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Research Article

Relationship between the Pre-Operative USG and Doppler Findings of the Upper Limb and the Outcome of the AV Fistula in Patients Undergoing Haemodialysis Access

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Abstract

Background: Haemodialysis (HD) is the mainstay treatment in patients with End stage renal disease (ESRD). Arteriovenous fistula (AVF) is current vascular access of choice and is more preferred than graft due to fewer incidences of complications. Doppler Ultrasound (DUS) can be used to assess the vessels used for AVF creation and post-operative monitoring of AVF maturation. This study aims to associate the pre-operative DUS findings with the outcome of the AVF, and hence to broaden the horizon of understanding the vascular access (VA) in HD procedure.

Methods: This was a prospective study conducted in Department of Radio diagnosis of our hospital over a period of one and half year. 43 patients with ESRD were included in the study. The morphological and Doppler parameters were assessed before and after AVF creation and findings were compared.

Results: Pre-operative diameter of the artery and the vein used for the AVF creation showed positive association with the AVF maturation and are important predictive factors for maintenance and well-functioning of the AVF in HD. Post-operative evaluation of flow volume in the AVF revealed that it is one of the important independent predictors of the maturation of the fistula.

Conclusion: Doppler ultrasonography assessment of the upper limb vessels is a roadmap for appropriate selection of the arteries and veins for the creation of the AVF, which helps in reducing the chances of AVF failure.

Keywords: Arteriovenous Fistula; Doppler Ultrasound; End Stage Renal Disease

Introduction

The case load and burden of chronic kidney disease (CKD) is increasing a lot in India [1]. This has been attributed to the increasing rate of occurrence of diabetes, hypertension and coronary heart disease. Globally, CKD now is the 12th and 17th leading cause of death and disability respectively. The number of dialysis patients in India is also increasing by 10-15 percent every year.

Haemodialysis (HD) is a revolutionary discovery in the last century for treatment of patients with renal failure. It is the most common treatment of choice. HD is used to remove waste products like Creatinine, Urea and excess fluid in the blood [2].

Vascular access (VA) is the foundation for the HD treatment. A channel on the patient's body is designed as a vascular access to permit blood to flow in and out during the HD. Two approaches can be used for HD: a permanent surgical procedure and a central venous dialysis catheter. There are two different methods of permanent surgically produced HD access: native Arteriovenous fistula (AVF) and then there is synthetic Arteriovenous graft [3]. An AVF is a surgically created direct anastomosis between an artery and a vein. More blood flows into the vein when an artery is connected to it due to the constant flow in both systole and diastole. As a result, arterialisation of the vein takes place and due to increased blood flow, the vein grows bigger and stronger and that makes re-

peated access for HD easier [4]. Synthetic Arteriovenous grafts are the type of VA created if a primary AVF cannot be created. It's an artificial graft placed into the superficial soft tissues of the forearm, upper arm, or upper thigh to create the anastomosis between an artery and the vein.

Recently, complications are also becoming more prevalent as there are more patients receiving HD treatment. Some of the complications include stenosis, aneurysm, pseudoaneurysm, abnormalities in the wall and hematoma development [5]. These complications are nowadays seen regularly with AVFs and grafts. Hence, steps must be taken to increase the life of VA. To track these issues, a number of diagnostic modalities are available, including colour Doppler ultrasonography (CD-US), angiography, computed tomography, and magnetic resonance imaging.

In recent years, Doppler Ultrasonography (DUS) has turned out to be the procedure of choice for evaluating HD related problems [6]. Since it is widely accessible, non-invasive, non-ionizing, and reasonably priced when compared to other modalities, DUS is easily accepted by the patients as well. In critically ill patients, this method can also be applied at the patient's bedside.

The advantage of DUS is that peripheral vasculature can be evaluated from both a structural and functional point of view. Pre-operative Doppler testing, which makes it easier to choose appropriate vessels and greatly lowers AVF failure, is therefore highly advised. When we compare it to a clinician's physical examination (PE), it reveals significantly more anatomical detail and is more accurate. Portability, substantially less expensive, and requirement of little setup or room are few more added benefits. There are three main areas of application of DUS. They are evaluation of arteries and veins in surgical planning, AVF maturation testing, and evaluating AVF complications. Due to the efficiency, availability, non-invasiveness, and low cost the USG Doppler can be considered as a great technique for evaluating access to HD. Obese patients, diabetics, elderly, and the patients with history of prior access benefit from it the most because of poorly visible veins. In conclusion, DUS enables proper management of all the parameters of AVF care and requirements, and is of utmost significance in patient-centred assessment of vascular access.

With this background we conducted the present study with main aim of studying relationship between the pre-operative USG and Doppler findings of the upper limb and the outcome of the AV fistula in patients undergoing Haemodialysis access.

Materials and Methods

The study was conducted after obtaining approval from the institutional review board to review the patients' images and medical charts.

This is a Hospital based prospective study conducted in the Department of Radio diagnosis, Justice KS Hegde Charitable hospital, Mangalore from 01st April 2021 to 30th September 2022.The study included 43 patients with chronic kidney disease who were planned for AVF. The vessels of the upper limb were mapped and Doppler indices were noted. After the AVF creation, patients were evaluated and pre-operative Doppler findings were compared with the outcome of the fistula. AVF mapping was done with both B-mode and Doppler using Logiq P9 pro ultrasound scanner using linear array high frequency (7 Mhz or higher) probe. Patients planned for surgical AVF construction were enrolled in the study and vascular mapping of the upper limb was done using USG and Doppler with assessment of following parameters: 1. Diameter of the arteries and veins (Brachial artery, radial artery, ulnar artery, cephalic vein, basilic vein and the medial cubital vein). 2. The vascular wall morphology. 3. Peak systolic velocity and RI. Following Post-surgical fistula procedure, vascular parameters were re-accessed. Any evidence of complications like narrowing and thrombosis were accessed. The data collected from the investigation was entered and compiled. The data was analysed and conclusions were drawn.

Results

In this study, the B-mode and Doppler ultrasound was performed for the pre-operative evaluation of the vasculature of the upper limb. Diameter of the arteries and veins, arterial velocity and morphological characteristics of the vessels were noted. Following AVF creation, the diameter of the AV fistula and the flow volume in the AVF was monitored.

Majority (48.8%) of the study population were belonged to the age group of 46 to 60 years, followed by 32.6% > 60 years and 18.6% subjects between 30-45 years old. The mean age group was 53.4 years with a standard deviation of 10.5 years.

There was male predominance in the study population with 76.7% males and 23.3% females.

Number of previous AVFs and type of AVF's among study subjects

Majority (76.7%, n = 33) of the patients in the study had no previous AVF. Those who had previous AVF, 4 patients (9.3%) had one, 5 patients (11.6%) had 2 and 1 patient (2.3%) had three previous AVFs.

The most common type of AVF among the patients was Radiocephalic (69.8%), followed by Brachiocephalic (27.9%) and least common was Brachiobasilic (2.3%).

Diameter of blood vessels of upper limb – pre operative assessment

The mean diameter of upper limb arteries obtained during preoperative vascular mapping was 3.11+/-1.2 mm. The mean+/-SD diameter of the brachial artery in the study was 4.54+/-0.798 mm and radial artery was 2.48+/-0.687 mm. The mean diameter of Veins was 2.54+/-0.93mm. In most of the patient's cephalic vein was used for AVF creation except for one patient where basilic vein was used.

Diameter of the blood vessels forming AVF

In this study, the mean diameter of the AVF created was 3.36 mm (SD = +/- 1.16 mm) and of the outflow vein was 5.12 mm (SD = +/-1.49 mm). The mean diameter of the AVF when radial artery used was 2.89 mm (SD = +/-0.54 mm) and when the brachial artery used was 4.43 mm (SD = +/-1.47 mm).

Diameter of inflow artery of the fistula

In this study, 83.7% patients had >2mm and 16.3% patients had <2mm of the arterial diameter proximal to the fistula. The mean velocity of feeding artery used for AVF creation was 56.65 +/- 16.42 cm/sec.

The mean flow volume in the AVF was 1028.58 +/- 358.66 ml/min and RI in the AVF was 0.584 +/- 0.139. The mean flow volume when brachial artery was used for AVF was 1205.69+/-390.68 ml/min and when radial artery was used was 951.833+/- 320.92 ml/min. The mean RI of AVF was 0.584 (SD = 0.139).

	Mean PSV of the feeding arteries used for AVF creation.	Flow volume in AVF	RI of AVF
Mean	56.65 cm/sec	1028.58 ml/min	0.584
Standard deviation	16.42 cm/sec	358.66 ml/min	0.139
Minimum	26 cm/sec	232 ml/min	0.340
Maximum	93 cm/sec	1654 ml/min	0.900

Table 1: Mean PSV of the feeding arteries used for AVF creation and Doppler parameters in the AVF.

In this study, 36 (83.7%) patients had AVF maturation following surgery.

AVF maturation status	Frequency	Percentage
AVF maturation occurred	36	83.7%
No AVF maturation	07	16.3%
Total	43	100%

Table 2: Distribution of study subjects based on AVF maturation.

Out of 43 patients, 39.5% had complications post AVF surgery. Among them stenosis in the AVF was seen in 18.6% patients. Thrombosis of the cephalic vein and AVF was noted in 11.6% and 2.3% of the patients respectively. The hematoma and the pseudoaneurysm were detected in one patient each.

Complications	Frequency	Percentage
None	26	60.5%
Present	17	39.5%
Total	43	100%
Distribution of the study population based on type of complications.		
Stenosis of the AVF	08	18.6%
Thrombosis of cephalic vein	05	11.6%
Aneurysm	01	2.3%
Hematoma	01	2.3%
Thrombosis of AVF	01	2.3%
Thrombosis with pseudoaneurysm	01	2.3%

Table 3: Occurrence of complications among study participants.

Our study found statistically significant association between flow volume in the AVF and AVF maturation. On comparing diameter of the feeding artery with AVF maturation, it revealed significant relationship with maturation. The comparison between the diameter of the vein used for AVF creation is statistically significant with respect to AVF maturation. No significant association was seen between the RI in the AVF with AVF maturation. No significant statistical association was found between the feeding arterial velocity and AVF maturation. The arterial diameter used for AVF creation did not show any significant association with the complications in the follow up period. The diameter of the vein used for AVF creation did not show any significant association with the complications of AVF in the follow up period.

Parameters	AVF maturation		p-value
	Yes	No	
Flow volume in AV fistula			0.021
Mean	1089.14 ml/min	717.14 ml/min	
Standard deviation	325.69 ml/min	383.35 ml/min	
Diameter of the artery			<0.001
Mean	3.35 mm	1.18 mm	
Standard deviation	1.15 mm	0.37 mm	
Diameter of the vein			0.004
Mean	2.70 mm	1.73 mm	
Standard deviation	0.92 mm	0.34 mm	
RI of the AV fistula			0.06
Mean	0.565	0.680	
Standard deviation	0.129	0.159	
Velocity in the feeding artery (PSV)			0.351
Mean	57.69 cm/s	51.28 cm/s	
Standard deviation	16.99 cm/s	12.76 cm/s	

Table 4: Association between AVF maturation with flow volume and RI in the AVF, diameter of the arteries and veins used in the AVFs, velocity in the feeding artery. Association between diameter of artery and vein with complications.

	Complications		P value
	Yes	No	
Mean Diameter of the artery	2.86 mm	3.27 mm	
Standard deviation	1.36 mm	1.07 mm	0.103
Mean Diameter of the vein	2.86 mm	3.27 mm	
Standard deviation	1.36	1.07 mm	

Table 5: Association between diameter of artery and vein with complications.

Statistically significant association was found between the maturation status and the complications seen among the patients of the study population.

Complications	AVF maturation		Total
	No	Yes	
Absent	0	26 (72.2%)	26 (60.5%)
Present	07 (100%)	10 (27.8%)	17 (39.5%)
Total	07 (100%)	36 (100%)	43 (100%)
p-value	0.001		

Table 6: Comparison of complications status and AVF maturation.

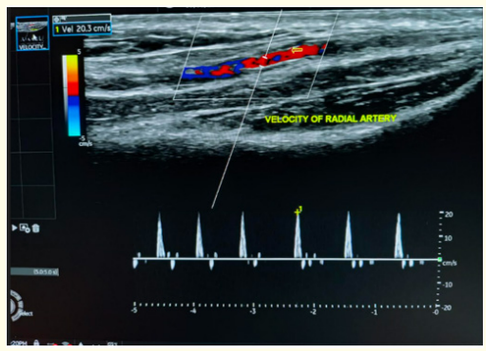

Figure 1: USG image demonstrating velocity of the radial artery with triphasic spectral pattern.

Figure 2: USG image showing diameter of the brachial artery.

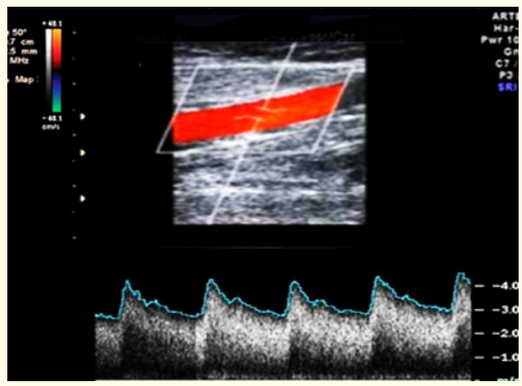

Figure 3: USG image showing normal AVF demonstrating marked spectral broadening and elevated velocity.

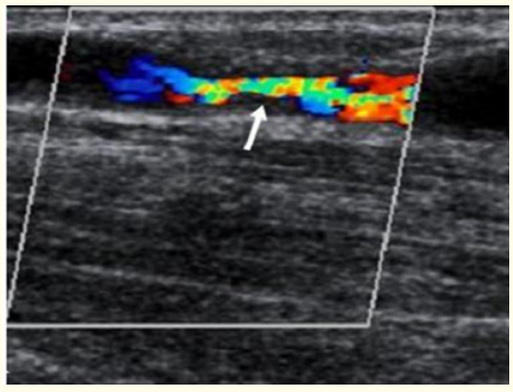

Figure 4: USG image of Stenosis of the outflow vein.

Discussion

Haemodialysis is the baseline treatment of the choice for patients with ESRD. AVF is the vascular access of choice, which helps in repeated cannulation of the vein as the vein grows thicker and stronger due to its arterialization. A functioning AVF is crucial to maintain HD in patients with ESRD. Although aberrant hemodynamic in the AVFs are typically discovered after HD, sonographic assessment during the initial phase of dysfunction may identify an underlying correctable abnormality, allowing for the initiation of the appropriate therapy prior to the situation getting worse.

In our study, the mean flow volume seen in the AVF was 1028.58+/-358.66 ml/min. Among these patients 13 had high flow fistula (>1300ml/min), 26 patients had normal flow volume (500–1300 ml/min) and rest of the 4 patients had low flow volume (<500 ml/min). The mean flow volume noted in the AVF when brachial artery was used was 1205.69+/-390.68 ml/min and for radial artery was 951.833+/-320.92 ml/min. When the brachial artery was used as the feeding artery, the average flow volume in the AVF was greater.

In this study, the association between the flow volume and AVF maturation was statistically significant [7]. It has been established in multiple studies that the flow volume in the AVF is one of the primary determinants for maturation [8]. We found that the feeding artery's diameter and average flow volume in the AVF showed a significant association ($p < 0.001$). Significant association was seen between the diameter of the vein and AVF maturation (p-value = 0.004), stating that the outflow venous diameter and patency is crucial for maintenance for HD.

In this study a total of 7 patients did not have AVF maturation and remaining 36 patients developed a mature well-functioning fistula. Post op complications were noted in 17 patients, out of which all the patients with non-maturation of the AVF developed complications. Hence a significant association was found between the failure of maturation of AVF and complications [5] in the follow up period (p value = 0.001).

Conclusion

Our study has further confirmed that, DUS is a standard approach for assessing morphological and hemodynamic parameters of the AVF for HD. DUS assessment of the upper limb vessels is a roadmap for appropriate selection of the arteries and veins for the creation of the AVF, which helps in reducing the chances of AVF failure. After the creation of the AVF, DUS is also an excellent imaging modality for monitoring the maturation and functioning of the fistula [9]. DUS can also detect the complications like stenosis, aneurysm, pseudoaneurysm [10] at an early stage, so that the early intervention can be undertaken to prevent the failure of the fistula in treatable conditions.

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