

Original Research Article

# Role of preoperative duplex ultrasonography to predict maturation of radiocephalic arteriovenous fistula

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## Abstract

**Background:** Current DOQI guidelines encourage creating arteriovenous fistulas in more number of hemodialysis patients. However, many new fistulas fail to mature enough for use in hemodialysis. Preoperative vascular mapping to select suitable vessels may improve vascular access outcomes. Thus our study aims to evaluate role of preoperative vascular mapping in fistula maturation.

**Results:** Among 54 radiocephalic fistulas, mean preoperative radial artery diameter and cephalic vein diameter at wrist was  $2.24 \pm 0.53$  mm and  $2.05 \pm 0.58$  mm respectively in successful group. The mean radial artery PSV was  $47.57 \pm 7.67$  cm/sec in successful group with p value < 0.001. Thrombosis was the most common complication seen in about 18.5%. Overall maturity rate of 77.8% was recorded at 4 weeks with primary failure rate of 22.2%.

**Conclusion:** Duplex ultrasound reliably evaluates both structural and functional aspects of the peripheral vessels and helps in preoperative vascular mapping. Hence, preoperative ultrasound should be used to improve AVF outcome.

**Keywords:** Arteriovenous fistula, Color Doppler ultrasonography, Preoperative mapping, Vascular access

## 1. BACKGROUND

Chronic kidney disease is a global health problem. International Society of Nephrology's Kidney Disease Data Center Study reported a prevalence of 17% population worldwide is affected by CKD. India owns <3% of land mass and 17% of the earth's population.<sup>(1)</sup> Modi and jha reported an age-adjusted incidence of end stage kidney disease (ESKD) as 229/million population.<sup>(2)</sup> The approximate prevalence of CKD is 800 per million population (pmp), and the incidence of end-stage renal disease (ESRD) is 150-200 pmp. For all patients of end stage renal disease (ESRD) only option is renal replacement therapy (RRT). Hemodialysis is most common modality followed by transplantation and peritoneal dialysis.<sup>(3)</sup>

India has close to 1850 nephrologists all over the country who are unequally distributed but mostly concentrated in urban centres. There are over 130,000 patients undergoing dialysis at these centre.<sup>(1)</sup>

One of the major functions of the kidney is to eliminate waste products and toxins generated

from a variety of metabolic processes.<sup>(1)</sup> Normal kidney function provides efficient elimination of these solutes, allowing for control of their blood and tissue concentrations at relatively low levels. On the other hand, in end stage renal disease (ESRD) these "uremic toxins" accumulate in body and affect nearly all body organs and systems. Dialysis is efficient for the removal of uremic toxins, and thus restores the electrolyte balance in ESRD patient despite the kidney's inability to function optimally. To maintain them on long-term dialysis, vascular access procedures are required.

The 3 most common types of vascular access used in clinical practice are arteriovenous fistula (AVF), arteriovenous graft (AVG) and central venous catheters (CVC). AVF is preferred over AVG and CVC<sup>(4)</sup>. Because of better survival with lower rate of access related complications as well as longer survival and functional patency rates.

Although an arteriovenous fistula (AVF) is considered the preferred type of access, 20%–60% of AVFs fail to mature for successful dialysis use. Risk factors for primary failure of fistulas are not well established, but the quality of vessels is thought to play an important role<sup>(5)</sup>. Small-sized, stenosed, or partially thrombosed vessels have been suggested as possible causes. The creation and maintenance of a patent and well-functioning AVF have become a real challenge to nephrologists. Since duplex doppler ultrasound reliably evaluates both structural and functional aspects of the peripheral vessels, it helps in preoperative vascular mapping which involves proper selection of a target vessel with adequate luminal diameter for AVF creation. And also aids in assessing maturity of AVF thus suggesting prime time for puncture. Being non-invasive and non-radiative modality it can be used repetitively for follow-up and early diagnosis of vascular access (VA) complications in hemodialysis patients.<sup>(6)</sup>

We aimed to determine the clinical utility of preoperative vascular mapping prior to arteriovenous fistula creation for hemodialysis access.

## 2. METHODS

After receiving approval from Institutional Scientific and Ethical Committee, a hospital based and prospective observational study, was conducted in the Department of Radio-diagnosis, M.G.M. Medical College and M.Y. Hospital and Superspeciality hospital, Indore, Madhya Pradesh, India. The duration of the study was from March 2021 to August 2022. A total of 96 End Stage Renal Disease (ESRD) patient with age >20yr planned for AVF construction were included in the study while arterio venous graft (AVG) patients, hemodynamically unstable patient and those with vascular disorders were excluded.

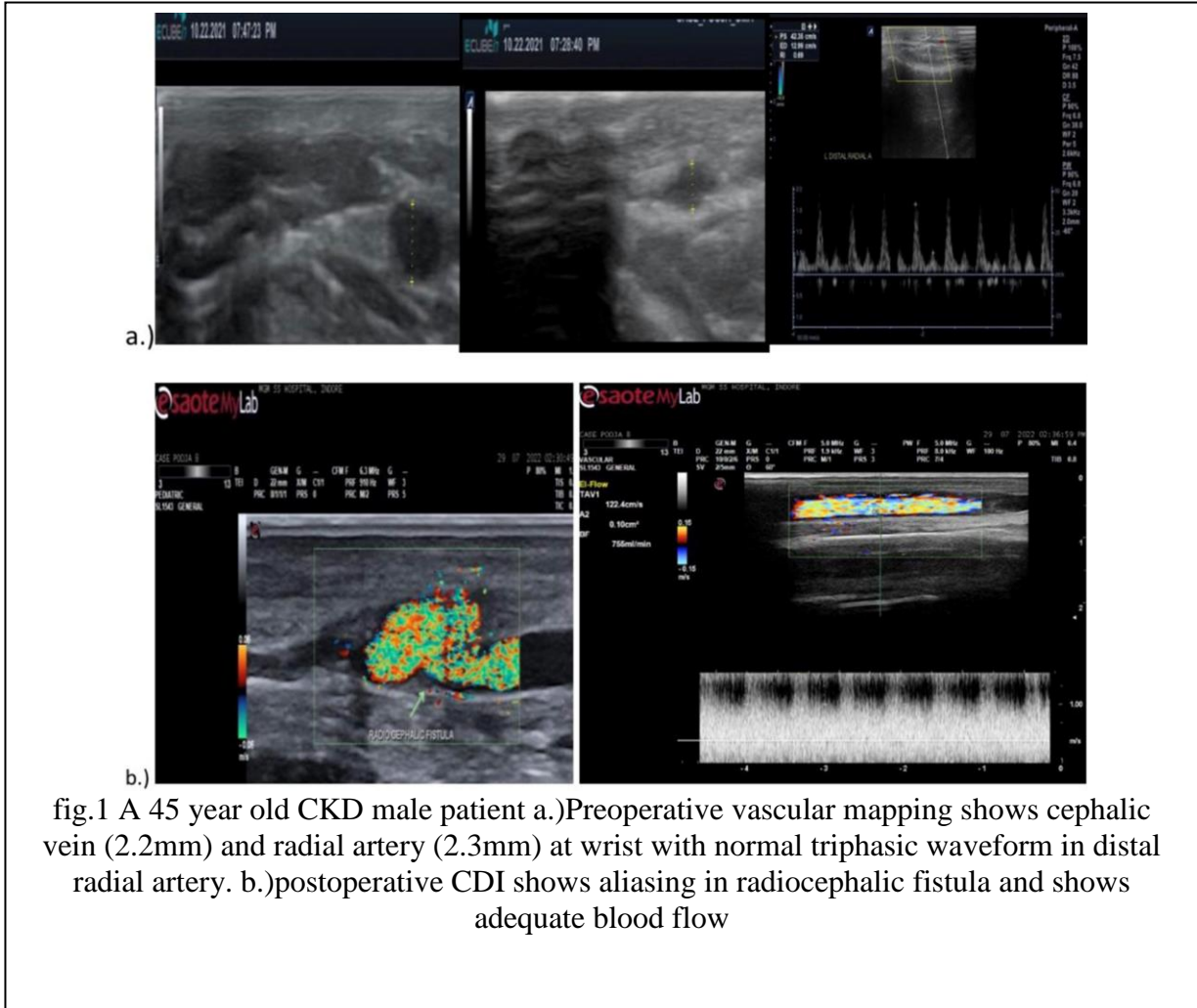
A standard preoperative examination was performed using a linear phased-array transducer starting from the cephalic vein at the forearm up to the cephalic and basilic veins at the upper arm and from the radial and ulnar arteries at the wrist upto the brachial artery. Course of vein and tributaries are noted. Appearance, diameter and patency of the vein is assessed by frequent intermittent compression with probe placed in transverse section.

Selection of suitable artery is based on location of suitable vein selected. Measure the internal diameter of radial and brachial artery on B mode. Vessel course is noted. Any anatomical variation in arterial and venous system is noted. Doppler waveform of the radial and brachial artery and its peak systolic velocity (PSV). Reactive hyperemia test was done to assess artery's ability to increase its caliber.

In postoperative evaluation patient was followed up at the end of one month to assess blood flow volume and further for complications of AVF. Three blood flow measurements were performed within 6 cm in the AVF draining vein and averaged. Also measure diameter of draining vein and its distance from skin surface and further trace the draining vein till joining

to subclavian vein to look for any thrombosis /stenosis.

Figures



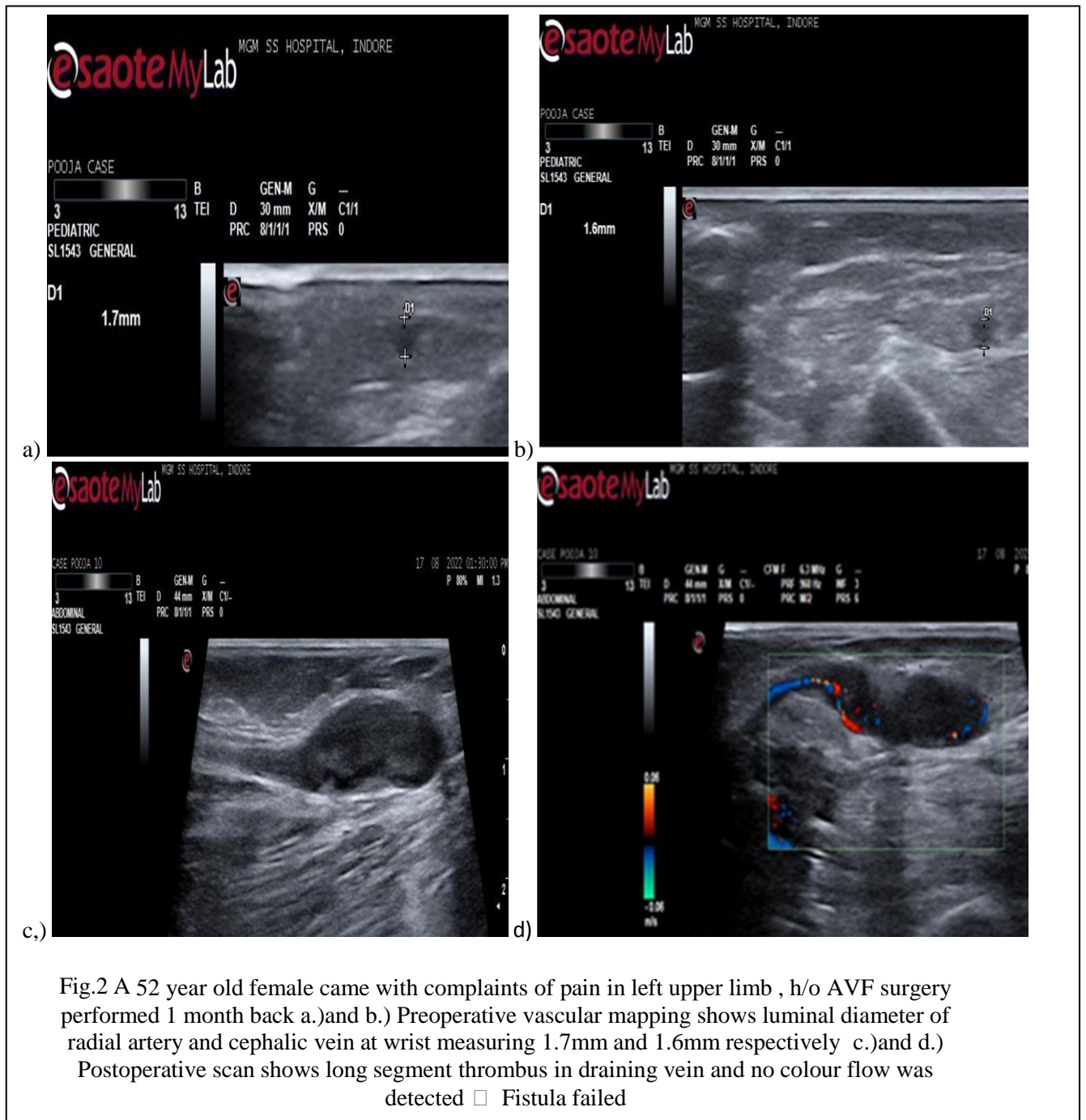


Fig.2 A 52 year old female came with complaints of pain in left upper limb , h/o AVF surgery performed 1 month back a.)and b.) Preoperative vascular mapping shows luminal diameter of radial artery and cephalic vein at wrist measuring 1.7mm and 1.6mm respectively c.)and d.) Postoperative scan shows long segment thrombus in draining vein and no colour flow was detected □ Fistula failed

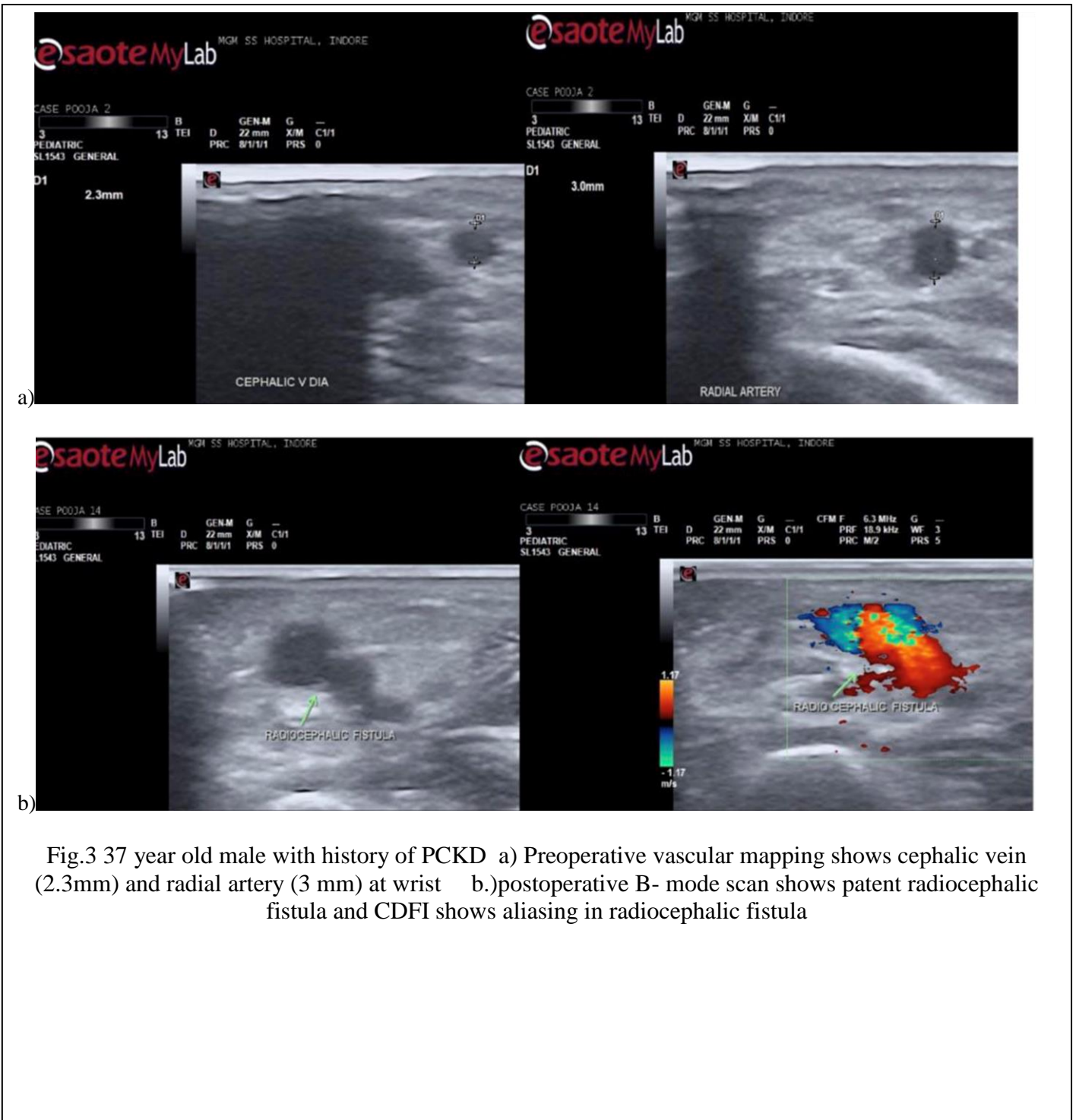


Fig.3 37 year old male with history of PCKD a) Preoperative vascular mapping shows cephalic vein (2.3mm) and radial artery (3 mm) at wrist b.)postoperative B- mode scan shows patent radiocephalic fistula and CDFI shows aliasing in radiocephalic fistula

### 3. RESULTS

The study included 96 patients with ESRD planning for AVF creation aged from 21 to 80 years, with the mean range of  $42.51 \pm 12.74$  years. Males in the study group are 55 (57.3%), and females are 41(42.7%). Fifty percent of patients in the study have diabetic nephropathy, 27% with hypertensive nephropathy, 14% had chronic nephritis, 3.8% polycystic kidney, and 5% have unknown primary renal disease .

In the preoperative mapping of the upper limb vessels, the mean diameter of cephalic vein is  $2.05 \pm 0.58$  mm; radial artery mean diameter is  $2.24 \pm 0.53$  mm; radial artery mean PSV is  $47.57 \pm 7.67$  cm/sec.

AVF creation was possible only in 78 patients out of 96 as 11 patients expired while remaining 7 were lost to follow up. Out of 78 fistulas, radiocephalic fistula was constructed in 54 (69.2%) patients, brachiocephalic fistula in 19 (24.4%) patients and brachio basilic fistula was constructed in 5 (6.4%) patients. In majority (69.2%) of the patients radiocephalic fistula was made.

During the follow-up period (4 weeks), among 54 radiocephalic fistulas, 42 were considered mature (77.7%), and the cannulation was done at least 1 month after surgery; 12 AV fistulas (22.22%) were considered failed at 4 weeks.(Table 2)

In our study, the mean value of preoperative cephalic vein diameter at wrist was  $2.05 \pm 0.58$  mm and  $1.00 \pm 0.01$  mm in mature group and failure group respectively and this difference between the two groups was found to be statistically significant (P value < 0.0001) according to Mann-whitney u test for radiocephalic fistulas.

In our study, the mean value of preoperative radial artery diameter was  $2.24 \pm 0.53$  mm and  $1.00 \pm 0.01$  mm in mature group and failure group respectively and according to Mann-whitney u test this difference between the two groups was found to be statistically significant (P value < 0.0001) for radiocephalic fistulas.

In our study, mean preoperative PSV of radial artery at wrist was  $47.57 \pm 7.67$  cm/sec and  $26.17 \pm 3.46$  cm/sec in mature group and failure group respectively and this difference between the two groups was found to be statistically significant (P value < 0.0001) for radiocephalic fistulas.

Highly significant relation between outcome of the fistula and radial artery PSV (P value = 0.001) was seen. Similarly, there was significant relation between outcome of the fistula and radial artery diameter (P value = 0.001). (Table 3)

In our study, total 49.1% of the cases had complications following construction of AVF which included diffuse subcutaneous edema(16.3%), thrombosis(18.5%), stenosis(3.6%), infection(3.6%), haematoma(5.4%), pseudoaneurysm formation (1.8%). (Table 4) Thrombosis (18.5%) was most common complication noted in radiocephalic fistula. However, there were no complications in 50.9% of the radiocephalic fistula.

In our study, out of 54 radiocephalic fistulas, 12 failures were noted.

**Tables**

**Table 1: Distribution of patients based on prevascular mapping**

	Cephalic vein Diameter (in mm)		Radial artery Diameter (in mm)	
	<2 mm	≥2 mm	<2 mm	≥2 mm
Number of patients	33	63	36	60

**Table 2: Outcome of radiocephalic AV fistula**

Studied Variables	Number (N)	Percentage (%)
Mature	42	77.8
Failure	12	22.2
Total	54	100.0

**Table 3: Relation between preoperative ultrasound parameters and outcome of fistula**

No.	Studied Variables	Outcome of Fistula		Test of sig.	P value
		Successful/mature (N=42) Mean ± SD	Failure (N=12) Mean ± SD		
1.	Cephalic vein diameter (at wrist) (in mm)	2.05 ± 0.58	1 ± 0.001	6.189	<0.0001
2.	Radial artery diameter (in mm)	2.24 ± 0.53	1 ± 0.001	8.002	<0.0001
3.	Radial artery PSV (in cm/sec)	47.57 ± 7.67	26.17 ± 3.46	9.346	<0.0001

**Table 4: Distribution of patients according to postoperative complications seen with radiocephalic fistula**

Complications	Frequency (N)	Percentage (%)
No complications	28	50.9
Diffuse subcutaneous edema	9	16.3

Thrombosis	10	18.5
Stenosis	2	3.6
Pseudoaneurysm formation	1	1.8
Hematoma formation	3	5.4
Infection	2	3.6

#### 4. DISCUSSION

Chronic Kidney Disease (CKD) is a world-wide health problem common in the elderly and presently with the increase in diabetes mellitus, hypertension and cardiovascular diseases, there is a steep rise in younger people. Patients with renal failure require renal replacement therapy (RRT) for survival such as kidney transplantation or dialysis.<sup>(6)</sup> Over 90% of patients requiring RRT in India die because of inability to afford care, and even in those who do start renal replacement therapy, 60% stop for lack of finances. There are over 130,000 patients receiving dialysis and their number is increasing by about 232 per million population.<sup>(7)</sup>

Escalation in the number of ESRD patients requiring expensive kidney transplantation with an impact on medical economics has resulted in growing focus on providing an efficient vascular access for hemodialysis which is an affordable option.

The gold standard procedure till date for the creation of an autologous vascular access is the surgical creation of an AVF between the radial artery and the cephalic vein which is called Cimino-Brescia fistula named after the persons who described it for the first time in 1966. Arteriovenous fistulas are preferred over other hemodialysis access due to lower risk of infection, lower risk of thrombosis, greater longevity and long term accessibility, greater blood flow volume, shorter duration of dialysis, most cost effective.<sup>(8)</sup>

The patency and quality of arteriovenous fistulas made for hemodialysis purpose in ESRD patients is critically important. It should be suitable for repeated puncture and allow a high blood flow rate for high-efficiency dialysis with minimal complications. The creation and maintenance of a patent and well functioning AVF have become a real challenge to nephrologists and vascular surgeons. Thus in most patients, additional studies are required to evaluate the vasculature prior to its fistula creation. Ultrasound doppler has been recommended for all patients being considered for vascular access by European Renal Best Practice Guidelines<sup>(9)</sup> because of its unique ability to assess structural aspect of peripheral vessels along with the dynamic characteristics which will help in identification of durable anatomical site for fistula formation.<sup>(10)</sup>

Preoperative vascular mapping was done to identify its predictive role in fistula failure, in agreement with previous studies, Niyar VD et al.<sup>(11)</sup>, we reported that in addition to the diameters of cephalic vein, and radial artery, the peak systolic velocity of the radial artery was significantly lower in the failure group than in the mature group in our study, which indicated that the PSV and the vascular diameter are associated with the AV fistula failure.

Cephalic vein diameter is a very important factor, mostly single most important predictor



of maturation as fistulae created using small veins are more likely to fail. Similar results were observed in study done by Leigh Anne Dageforde et al. (2015)<sup>(12)</sup> who concluded that patients with larger mean venous diameter on preoperative vein mapping are at lower risk for failure of fistula maturation.

Similarly preoperative radial artery diameter and PSV were also found to significantly affect fistula maturation. This was in agreement with study done by Dasari et al<sup>(13)</sup>.

In the follow-up period, 22.2% of arteriovenous fistulas (12 of 54) developed failure in our study which was less as compared to previous studies done and can be attributed to a routine preoperative scan which was carried out prior to AVF creation.

Our study agrees with that complications were seen in 49.1% cases with thrombosis being most common complication in radiocephalic fistulas (18.5%) This was in concordance with study conducted by Serdar Demiral (2017).<sup>(14)</sup>

#### Limitations

We are aware that our study had limitations. Our study included small number of patients and short period of follow-up. Intraoperative and postoperative CDU assessment of arteriovenous fistula would be more helpful for prediction of maturity, and this was unavailable in our hospital.

### 5. CONCLUSION

In conclusion, our study demonstrates a benefit of routine preoperative ultrasound in AVF outcomes with a small number needed to treat to save one fistula. Although nonmaturation may remain an important problem, preoperative ultrasound combined with appropriate AVF salvage leads to better long-term AVF use in hemodialysis.

#### Abbreviations

AVF: Arteriovenous fistula; CDU: Color Doppler ultrasonography; ESRD: End stage renal disease; US: Ultrasound; PSV: Peak systolic velocity; VF: Volume flow; CRF: Chronic renal failure; RRT: Renal replacement therapy

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