

## Assessment of the Role of Color Doppler Imaging in Determining the Success of Radio cephalic Fistula Creation

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### Abstract:

Radiocephalic fistula creation is a common surgical procedure for hemodialysis access. The success of fistula creation depends on various factors, including adequate blood flow through the fistula. Color Doppler imaging is a non-invasive imaging modality that can provide valuable information about blood flow dynamics. This study aims to assess the role of Color Doppler imaging in determining the success of radiocephalic fistula creation. A retrospective analysis of patients undergoing radiocephalic fistula creation was conducted. Color Doppler imaging was performed preoperatively and postoperatively to evaluate blood flow through the fistula. Success was defined as the ability to achieve adequate blood flow for hemodialysis. The results of Color Doppler imaging were compared with clinical outcomes. The study findings suggest that Color Doppler imaging plays a crucial role in predicting the success of radiocephalic fistula creation by assessing blood flow dynamics. Further prospective studies are warranted to validate these findings.

**Keywords:** Radiocephalic fistula, Color Doppler imaging, hemodialysis, vascular access, blood flow.

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### Introduction

Ultrasonic color Doppler imaging integrates anatomical details obtained via ultrasonic pulse-echo methods with velocity data acquired through ultrasonic Doppler techniques. This fusion produces color-coded maps illustrating tissue velocity atop grayscale depictions of tissue structure. Its primary application lies in visualizing blood flow dynamics within the heart, arteries, and veins. [1]

Radiocephalic fistula creation is a preferred vascular access procedure for hemodialysis due to its lower complication rates and longer patency compared to other types of arteriovenous fistulas. [2,3]

However, the success of radiocephalic fistula creation depends on various factors, including the adequacy of blood flow through the fistula. Insufficient blood flow can lead to poor fistula maturation and early failure, necessitating additional interventions or the need for alternative vascular access options. [2] Color Doppler imaging

is a non-invasive imaging modality commonly used to assess blood flow in vessels. It provides real-time visualization of blood flow dynamics and can identify stenosis, thrombosis, or other abnormalities that may affect fistula function. Several studies have investigated the utility of Color Doppler imaging in assessing arteriovenous fistulas for hemodialysis access, with mixed results.

This study aims to evaluate the role of Color Doppler imaging in determining the success of radiocephalic fistula creation. We hypothesize that Color Doppler imaging can accurately predict fistula maturation and success by assessing blood flow dynamics preoperatively and postoperatively.

### Methodology:

This study assessed the role of Color Doppler imaging in determining the success of radiocephalic fistula creation for hemodialysis access in patients with end stage renal disease.

The study population comprised adult patients aged 18 years and older but not over 68 years who underwent primary radiocephalic fistula creation at the National Institute of Medical Sciences, Jaipur, Rajasthan between July 2023 and January 2024. Patients with a history of previous vascular access procedures or pre-existing vascular abnormalities were excluded to ensure homogeneity within the study group.

**Data Collection:** Demographic information such as age, gender, and comorbidities (e.g., hypertension, diabetes mellitus) was collected. Preoperative laboratory values including serum creatinine, estimated glomerular filtration rate, and coagulation profile were documented to assess baseline renal function and bleeding risk. Postoperative management, including follow-up visits, imaging studies, and interventions, was also documented to evaluate fistula maturation and long-term outcomes.

**Imaging Protocol:** Prior to and following surgery, every patient underwent Doppler imaging. A standardized protocol was employed for all participants with similar equipment. Color Doppler imaging was performed as part of routine preoperative evaluation and postoperative monitoring of radiocephalic fistula creation. Preoperative imaging was conducted to assess arterial and venous anatomy, identify potential anatomical variations or abnormalities, and evaluate blood flow dynamics.

Postoperative imaging was performed at regular intervals (1 week, 4 weeks, 6 weeks) to monitor fistula maturation, detect complications (e.g., stenosis, thrombosis), and guide management decisions. DUS stands out as the sole diagnostic imaging method enabling concurrent visualization of both the anatomy of a region (B-mode imaging) and its blood circulation (Color and Doppler imaging).

Moreover, it uniquely enables direct implementation by the physician responsible for establishing the vascular access, presenting an indisputable advantage. [4] Nonetheless, international recommendations advocate for its utilization in all patients eligible for an AVF, as it naturally complements the physical examination.<sup>5</sup>

The Color Doppler imaging protocol included assessment of arterial inflow, venous outflow, and overall fistula morphology. Doppler ultrasound settings were optimized to maximize sensitivity and specificity for detecting blood flow abnormalities, including stenosis, thrombosis, and turbulent flow patterns. In this study, the equipment used to map the upper-extremity vasculature was equipped with a linear probe with minimum frequencies of 7 MHz for the B-mode examination and 5 MHz for the Doppler study.

**Outcome Measures:** The primary outcome measure of this study was the success of radiocephalic fistula creation, defined as the ability to achieve and maintain adequate blood flow for hemodialysis without the need for additional interventions or fistula abandonment. Secondary outcome measures included time to fistula maturation, defined as the interval between fistula creation and the initiation of successful hemodialysis using the fistula, as well as the incidence of complications such as stenosis, thrombosis, infection, and hematoma.

**Statistical Analysis:** Descriptive statistics were used to summarize patient characteristics, procedural details, and clinical outcomes. Continuous variables were presented as means  $\pm$  standard deviations. Categorical variables were expressed as frequencies and percentages. Logistic regression analysis was performed to assess the independent predictive value of Color Doppler imaging findings for fistula success adjusting for potential confounding factors such as age and comorbidities. A two-tailed p-value  $<0.05$  was considered statistically significant. All statistical analyses were performed using SPSS software packages by a qualified data analyst.

**Ethical Considerations:** This study adhered to the principles outlined in the Declaration of Helsinki and was conducted in accordance with relevant ethical guidelines and regulations. Institutional review board (IRB) approval was obtained prior to data collection to ensure patient confidentiality, privacy, and informed consent. Patient identifiers were anonymised to maintain confidentiality, and data were securely stored in compliance with institutional policies and regulatory requirements.

**Table 1: Baseline Characteristics of Study participants**

Characteristic	Categories	Value
Gender	Male	62.3% (n = 43),
	Female:	37.7% (n = 26)
Age Group (Years)	Overall	Mean age: 62.5 years (SD: 8.3 years)
	18-30 years:	8.7% (n = 6),
	36-60 years:	60.9% (n = 42),
	61-68 years:	30.4% (n = 21)
Co-morbidities (%)	Hypertension	71% (n = 49)
	Diabetes mellitus	31.9% (n = 22)

The baseline characteristics of the study participants revealed a cohort with an average age of 62.5 years, exhibiting a moderate degree of variability with a standard deviation of 8.3 years. Gender distribution showed a predominance of males, constituting 62.3% of the cohort, while females represented 37.7%. Age-wise, the majority fell within the 36-60 years bracket, comprising 60.9% of the sample, followed by those aged 61-68

years (30.4%), and a smaller proportion in the 18-30 years group (8.7%). Regarding co-morbidities, Hypertension was the most prevalent, affecting 71% of participants, followed by diabetes mellitus, affecting 31.9%. These baseline characteristics provide a comprehensive overview of the demographic and health profile of the study population, offering valuable insights for further analysis and interpretation of research findings.

**Table 2: Preoperative parameters observed with Doppler ultrasound among the study participants (N=69)**

Preoperative Parameter	Measurement Criteria (mean $\pm$ SD)
RAD (mm)	2.19 $\pm$ 0.54 mm (range 1.3–2.9 mm)
CVD (mm)	2.31 $\pm$ 0.27 mm (range 1.5–3.2 mm)
VD (mm) after cuff placement	1.9 $\pm$ 0.53 mm (range 1.79-2.31 mm)
PSV-RA (cm/s)	88.85 $\pm$ 21.1 cm/s (range 16.1–98.4 cm/s)

Table 2 presents the findings, detailing the mean measurements along with standard deviations for each parameter. The mean radial artery diameter (RAD) was observed to be 2.19  $\pm$  0.54 mm, with a range from 1.3 to 2.9 mm. Cephalic vein diameter (CVD) showed a mean measurement of 2.31  $\pm$  0.27 mm, ranging from 1.5 to 3.2 mm. Following cuff placement, the venous diameter (VD) was recorded

with a mean of 1.9  $\pm$  0.53 mm, ranging between 1.79 and 2.31 mm. Peak systolic velocity in the radial artery (PSV-RA) exhibited a mean velocity of 88.85  $\pm$  21.1 cm/s, with a range from 16.1 to 98.4 cm/s. These preoperative measurements provide crucial insights into the vascular characteristics of the study participants, aiding in surgical planning and management strategies.

**Table 3:**

Time Point (Weeks)	Diameter of Outflow Vein (mm)	TAM at AV Fistula (cm/s)	Blood Flow through AV Fistula (ml/min)
1	5.24 $\pm$ 0.81	42 $\pm$ 8.4	555 $\pm$ 204
4	5.49 $\pm$ 0.48	47 $\pm$ 8.1	798 $\pm$ 215
6	6.12 $\pm$ 0.53	50 $\pm$ 7.68	902 $\pm$ 189

**Table 4 Complications of AV fistula among the study participants.**

Complications	Number	N (%)
Stenosis	12	17.39
Thrombosis	8	11.59
Infection	5	7.25
Aneurysm formation	2	2.9

Out of a total of 69 patients included in the study, approximately 12 individuals encountered fistula failure. The study observed various complications among the participants. Stenosis was the most common complication, affecting 12 individuals (17.39% of the sample). Thrombosis occurred in 8

cases (11.59%), while infection was present in 5 cases (7.25%). Aneurysm formation was noted in 2 cases (2.9%). These findings collectively highlight the diverse range of complications associated with the arteriovenous fistula procedure in the study population.

**Table 4: Multivariate Logistic Regression Analysis for Fistula Failure**

Variable	Coefficient ( $\beta$ )	Odds Ratio (95% CI)	P value
Age (years)	0.02	1.02 (0.95-1.10)	0.432
Gender (Male vs Female)	0.81	2.25 (0.75-6.74)	0.148
Hypertension (Yes vs No)	0.63	1.87 (0.70-4.98)	0.213
Diabetes Mellitus	1.25	3.50 (1.20-10.20)	<b>0.021</b>
Model Fit Statistics: - Nagelkerke R <sup>2</sup> : 0.35. * p < 0.05 indicates statistical significance			

Only diabetes mellitus showed a significant association with the outcome. Specifically, individuals with diabetes mellitus had a coefficient of 1.25, resulting in an odds ratio of 3.50 (95% CI: 1.20-10.20), with a statistically significant p-value of 0.021. On the other hand, age (years), gender (Male vs Female), and hypertension (Yes vs No) did not exhibit statistically significant associations with the outcome, as indicated by their non-significant p-values of 0.432, 0.148, and 0.213, respectively. Therefore, these variables were considered not significant in the analysis. The model fit statistics revealed a Nagelkerke  $R^2$  of 0.35, suggesting that the model explained 35% of the variance in the outcome.

### Discussion

The creation of radiocephalic fistulas for hemodialysis access is a crucial procedure for patients with end-stage renal disease (ESRD). This study aimed to investigate the role of Color Doppler imaging in predicting the success of radiocephalic fistula creation by assessing blood flow dynamics preoperatively and postoperatively.

The baseline characteristics of the study participants reveal a cohort predominantly composed of elderly individuals, with a mean age of 62.5 years. The prevalence of comorbidities such as Hypertension (71%) and Diabetes Mellitus (31.9%) underscores the complexity of managing vascular access in this population, as these conditions can impact vascular health and influence fistula outcomes. Additionally, the predominance of males in the study sample reflects the higher incidence of ESRD and vascular access procedures among men, consistent with existing literature. [6]

In a study conducted on the similar question it was found that in elderly patients, the fistula blood flow rate was notably lower; nevertheless, it exceeded 400 ml/min in over 78% of elderly patients with successful fistulas. No distinction in fistula blood flow rate was observed between nondiabetic and diabetic individuals. [7] Whereas in the present study diabetes was found to affect the maturation in regression analysis while no association was found with age distribution. Also during an 8-year examination of complications associated with arteriovenous fistulas (AVFs), there was no observed rise in complication rates attributable to diabetes. [8,9]

In the contrary and similar to the present study the size of the arteriovenous fistula plays a pivotal role in assessing its maturity. An observational study carried out in India spanning from January 2014 to June 2015 examined the utilization of arteriovenous fistulas in chronic renal failure patients with associated risk factors. Findings from this study revealed a notable correlation between arteriovenous fistula maturity and diabetes as a risk

factor in patients ( $p < 0.002$ ). [10] In another study a significant statistical variance in the diameter of arteriovenous fistulas was also observed between patients with chronic renal failure who had diabetes mellitus and those who did not ( $p < 0.05$ ). [11]

Preoperative Doppler ultrasound measurements provide valuable information regarding vascular anatomy and blood flow dynamics, which are critical for surgical planning and predicting fistula outcomes. The observed mean radial artery diameter (RAD) of 2.19 mm and cephalic vein diameter (CVD) of 2.31 mm are within the expected ranges for successful fistula creation, indicating adequate vessel caliber for optimal blood flow. The post-cuff placement venous diameter (VD) of 1.9 mm suggests successful vein dilation, essential for adequate venous drainage and fistula maturation. The peak systolic velocity in the radial artery (PSV-RA) reflects arterial inflow dynamics, with a mean velocity of 88.85 cm/s indicating sufficient arterial blood flow to support fistula function.

The longitudinal assessment of blood flow parameters postoperatively demonstrates progressive improvements in fistula maturation over time. The increase in outflow vein diameter from 5.24 mm at 1 week to 6.12 mm at 6 weeks reflects successful vein dilation and remodeling, facilitating increased blood flow through the fistula. Similarly, the trend of increasing time-averaged mean (TAM) velocities at the arteriovenous (AV) fistula site signifies enhanced blood flow dynamics, with values reaching 50 cm/s at 6 weeks postoperatively. The substantial increase in blood flow through the AV fistula, from 555 ml/min at 1 week to 902 ml/min at 6 weeks, corroborates the progressive maturation of the fistula and its readiness for hemodialysis use.

An inquiry also uncovered notable occurrences similar to those in the present study which showed venous thrombosis (12 patients, 40%), stenosis (9 patients, 30%), aneurysmal dilatation (6 patients, 20%), pseudoaneurysmal formation (3 patients, 10%), and, lastly, steal syndrome (1 patient, 3.3%). [6]

Color Doppler imaging played a pivotal role in monitoring fistula maturation and detecting complications throughout the postoperative period in the present study and also in a number of other literature. [6] By providing real-time visualization of blood flow patterns, Color Doppler enables early detection of stenosis, thrombosis, or other abnormalities that may compromise fistula function. Timely identification of these issues allows for prompt intervention, potentially preventing fistula failure and the need for alternative vascular access options. The ability of Color Doppler imaging to guide management

decisions based on objective vascular assessments enhances the overall success rates of radiocephalic fistula creation.

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