97 mL/min; the mean vein diameter was 0.59 ± 0.13 cm while for AVF which failed to mature it was 363.33 ± 257.65 mL/min and 0.34 ± 0.08 cm. The differences were statistically significant [Table 2]. The Doppler features of distal and proximal AVF are shown in Tables 3 and 4. There was also a statistically significant difference in the flow rate and

Table 1: Baseline features of the group of arteriovenous fistula which matured and arteriovenous fistula which failed to mature

Parameters	Failure to mature AVF (*n*=18), *n* (%)	Successful maturation (*n*=114), *n* (%)	*P*
Age (years)	44.94±16.34	43.75±13.52	0.73
Males	12 (66.7)	69 (60.5)	0.64
Females	6 (33.3)	45 (39.4)	
Presence of diabetes	9 (50)	56 (49.1)	0.94
RA AVF	6 (33.3)	41 (35.9)	0.76
BA AVF	12 (66.7)	73 (64)	

AVF: Arteriovenous fistula, RA: Radial artery, BA: Brachial artery

Table 2: Doppler parameters of successful and unsuccessfully matured arteriovenous fistula

Doppler parameters	Mean±SD		*P*
	Unsuccessful maturation (*n*=18)	Successful maturation (*n*=114)	
Doppler flow (mL/min)	363.33±257.65	679.78±163.97	<0.001
Doppler vein diameter (mm)	3.4±0.08	5.9±0.13	<0.001
Doppler vein depth (mm)	3.4±0.16	3.6±0.12	0.545

SD: Standard deviation

Table 3: Doppler parameters of distal arteriovenous fistula (radial artery-based)

	Successful maturation (*n*=41)	Unsuccessful maturation (*n*=6)	*P*
Flow rate (mL/min)	706.88±154.18	488.33±375.09	<0.001
Diameter of vein (mm)	6±0.10	3.3±0.05	<0.001
Depth of vein (mm)	3±0.12	2.4±0.07	0.545

Table 4: Doppler parameters of proximal arteriovenous fistula (brachial artery based)

	Successful maturation (*n*=73)	Unsuccessful maturation (*n*=12)	*P*
Flow rate (mL/min)	664.56±168.34	280.00±93.33	0.012
Diameter of vein (mm)	0.59±0.14	3.5±0.10	<0.001
Depth of vein (mm)	4.0±0.11	4.1±0.18	0.209

diameter between successful and unsuccessful maturation. The differences in the depth of the vein were not statistically significant. The area under the ROC curve was 0.829 (95% confidence interval [CI] - 0.54, 1.118) for blood flow in radial artery (RA)-based distal AVF [Figure 1] and for vessel diameter area under the curve was 0.965 (95% CI - 0.915, 1.015) [Figure 2]. The area under the curve was 0.983 (95% CI - 0.959, 1.007) for blood flow in the brachial artery (BA)-based proximal AVF [Figure 3], and for vessel diameter area under the curve was 0.902 (95% CI - 0.832, 0.972) [Figure 4]. The optimal cutoff value with the highest sensitivity and specificity is shown in Table 5.

Discussion

The various causes for the failure of AVF to mature are increasing age, female gender, diabetes mellitus, dependence on dialysis at the time of access placement, small caliber artery, and faulty surgical technique.[7-9] However, apart from smaller arterial and venous diameters and gender, no other factor is consistently associated with failure. If the failure of a native AVF can be predicted, these patients may be offered AV grafts. If an autologous AVF fails to mature, the patient has to be on dialysis by central catheters for a prolonged period. Central catheters are prone to infections and usually need to be changed in 2–3 months. If the chances of AVF maturity can be predicted before the usual 6 weeks, then the salvage procedure can be done or an alternative AVF can be made earlier. In our study, the fistula maturation rate was 86.4%, which is similar to that reported in other studies.[8]

Measurement of blood flow by Doppler studies has been performed to predict the chances of AVF failure, but this has not been included in any guidelines. USG evaluation helps in the assessment of AVF for maturation compared to physical examination, especially for deep veins. Intraoperative blood flow of <200 mL/min is found to be predictive of early failure of AVF.[10] The greatest increase in blood flow and vascular diameter was seen within 4 weeks after AVF creation. The changes then slowed

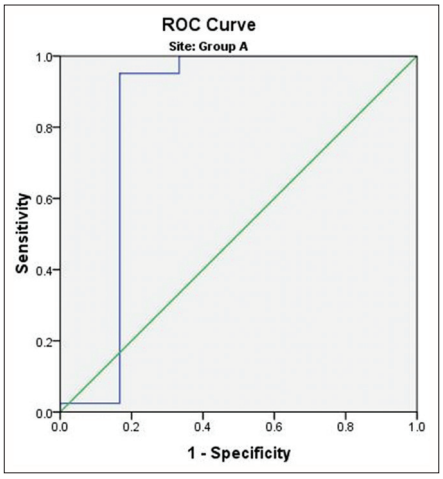

Figure 1: Receiver operating characteristic curve for the Doppler flow in distal arteriovenous fistulas. ROC: Receiver operating characteristic

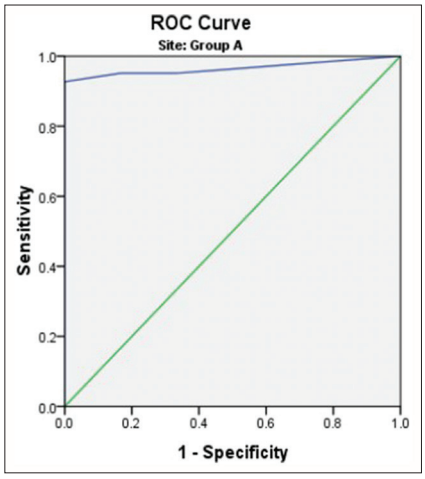

Figure 2: Receiver operating characteristic curve for the diameter of vein distal arteriovenous fistulas. ROC: Receiver operating characteristic

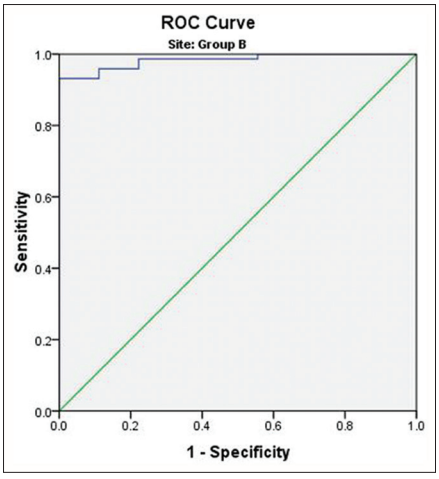

Figure 3: Receiver operating characteristic curve for the Doppler flow in proximal arteriovenous fistulas. ROC: Receiver operating characteristic

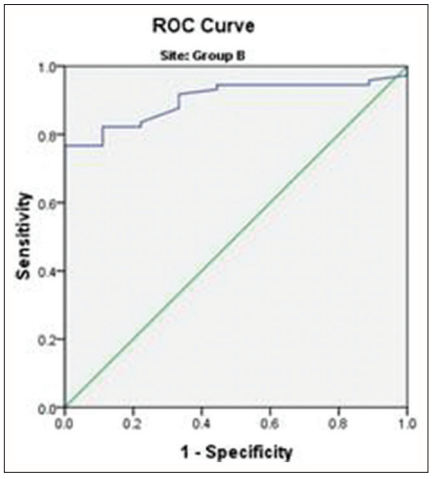

Figure 4: Receiver operating characteristic curve for the diameter of vein proximal arteriovenous fistulas. ROC: Receiver operating characteristic

Table 5: Values of blood flow and vessel diameter for highest sensitivity and specificity for proximal and distal arteriovenous fistula

	Successful maturation	Unsuccessful maturation	Statistics
Distal AVF			
Flow of blood			
<539	2	5	Sensitivity - 95.1
≥539	39	1	Specificity - 83.3
			PPV - 97.5
Diameter of vein			
<0.42	3	6	Sensitivity - 92.7
≥0.42	38	0	Specificity - 100
			PPV – 100
Proximal AVF			
Flow of blood			
<456	5	9	Sensitivity - 93.2
≥456	68	0	Specificity - 100
			PPV – 100
Diameter of vein			
<0.57	17	9	Sensitivity - 76.7
≥0.57	56	0	Specificity- 100
			PPV – 100

AVF: Arteriovenous fistula, PPV: Positive predictive value

in the next 2 months. Based on this, it is indicated that examination for AVF maturity could commence at least 4 weeks after creation, and blood flow of >529 mL/min or cephalic diameter >5.2 mm is associated with AVF maturity with the highest degree of sensitivity and specificity.[11]

It is suggested that for radiocephalic-AVF, a flow rate should be studied at 30 days and a flow rate <400 mL/min is predictive of unsuccessful maturation, and these AVFs should be considered for intervention.[12] Ladenheim *et al*. reported that intraoperative flow was not a significant predictor of primary patency, but an AVF with blood flow of <200 mL/min 1 week after operation is unlikely to mature without undergoing a maturation procedure.[13] In addition, Robbin *et al*. concluded that flow measurement 2 weeks after access creation is more predictive of a 6-week diameter and flow rate than the values 1 day after access creation.[14]

In this study, we investigated the role of duplex USG in predicting AVF maturity. We observed that the mature fistulas had a mean Doppler flow rate of 679.78 mL/min and those that failed had a mean flow rate of 320.59 mL/min. In addition, mature fistulas showed a mean vein diameter of 0.59 cm and those that failed had a mean diameter of 0.34 cm. Vein depth was not found to be statistically significant.

The significance of our study is that USG evaluation of AVF at 3 weeks can predict the chances of AVF maturation. The presence of vein diameter of more than 0.59 cm and flow rate of more than 679.78 mL/min amounted to successful maturation, and hence a successful outcome of AVF. If the patient will not achieve these parameters, then the AVF will not mature and the decision regarding alternate access can be taken earlier without waiting for the customary 4–6-week period, sometimes extend up to 3–6 months.

There are certain limitations of our study. First is the relatively smaller sample size and the results should be validated by studies of large sample sizes. However, certain other parameters should be included in the examination to increase the sensitivity such as the flow pattern.

Conclusion

For radial artery AVF, a flow rate of 539 mL/min and 4.2 mm diameter of vein are predictive of successful maturation. For BA AVF, successful maturation was predicted by a flow rate of 456 mL/min and 5.7 mm diameter of the vein. It will be beneficial to do USG Doppler study 3 weeks after making AVF, as the measurement of flow and diameter may predict the maturation of AVF.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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