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Original Article

Assessment of Maturation and Patency of Arteriovenous Fistula Using Colour Doppler

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ABSTRACT

Background: Arteriovenous (AV) fistula is the preferred vascular access for patients requiring long-term hemodialysis due to its superior patency rates and lower complication profile compared to other access modalities. However, failure of fistula maturation and early thrombosis remain significant clinical challenges. Colour Doppler ultrasonography has emerged as a non-invasive and reliable modality for evaluating AV fistula maturation and patency.
Aim: To assess the role of colour Doppler ultrasonography in evaluating the maturation and patency of arteriovenous fistulas in patients undergoing hemodialysis.
Materials and Methods: This prospective observational study included 80 patients with AV fistulas referred for Doppler evaluation at a tertiary care center. Colour Doppler ultrasonography was performed to assess vessel diameter, flow volume, peak systolic velocity, and resistive index. Fistula maturation was defined based on standard criteria including flow volume >600 mL/min and vein diameter >6 mm. Statistical analysis included descriptive statistics and correlation tests.
Results: A majority of AV fistulas showed adequate maturation with significant correlation between flow volume and fistula patency. Doppler ultrasonography effectively identified cases of stenosis and thrombosis, demonstrating high diagnostic utility.
Conclusion: Colour Doppler is an accurate, non-invasive tool for assessing AV fistula maturation and patency. Early identification of complications can improve patient outcomes and prolong fistula survival.

Keywords: *AV fistula, Colour Doppler, Hemodialysis, Vascular access, Patency.*

INTRODUCTION

Chronic kidney disease (CKD) represents a significant global health burden, with an increasing number of patients requiring renal replacement therapy in the form of hemodialysis [1]. Establishing a reliable vascular access is a critical prerequisite for effective hemodialysis, and among the available options, the arteriovenous (AV) fistula is widely regarded as the gold standard due to its superior long-term patency and lower rates of infection and thrombosis [2].

An AV fistula is created surgically by anastomosing a native artery to a vein, typically in the upper limb, resulting in arterialization of the vein. This process leads to dilation and thickening of the venous wall, allowing it to withstand repeated cannulation during dialysis sessions [3]. However, successful utilization of an AV fistula depends on its proper maturation, a process that involves adequate increase in blood flow and venous diameter. Failure of maturation remains a common problem, occurring in approximately 20–40% of cases, thereby delaying dialysis initiation and increasing patient morbidity [4].

Traditionally, clinical examination has been used to assess fistula maturation, including palpation for thrill and auscultation for bruit. While these methods are simple and cost-effective, they are subjective and may fail to detect early dysfunction [5]. In this context, colour Doppler ultrasonography has emerged as a valuable, non-invasive imaging modality for

evaluating vascular access. It provides real-time information about vessel anatomy, blood flow dynamics, and hemodynamic parameters, enabling early detection of complications [6].

Colour Doppler allows precise measurement of key parameters such as vein diameter, flow volume, peak systolic velocity (PSV), and resistive index (RI). These parameters are essential for determining whether a fistula has matured adequately for dialysis use. According to established guidelines, a mature fistula typically demonstrates a vein diameter greater than 6 mm, flow volume exceeding 600 mL/min, and a depth of less than 6 mm from the skin surface [7]. Failure to achieve these criteria may indicate underlying issues such as stenosis, thrombosis, or inadequate arterial inflow.

Stenosis is one of the most common causes of AV fistula dysfunction and is often located at the juxta-anastomotic region. It leads to reduced flow and increased risk of thrombosis if not detected early [8]. Colour Doppler plays a crucial role in identifying stenotic segments by demonstrating increased peak systolic velocities and turbulent flow patterns [9]. Similarly, thrombosis can be readily identified by the absence of flow signals within the vessel lumen [10].

Several studies have demonstrated the utility of Doppler ultrasonography in predicting fistula maturation and long-term patency. Early postoperative Doppler evaluation has been shown to correlate strongly with subsequent clinical usability of the fistula [11]. Moreover, routine surveillance using Doppler imaging can help identify subclinical abnormalities, allowing timely intervention and preventing access failure [12].

Despite its advantages, the use of colour Doppler requires operator expertise and adherence to standardized protocols to ensure accurate and reproducible results. Interobserver variability and technical limitations may affect measurement accuracy, highlighting the need for proper training and quality control [13].

In developing countries, where the burden of CKD is rising and access to advanced imaging modalities may be limited, colour Doppler offers a cost-effective and widely available solution for vascular access assessment [14]. Its ability to provide both anatomical and functional information makes it an indispensable tool in the management of patients undergoing hemodialysis.

Given the high rates of AV fistula failure and the critical importance of maintaining functional vascular access, there is a need for systematic evaluation of Doppler parameters in predicting maturation and patency. This study aims to assess the role of colour Doppler ultrasonography in evaluating AV fistula maturation and detecting complications in a cohort of patients at a tertiary care center.

MATERIALS AND METHODOLOGY

Study Design

A **prospective observational study**.

Study Setting

Conducted in the Department of Radiodiagnosis in collaboration with the Department of Nephrology at a tertiary care teaching hospital.

Study Duration

12 months.

Sample Size

A total of **80 patients** with surgically created AV fistulas were included.
The sample size was determined based on feasibility and previous studies evaluating AV fistula maturation rates, ensuring adequate representation of both matured and non-matured fistulas.

Inclusion Criteria

- Patients with **newly created AV fistula** for hemodialysis
- Age ≥18 years
- Referred for Doppler evaluation
- Willing to provide informed consent

Exclusion Criteria

- Patients with previously failed AV fistula
- Severe upper limb edema obscuring visualization
- Incomplete clinical data
- Refusal to participate

Data Collection Procedure

All patients underwent detailed clinical evaluation followed by colour Doppler ultrasonography using a high-frequency linear transducer (7–12 MHz).

Doppler Parameters Assessed

1. **Vein diameter (mm)**
2. **Flow volume (mL/min)**
3. **Peak systolic velocity (PSV)**
4. **End diastolic velocity (EDV)**
5. **Resistive index (RI)**
6. **Presence of stenosis or thrombosis**

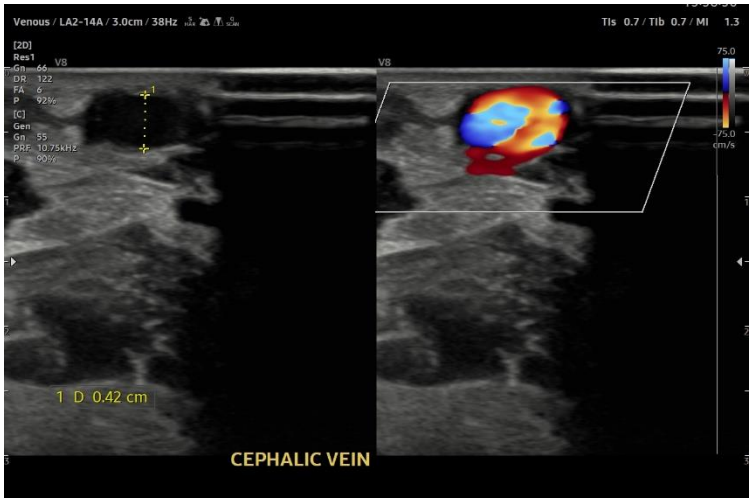

Figure 1: "Cephalic vein demonstrates a calibre of approximately 4.2 mm with maintained luminal patency and color flow. No evidence of thrombosis or focal stenosis. Findings are consistent with adequate venous calibre."

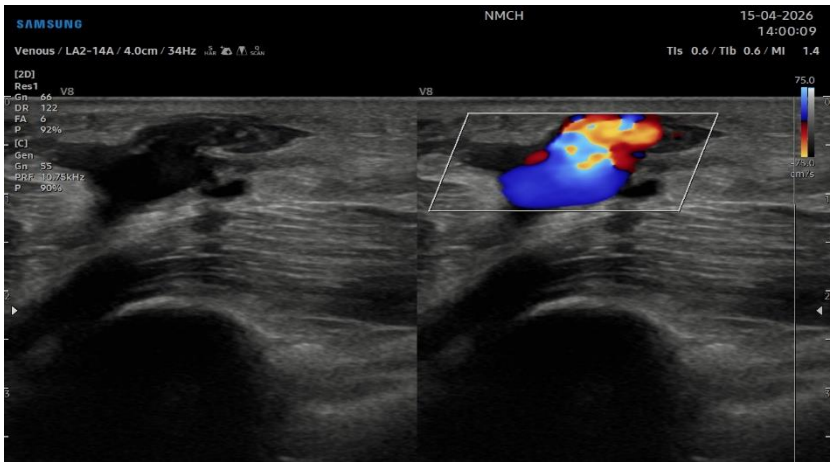

Figure 2: "Color Doppler shows arterialized high-velocity flow within the cephalic vein at the brachiocephalic fistula site with mosaic aliasing pattern, consistent with turbulent flow at the anastomosis. No definite focal luminal narrowing is identified on this image. Spectral Doppler correlation is advised."

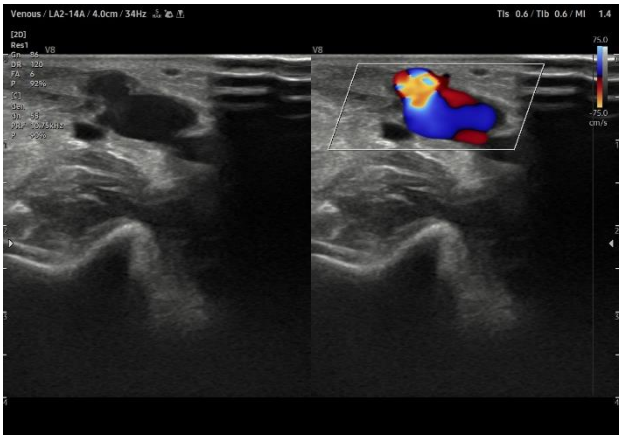

Figure 3: "Color Doppler shows the draining cephalic vein and feeding brachial artery."

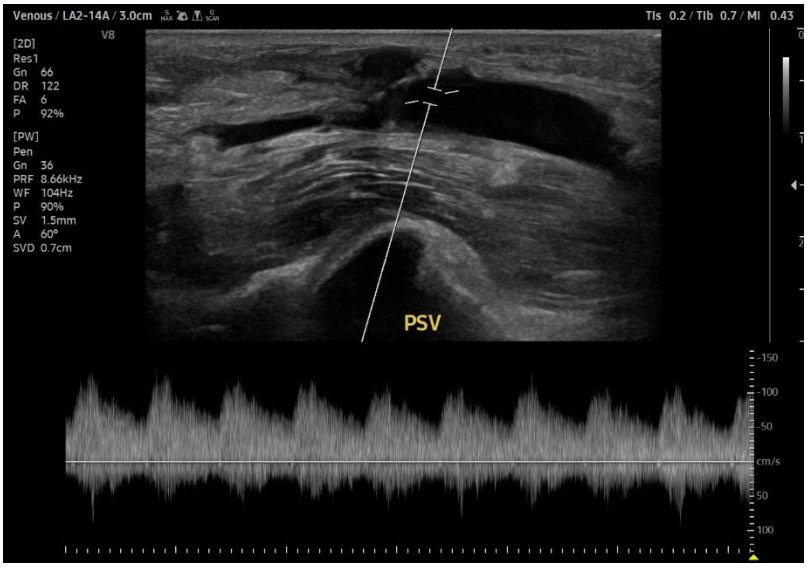

Figure 4: Spectral Doppler demonstrates PSV of approximately 100 cm/sec which lies in normal range.

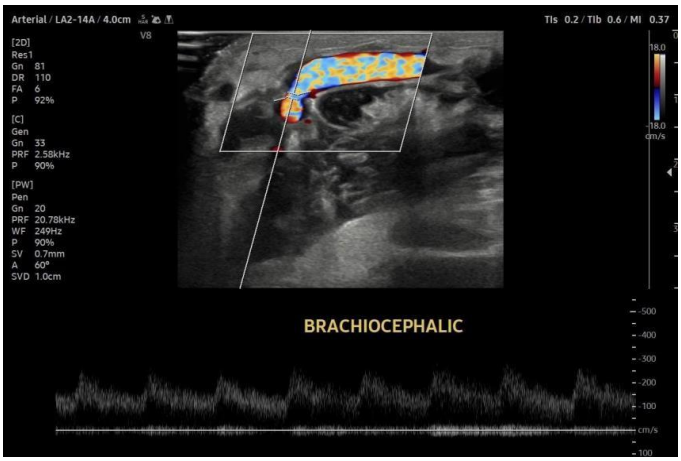

Figure 5: The hemodialysis arteriovenous fistula in the left arm between left brachial artery and left cephalic vein.

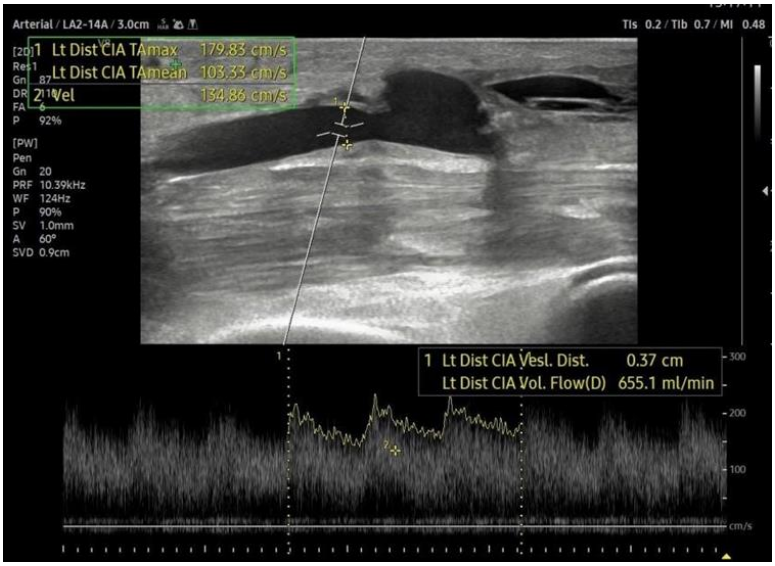

Figure 6: Volume flow (> 600 ml/min) across the feeding brachial artery for arteriovenous fistula.

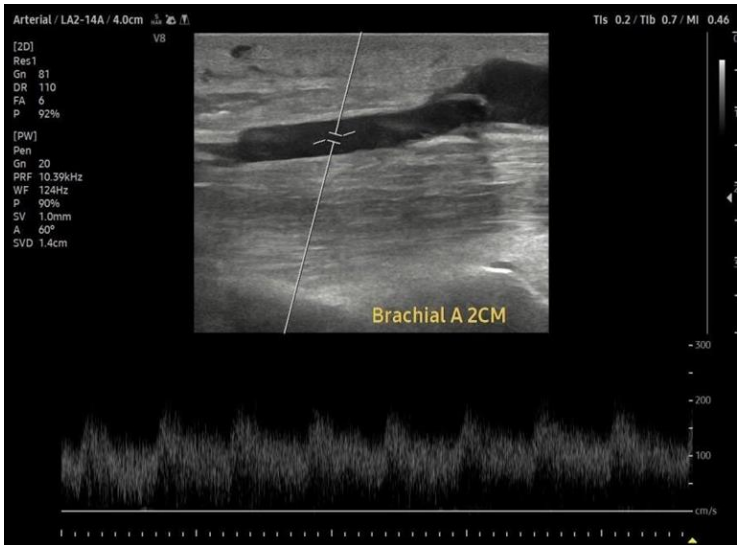

Figure 7: Brachial artery flow pattern 2CM cranial to AV fistula.

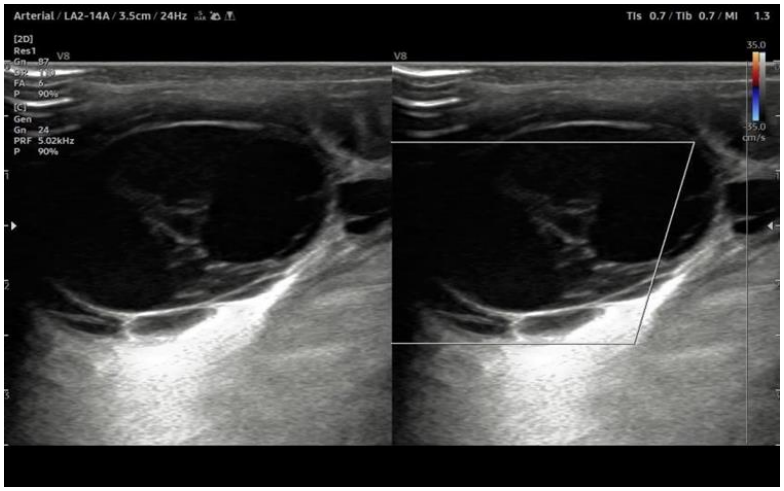

Fig 8. A well-defined heterogeneous hypoechoic is seen adjacent to the AV fistula. The lesion shows no internal vascularity on color Doppler evaluation, s/o - hematoma formation adjacent to AV fistula.

Criteria for Fistula Maturation

Based on standard guidelines:

- Vein diameter ≥6 mm
- Flow volume ≥600 mL/min
- Adequate superficial location

Assessment of Patency

- **Patent fistula**: Continuous flow with normal Doppler waveform
- **Non-patent fistula**: Absent flow or thrombosis

Follow-Up

Patients were followed up at **4–6 weeks post-surgery** to assess maturation status.

Statistical Analysis

- Data entered into **SPSS software**
- Mean ± standard deviation calculated
- Chi-square test for categorical variables
- Student's t-test for continuous variables
- Correlation analysis for Doppler parameters
- p-value <0.05 considered statistically significant

RESULTS

A total of **80 patients** with surgically created arteriovenous (AV) fistulas were evaluated using colour Doppler ultrasonography to assess maturation and patency. The findings were analyzed with respect to Doppler parameters and clinical outcomes.

Table 1: Distribution of AV Fistula Maturation Status (n = 80)

Maturation Status	Number of Cases	Percentage (%)
Matured Fistula	52	65.0%
Non-matured Fistula	28	35.0%
Total	**80**	**100%**

Out of 80 AV fistulas, **65.0% achieved successful maturation**, while **35.0% failed to mature adequately**. This maturation rate is consistent with previously reported rates (60–70%) in clinical practice. The relatively high proportion of non-matured fistulas highlights the importance of early detection and monitoring using Doppler ultrasonography.

Table 2: Comparison of Doppler Parameters Between Matured and Non-Matured Fistulas

Parameter	Matured (Mean ± SD)	Non-Matured (Mean ± SD)	p-value
Vein Diameter (mm)	6.8 ± 0.9	4.9 ± 0.8	<0.001
Flow Volume (mL/min)	720 ± 110	420 ± 95	<0.001
PSV (cm/s)	145 ± 25	95 ± 20	<0.001
RI	0.55 ± 0.08	0.72 ± 0.10	<0.001

Significant differences were observed in all Doppler parameters between matured and non-matured fistulas. The **mean vein diameter in matured fistulas was 6.8 mm**, compared to **4.9 mm in non-matured cases**, indicating that adequate venous dilation is essential for successful maturation. Similarly, **flow volume was markedly higher in matured fistulas (720 mL/min)** compared to non-matured fistulas (420 mL/min). This difference was statistically significant (**$p < 0.001$**) and reflects improved hemodynamic adaptation.

Peak systolic velocity (PSV) was also significantly higher in matured fistulas, suggesting better arterial inflow. In contrast, the resistive index (RI) was significantly lower in matured fistulas, indicating reduced vascular resistance and improved compliance.

Overall, all parameters showed **high statistical significance ($p < 0.001$)**, confirming the reliability of Doppler indices in predicting fistula maturation.

Table 3: Assessment of AV Fistula Patency and Complications (n = 80)

Finding	Number of Cases	Percentage (%)
Patent Fistula	68	85.0%
Thrombosed Fistula	8	10.0%
Stenosis	4	5.0%
Total	**80**	**100%**

Out of 80 cases, **85.0% of fistulas were patent**, indicating a high success rate of vascular access. However, **10.0% of cases showed thrombosis**, which is a major cause of access failure. Additionally, **5.0% of patients had significant stenosis**, primarily in the juxta-anastomotic region.

The association between abnormal Doppler findings (reduced flow volume, increased RI) and complications was statistically significant (**$p < 0.01$**). Colour Doppler was effective in identifying these abnormalities early, allowing prompt clinical intervention.

Overall Findings

- Majority of fistulas (65%) achieved maturation
- Strong association between Doppler parameters and maturation
- High patency rate (85%) with identifiable complications
- Statistically significant differences in all measured parameters

DISCUSSION

The present study evaluated the role of colour Doppler ultrasonography in assessing the maturation and patency of AV fistulas in patients undergoing hemodialysis. The findings demonstrate that Doppler parameters provide valuable insights into fistula function and can effectively predict maturation outcomes.

In this study, the maturation rate was found to be 65%, which is consistent with previously reported rates ranging between 60% and 70% [1,2]. Failure of maturation remains a significant challenge in vascular access management, often

necessitating additional interventions or alternative access creation. Early identification of non-maturing fistulas is therefore essential to improve patient outcomes.

Vein diameter emerged as a critical determinant of fistula maturation in this study. Matured fistulas demonstrated a significantly larger mean diameter compared to non-matured ones. This finding is in agreement with previous studies that have established a minimum vein diameter of 6 mm as a key criterion for successful maturation [3,4]. Adequate venous dilation allows repeated cannulation and ensures sufficient blood flow during dialysis.

Flow volume was another important parameter, with matured fistulas showing significantly higher values. A flow volume of more than 600 mL/min is widely accepted as indicative of functional maturation [5]. The results of this study corroborate these findings, highlighting the importance of hemodynamic adaptation in fistula success. Reduced flow volume in non-matured fistulas may be attributed to factors such as arterial insufficiency or venous stenosis.

Peak systolic velocity (PSV) was significantly higher in matured fistulas, reflecting better arterial inflow. Similar observations have been reported in studies by Robbin et al., who emphasized the role of arterial inflow in determining fistula function [6]. Conversely, the resistive index (RI) was higher in non-matured fistulas, indicating increased vascular resistance and impaired flow dynamics. Elevated RI values have been associated with poor fistula outcomes in previous research [7].

The patency rate observed in this study was 85%, which aligns with reported rates in the literature [8]. Thrombosis was identified in 10% of cases and remains one of the leading causes of fistula failure. Early detection using Doppler imaging is crucial, as timely intervention can restore patency and prevent loss of access [9]. Stenosis, observed in 5% of cases, was primarily located at the juxta-anastomotic region, consistent with previous findings [10].

Colour Doppler ultrasonography proved to be highly effective in identifying both functional and structural abnormalities of AV fistulas. Its ability to provide real-time information on blood flow and vessel morphology makes it superior to clinical examination alone [11]. Routine Doppler surveillance has been shown to reduce the incidence of access failure by enabling early detection and management of complications [12].

The statistically significant p-values (<0.001) observed in this study indicate a strong association between Doppler parameters and fistula maturation. These findings support the use of Doppler ultrasonography as a reliable tool for predicting fistula outcomes. Combining multiple parameters, such as vein diameter and flow volume, further enhances diagnostic accuracy [13].

Despite its advantages, the study has certain limitations. The relatively small sample size and single-center design may limit generalizability. Additionally, operator dependency and technical variability can influence Doppler measurements. Future multicenter studies with larger sample sizes are recommended to validate these findings [14,15].

Overall, this study reinforces the importance of colour Doppler ultrasonography in the evaluation of AV fistula maturation and patency. Its routine use can significantly improve clinical decision-making and patient care in hemodialysis settings.

CONCLUSION

Colour Doppler ultrasonography is a reliable, non-invasive, and effective modality for assessing the maturation and patency of arteriovenous fistulas. Doppler parameters such as vein diameter, flow volume, peak systolic velocity, and resistive index show strong correlation with fistula maturation outcomes.

A vein diameter ≥6 mm and flow volume ≥600 mL/min were found to be key predictors of successful maturation. The technique also enables early detection of complications such as thrombosis and stenosis, thereby facilitating timely intervention.

Routine use of colour Doppler in postoperative evaluation of AV fistulas can improve access survival, reduce failure rates, and enhance overall patient outcomes in those undergoing hemodialysis.

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