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**Research Article**

# Vascular Mapping before Haemodialysis Access in CRF Patients and Evaluation of AVF Maturation by Doppler Ultrasound

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**Abstract:** This prospective hospital based study was undertaken to reckon the value of ultrasound in preoperative vascular mapping for AVF placement and in postoperative follow-up to evaluate its maturity and complications. 100 CRF patients who needed hemodialysis access underwent preoperative US vascular mapping and among them 62 patients, who were candidates for native fistulas were reviewed on 7th and 28th postoperative days. The results were analyzed and means were calculated using Epi-Info Ver7. The mean diameters of the radial and brachial arteries were 2.37mm and 3.13mm respectively. The mean venous diameters for forearm and arm fistulas were 2.69mm and 3.18mm respectively. There was a significant increase in native AVF creation when PE was combined with US(62%) as compared to PE alone(19%). Vascular anatomy as defined by sonography, matched the operative findings in all but one (98.39% accuracy). The mean diameter of the venous limb and its flow volume of radio-cephalic and brachio-cephalic/basillic fistulas at 28 day were 3.97mm & 404 ml/min and 4.52mm & 470 ml/min respectively. 67.7% of fistulas were mature at 4 weeks. In conclusion, pre-operative ultrasonographic vascular mapping is valuable in selecting potential sites for vascular access, helping in maximizing the native AVFs and decreasing the negative surgical exploration rates. Post operative follow up is of value when the status of fistula maturity is in doubt and when complications are clinically suspected.
**Keywords:** Dialysis Access, AV fistulas, Doppler Ultrasound.

## INTRODUCTION

Since its introduction in 1966, haemodialysis has revolutionized the management of patients with renal failure to an unforeseen extent. The expected life span of patients with end-stage renal disease has improved significantly and vascular access is the 'life line' of these patients, providing the route for HD therapy.

Vascular access procedures and complications have been major cause of morbidity accounting for over 20% of hospitalizations of dialysis patients in the United States and cost about $1 billion annually [1,2]. In an effort to improve vascular access outcomes the National Kidney Foundation published the Dialysis Outcome Quality Initiative (DOQI) set guidelines regarding the optimal management of vascular access [3]. AVF are the preferred access for HD because they are associated with a lower frequency of complications and greater longevity [4, 3]. Most of the AVF failures have been attributed to inadequate vessels used for surgery.

Physical examination is the traditional method of evaluation performed prior to hemodialysis access placement [5], however it is not fool proof.

With high-resolution US scanners, it is now possible to obtain precise anatomic knowledge, qualitative and quantitative data. It precisely identifies the quality of superficial veins and the status of the deep venous flow and also provides an analysis of the characteristics of arterial flow and wall, which may put a good functioning of AVF at risk.

After surgical creation, AVFs typically require several weeks to months of maturation and thus it would be advantageous to develop objective quantitative criteria to evaluate the suitability of fistulas for dialysis.

A blood pump usually routes 350-400 mL/min through a dialyzer. The definition of a functional access is an access that is able to deliver a flow rate of 350-400 mL/min without recirculation for the total duration of dialysis.

A substantial proportion of fistulas (28%–53%) never mature adequately to be usable for dialysis due to ill-defined mechanisms [6, 7, 8, 9]. An AVF is typically not evaluated for maturity until 2–3 months after placement, not used until 3 months after placement [6] and nephrologists often wait up to 6 months before declaring the fistula a failure [10]. If the AVF never matures, this is time wasted. Well-defined criteria applied early after fistula placement to help identify fistulas likely to fail would be extremely useful [11]. Ultrasonography also help identify other complications associated with grafts and fistulas, including hematoma, pseudoaneurysm, and abscess [12].

It is estimated that 100,000 new patients of end stage renal disease (ESRD) enter renal replacement programs annually in India [13]. In a population based study from Bhopal, Modi et al have reported the average crude and age adjusted incidence rates of stage 5 CKD (ESRD) as 151 and 232 per million population[14]. With increasing prevalence of CKD and steeply raising trend in dialysis there is a current need of a low-cost easy to perform method that provides reliable information on sonographic mapping on planning access placement with subsequent decrease in negative surgical exploration [15] . It is this need that has motivated this study.

## MATERIALS & METHODS

This hospital based prospective study of 100 cases of CRF who need hemodialysis access was conducted in the Department of Radiodiagnosis and Imaging at Gandhi Medical College and Hamidia Hospital, Bhopal, Madhya Pradesh from June 2012 to December 2013.

### Inclusion Criteria

- Chronic renal failure-Stage IV & V [18].
- Clinically stable.
- Patients referred for native AVF in upper limb for haemodialysis.
- Willingness to attend follow-up Color Doppler ultrasound.

### Exclusion Criteria

- Previously failed AV Grafts/ fistulas
- Deformed or scarred upper limb
- Upper limb arterial disorder like Reynaud's
- Need to puncture the graft before the end of study.
- All patients where AVF for access is contraindicated or technically not feasible or do not fulfill any inclusion criteria.

### Source of Data

CRF patient who present to Department of medicine for dialysis are referred to the Department of Radiodiagnosis at GMC and HH, Bhopal, for Colour Doppler mapping for assessment of site for AV fistula formation before the procedure in done in CTVS department.

### Methodology

Ultrasonographic evaluation with Colour Doppler is done for the preferred site of vascular access by evaluation of vessel size, patency and wall morphology.

Transverse plane is used to identify vessels and evaluate their diameter and wall thickness. Colour and Spectral Doppler waveforms are obtained in longitudinal plane of vessels selected for potential vascular access. Depth from the skin surface of the anterior wall of vein is measured. Arteries are assessed for intimal thickening and stenosis [16].

- The most distal site is used first, moving proximally, depending on the availability of good veins & disease free arteries.

The preoperative criteria to be met for vascular access are summarized as,

- Arteries 2.0 mm or larger
- Veins, 2.5 mm or larger for AVF, or 4.0 mm or larger for graft.
- Depth of the vein from the skin surface < 5 mm
- Superficial vein continuing to the deep venous system;
- Absence of central venous stenosis
- Absence of evidence of arterial stenosis segments

Patients who are candidates for upper limb native AVFs will be followed up with US at day 7 and 28 for assessment of diameter of the venous arm of fistula and flow volume.

### Post Procedure Ultrasound Technique

The diameter and compressibility of the draining vein is studied routinely in the caudal, mid-, and cranial portions of the forearm, and similarly in the upper arm. The entire draining vein is scanned and the minimum diameter is measured.

The depth of the anterior wall of the AVF from the skin surface is also measured. Blood flow is measured in the AVF in ml/min using the volume flow measurement function of the duplex instrument at a site far enough from the anastomosis. Three measurements were performed, and the final value used in the study was the arithmetic mean.

### Criteria For Maturation After The Procedure

- Vein diameter larger than 4 mm remote from the site of fistula.
- Vein located at a depth of <5 mm from skin surface.

- Flow volume > 400 mL/min safely away from turbulence at fistula site.

**Method of Statistical Analysis**

Means calculated using MS Excel and correlations using Epi Info Version7.

**RESULTS**

In the study population of 100 patients who were in need of a vascular access for hemodialysis, 63 were males and 37 were females.

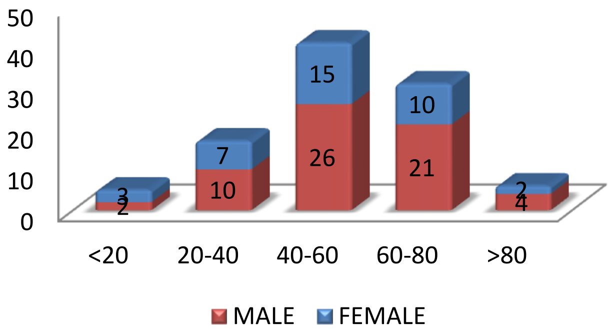


**Fig. 1: Distribution of study population according to sex and age**

62 of the 100 patients were diabetic, 71 were hypertensive and 45 had both morbidities. These vascular risk factors are associated with increased risk of AVF failure [17].

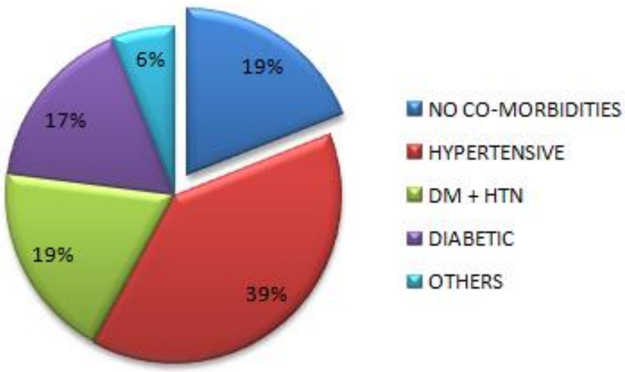


**Fig. 2: Distribution of Co- Morbidities**

In the present study, 62 patients who underwent Preoperative US mapping had native upper limb fistula placed successfully and 38 had vessels suitable for graft placements.

The most common upper limb fistula was radio-cephalic fistula. Of the 62 native fistulas made 42 were radio-cephalic, 31 and 11 each in the dominant and non dominant limb respectively. 19 were brachial artery cephalic vein fistulas. Basilic artery transposition was done in 1 patient.

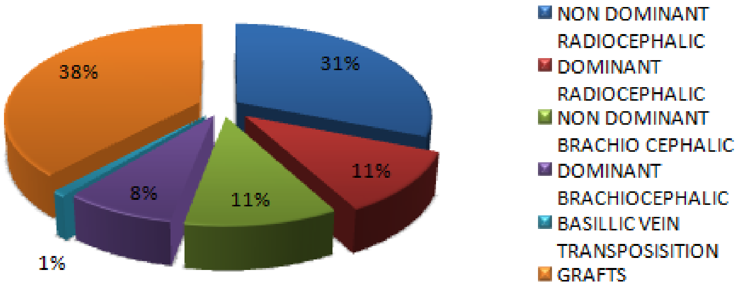


**Fig. 3: Type of Vascular Access**

**Table: 1 Diameter of Vessels Used in Access**

| **Artery** | **N** | **Mean Dia. (mm)** | **Medain** | **Std. Deviation** | **Min (mm)** | **Max (mm)** |
|---|---|---|---|---|---|---|
| Radial A (Wrist) | 42 | 2.37 | 2.4 | 0.117 | 2.1 | 2.6 |
| Brachial A (Arm) | 20 | 3.13 | 3.1 | 0.240 | 2.8 | 3.6 |
| **Vein** | **N** | **Mean Diam. (mm)** | **Median** | **Std. Deviation** | **Min (mm)** | **Max (mm)** |
| Cephalic V (Wrist) | 42 | 2.69 | 2.7 | 0.132 | 2.5 | 3 |
| Cephalic V (Elbow) | 19 | 3.18 | 3.2 | 0.185 | 2.9 | 3.5 |
| Basillic V (Elbow) | 1 | 3.2 | | | | |

**Table 2: Diameter and Volume of Radiocepahlic and Brachiocephalic/Basillic**

| **Diameter (mm)** | **Day 7** | | | **Day 28** | | |
|---|---|---|---|---|---|---|
| | Mean | Median | Std. Dev. | Mean | Median | Std. Dev. |
| Radiocepahlic | 2.83 | 2.80 | 0.155 | 3.97 | 4.05 | 0.42 |
| Brachiocephalic/Basillic | 3.47 | 3.4 | 0.229 | 4.52 | 4.6 | 0.451 |
| **Volume (ml/min)** | **Day 7** | | | **Day 28** | | |
| | Mean | Median | Std. Dev | Mean | Median | Std. Dev |
| Radiocepahlic | 274.0 | 280.0 | 33.48 | 404.0 | 410.0 | 49.78 |
| Brachiocephalic/Basillic | 335.5 | 340 | 37.38 | 470 | 465 | 54.77 |

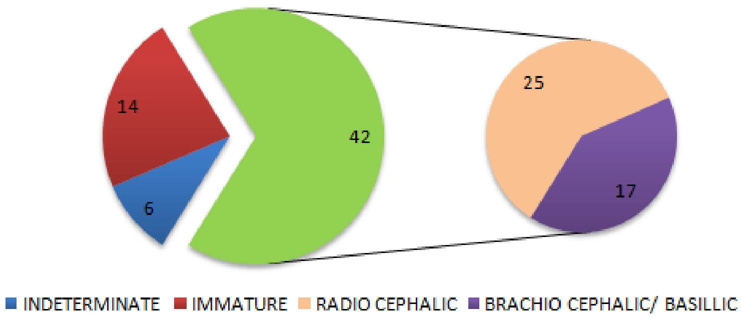


**Fig. 4: Maturity at 4 Wks According to Fistula Site**

The mean diameter of the venous limb and its flow volume at 28 day at the radio-cephalic and brachio cephalic/ basillic fistulas were 3.97mm & 404 ml/min and 4.52mm and 470 cc respectively. Of the 20 upper arm fistulas 17 (85%) met all the laid criteria for maturity. Of the 42 radio-cephalic fistulas only 25 (59.5%) met all the criteria for maturity and 13 (30.95%) were immature at 4 weeks. This is at least partly contributed by the fact that the distal forearm fistulas have reduced caliber of the arterial and venous limbs as compared to the proximal fistulas (2.37 and 2.69 mm Vs 3.13 and 3.18 mm respectively).

## DISCUSSION

In our study evaluation by physical examination favorable anatomy was found in 19 patients and was inconclusive in 81 patients.

In patients who had favorable forearm anatomy under physical examination, ultrasound validated the findings. Of the 81 patients who had unfavorable or in-assessable vascular anatomy, 43(62%) had vessels suitable for native upper limb fistulas.

**Table 3: Comparison of present study with other studies for increase in AVF creation when PE was combined with US for pre-operative vascular mapping**

| **Author/ Study** | **PE (%)** | **PE + DUSG (%)** |
|---|---|---|
| Silva *et al*. 1998 [18] | 34% | 64% |
| Allon *et al*., 2001 [6] | 14% | 63% |
| Malvroh *et al*., 2002 [19] | 0% (n=62) | 77% |
| Wells *et al*., 2005 [20] | 73% (n=145) | 86.5% |
| Present study | 19% | 62% |

Diameter of the vessels is an important criterion for successful AVF construction. In a study by Malvroh et al[19], mean radial artery diameter measured by US and surgery was 2.3 + 0.66 (range: 1.4 – 3.2) and 2.1+ 0.58 (range: 2.1-2.8) respectively. In our study the mean diameter of the radial artery in patients who were candidates for radio-cephalic fistula was 2.37 mm and that of brachial artery in patients with upper arm fistulas was 3.13 mm. The mean venous diameter for forearm fistulas was 2.69 and that of upper arm fistulas was 3.18

In the present study, four anatomical variations were detected by US. Two were of high brachial artery bifurcation and one cephalic vein duplication and one patient with hypoplasia of the cephalic vein at the arm.

With thorough knowledge of anatomical variations and clear depiction of the vascular anatomy as by US, there is substantial decrease in negative surgical exploration rates. Malvroh et al, [19] documented 0% negative surgical exploration rate. Another study by Allon *et al*. [6] showed 11% (28 of 256) negative surgical exploration rate. In the present study there was a single case i.e., Negative surgical exploration rate 2 %. This was attributed to the variations in venous branching around the cubital fossa region.

Schillinger *et al*., observed 50% stenosis or occlusion rate at the site of subclavian cannulation [21]. In the present study out of the 5 patients who had history of central venous access through the subclavian route, 4 (80%) had either complete or partial thrombus in the deep venous system precluding possibility of further fistula formations. This substantiates the routine use of US preoperative screening, as it might provide with indirect evidences of thrombosis, or even better it may provide direct visualization of the thrombus as was in our case. However as suggested by Schillinger et al the value of angiography in these cases cannot be over emphasized.

Of the 100 patients, 62 who had native upper limb AV fistulas were followed up at 7 days and 28 days.

Historic study on fistula maturation by Robbin *et al*. observed that a single US evaluation for minimum venous diameter and blood flow rate at 2–4 months can be used to accurately assess the likelihood of AVF maturation [22].

One would assume that a preoperative strategy to identify suitable vessels for AVF creation would naturally evolve into decreased early failure rates and an increased proportion of prevalent patients dialyzing with an AVF, but this may not always be the case. In a study by Patel et al, the implementation of preoperative Ultrasonography and angiography to aggressively increase AVF creation resulted in a greater number of AVFs, but had the unintended consequence of reducing the AVF maturation rate from 73% to 57%[23].

**Table :4 Comparative data on Effect of Preoperative Vascular Mapping on Vascular Access Outcomes from various studies.**

| Author | Technique | AVF Creation rate | % of Usable AVF |
|---|---|---|---|
| Silva (1998) [18] | USS | 14% (pre) to 63% (post) | 8% (pre) to 64% (post) |
| Allon (2001) [6] | USS | 34% (pre) to 64% (post) | 16%(pre) to34% (post) |
| Huber (2002) [24] | USS + angiography | 90% | 71% |
| Patel (2003) [23] | PE + USS + angiography | 61% (pre) to 73% (post) | 73% (pre) to 57% (post) |
| Asif (2005) [25] | USS | 77 % | All functional at follow-up |

In our study at 4 weeks 42 out of the 62 fistulas (67.7%) were mature. However one should bear in mind that it is too early in course of natural history of fistulas to comment on its maturity. Hence follow up studies to access the long term functionality and failure rates are indicated.

Regarding postoperative complications, in our study 2 cases of post operative hematomas were noted, which were managed supportively.

There was a single case of thrombosis of the venous arm was reported in a patient with radio-cephalic fistula, which needed vascular surgical intervention.

## CONCLUSION & RECOMMENDATIONS

- Pre-operative vascular ultrasonographic mapping is valuable in selecting potential sites for vascular access, helping in maximizing the native AVFs and decreasing the negative surgical exploration rates.
- US mapping deserves merit particularly when physical findings are inconclusive.
- In light of evidence suggesting high incidence of thrombosis following central venous access [21] it would be appropriate to evaluate these patients with angiography, though US in our study picked up these.
- Post operative follow up is of value when the status of fistula maturity is in doubt and when complications are clinically suspected.
- There is however uncertainty in the literature on, whether routine preoperative US is fruitful in

patients with positive physical examination[26], if increasing AVF creation translates to increase in maturation[6], if aggressive routine monitoring of a hemodialysis access, can predict or affect subsequent thrombosis or cumulative patency [27-29] and regarding the time scale cut-off beyond which interventions are warranted. Further studies in this regard are in place.

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**LIST OF ABBREVIATIONS**

- ✓ AVF - Arteriovenous fistula
- ✓ CKD - Chronic kidney disease
- ✓ ESRD - End-stage renal disease
- ✓ HD – Haemodialysis
- ✓ mL/min- Millilitres per minute
- ✓ NKF-DOQI - National Kidney Foundation Dialysis Outcomes Quality Initiative
- ✓ PE - Physical examination
- ✓ PSV - Peak systolic velocity
- ✓ US - Ultrasound
- ✓ VA- Vascular access.