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Role Of Doppler Ultrasound In Assessing The Arterio-Venous Fistula In Hemodialysis

Author

Abstract
Autogenous arteriovenous fistulas (AVFs) are considered the gold standard for vascular access in hemodialysis because they last longer and have fewer complications compared to synthetic grafts or central venous catheters. The introduction of Doppler ultrasound (DUS) has greatly enhanced the evaluation process for AVF creation by enabling detailed vascular mapping. This non-invasive imaging modality also supports ongoing care post-surgery, helping detect issues like stenosis or thrombosis early, which in turn aids in maintaining access patency. Offering both anatomical and functional data in real time, DUS serves as an invaluable tool for both surgical planning and follow-up. This review explores the broad clinical applications of Doppler ultrasound in managing AVFs, from preoperative evaluation and maturation assessment to routine surveillance.

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I. Introduction

Hemodialysis is the primary therapy for patients with end-stage renal disease (ESRD), where reliable vascular access is critical. Autogenous AVFs are preferred due to their higher durability and fewer complications than central lines or synthetic grafts. However, maintaining AVF functionality is often challenged by issues like stenosis or thrombosis, which may compromise treatment effectiveness. Early identification and monitoring of AVF function are essential to minimizing complications.

Doppler ultrasound (DUS) has become a trusted, non-invasive, and economical tool for evaluating AVF integrity. It utilizes both color and spectral Doppler modalities to measure blood flow characteristics and vessel dimensions, enabling early diagnosis of abnormalities. Several key Doppler indicators—such as flow volume, peak systolic velocity (PSV), and resistive index (RI)—have been shown to correlate with AVF performance and complications. Despite medical advancements, stenosis remains the predominant reason for AVF failure. DUS exhibits high diagnostic accuracy for detecting these issues, and Doppler-derived flow metrics closely relate to dialysis adequacy, as reflected in parameters like Kt/V and URR.

Study Objectives

This research investigates how Doppler ultrasound contributes to evaluating AVF performance in patients undergoing hemodialysis. The main goals are:

1. To evaluate AVF patency and function using Doppler parameters.
2. To determine the diagnostic precision of DUS in identifying complications such as stenosis, thrombosis, or venous hypertension.
3. To relate Doppler findings with clinical indicators like dialysis adequacy and access-related complications.

II. Materials And Methods

Study Design & Setting

This was a cross-sectional, observational study conducted at GCS Medical College, Ahmedabad, focusing on how Doppler ultrasound assists in monitoring AVFs in hemodialysis patients.

Participants

A total of 120 patients undergoing hemodialysis were included, based on predefined eligibility criteria.

Inclusion Criteria

- Patients of all ages and genders currently receiving hemodialysis.
- Stable clinical condition for ultrasound evaluation.
- Voluntary consent for participation.

Exclusion Criteria
- Presence of skin lesions at the scan site.
- Known allergic reaction to ultrasound gel.

Clinical Assessment and Data Collection
- A detailed clinical history was obtained from each participant, including:
  - Duration of hemodialysis.
  - Number of previous AVFs.
  - Presence of symptoms suggestive of AVF dysfunction (e.g., prolonged bleeding post-dialysis, arm swelling, or reduced dialysis efficiency).
  - Any prior interventions for AVF complications.
- A physical examination was conducted to evaluate:
  - Presence of thrill or bruit over the AVF site.
  - Signs of stenosis (e.g., diminished pulse).
  - Any evidence of thrombosis or infection.

Doppler Ultrasound Examination

All patients underwent Doppler ultrasound evaluation of their AVF using a high-frequency linear transducer (7-12 MHz) with color Doppler and spectral Doppler imaging. The ultrasound was performed by a trained radiologist under standardized conditions.

Doppler Ultrasound Parameters Measured
1. Peak Systolic Velocity (PSV): Used to assess flow dynamics and detect stenosis.
2. End Diastolic Velocity (EDV): Helps in determining resistance to flow.
3. Resistive Index (RI): Calculated to assess vascular resistance.
4. Flow Volume (FV): Used to assess AVF functionality and dialysis adequacy.
5. Diameter of the AVF vessel: To evaluate any structural narrowing.
6. Turbulence or flow abnormalities: Suggestive of underlying stenosis or thrombotic complications.

Doppler Criteria for Stenosis and Thrombosis
- Stenosis was defined as a PSV > 400 cm/s or a PSV ratio > 2.5 at the narrowed segment compared to an adjacent normal segment. [3]
- Thrombosis was identified based on absence of Doppler flow signal and echogenic material within the vessel lumen. [5]

Clinical Correlation

The Doppler findings were correlated with dialysis adequacy parameters, including:
- Kt/V (urea clearance index)
- Urea Reduction Ratio (URR)
- Presence of AVF-related complications (stenosis, thrombosis, venous hypertension).

Statistical Analysis

Demographic and clinical data were summarized using descriptive statistical methods. Relationships between Doppler ultrasound variables and clinical outcomes were assessed through either Pearson's or Spearman's correlation tests, depending on data distribution. A significance level of $p < 0.05$ was used to determine statistical relevance.

Ethical Considerations

This study received approval from the Institutional Ethics Committee at GCS Medical College, Ahmedabad. All participants provided written informed consent before enrollment. Participant confidentiality was upheld throughout the research process.

III. Results

Table 1: Baseline characteristics

Baseline characteristics	n (%)
Gender	
Male	98 (81.7)
Female	22 (18.3)
Age group	

20-35	18 (15.0)
36-60	65 (54.2)
61-70	37 (30.8)
History of hypertension	100 (83.3)
History of diabetes	32 (26.7)
Nondominant limb	
Left	112 (93.3)
Right	8 (6.7)

The study population comprised 120 hemodialysis patients, with a notable male predominance (81.7%) compared to females (18.3%). The majority of participants (54.2%) were in the 36–60 age group, while 30.8% were between 61–70 years, and 15.0% fell into the 20–35 age category. A significant proportion (83.3%) of patients had a history of hypertension, whereas 26.7% had diabetes. Regarding limb preference for AVF creation, the nondominant limb was favored in most cases, with the left limb used in 93.3% of patients and the right limb in only 6.7%. These baseline demographic and clinical characteristics highlight the common risk factors and patient profiles associated with AVF creation in hemodialysis settings.

Table 2: Preoperative color Doppler scan measurements of study participants (n=120)

Preoperative color Doppler scan	Mean (±SD)	Minimum	Maximum
Radial artery diameter (mm)	2.12 (±0.38)	1.40	3.20
Peak systolic velocity at radial artery (cm/s)	34.5 (±9.2)	14	57
Cephalic vein diameter (mm)	2.02 (±0.48)	1.3	4.20
Cephalic vein diameter after applying BP cuff (mm)	2.89 (±0.60)	1.6	4.90
Vein distensibility (mm)	0.86 (±0.50)	0.10	2.10

Preoperative color Doppler ultrasound findings revealed a mean radial artery diameter of 2.12 mm (±0.38), ranging from 1.40 mm to 3.20 mm. The mean peak systolic velocity at the radial artery was 34.5 cm/s (±9.2), with a minimum of 14 cm/s and a maximum of 57 cm/s. The cephalic vein diameter had a mean value of 2.02 mm (±0.48), ranging from 1.3 mm to 4.20 mm. After applying a blood pressure cuff, the cephalic vein diameter increased to a mean of 2.89 mm (±0.60), indicating an enhanced venous distensibility of 0.86 mm (±0.50). These findings highlight the importance of vascular characteristics in predicting AVF success and potential complications.

Table 3: Association between preoperative parameters and arteriovenous fistula maturation (n=120)

Preoperative parameters	**AVF maturation**		**OR (95% CI)**	**P**
	Successful, n (%)	**Unsuccessful, n (%)**		
Radial artery diameter (mm)				
<1.6	10 (8.3%)	26 (78.8%)	14.73 (5.91 – 36.71)	<0.001
≥1.6	85 (70.8%)	15 (12.5%)		
Cephalic vein diameter (mm)				
<2.0	18 (15.0%)	50 (41.7%)	17.86 (6.83 – 46.71)	<0.001
≥2.0	45 (37.5%)	7 (5.8%)		
Vein distensibility (mm				
≥0.05	81 (67.5%)	5 (4.2%)	7.92 (2.68 - 14.9)	0.008
<0.05	14 (11.7%)	20 (16.7%)		
Peak systolic velocity (cm/s)				
<30	44 (36.7%)	25 (20.8%)	2.55 (1.35 - 5.85)	0.018
≥30	51 (42.5%)	9 (7.5%)		

The analysis of preoperative Doppler parameters and their association with AVF maturation demonstrated significant correlations. Patients with a radial artery diameter of ≥1.6 mm had a higher success rate of AVF maturation (70.8%), while those with a diameter <1.6 mm had lower success rates (8.3%). Similarly, a cephalic vein diameter of ≥2.0 mm was associated with a 37.5% maturation success rate compared to 15.0% for veins <2.0 mm. Vein distensibility was a critical predictor, with patients having a distensibility ≥0.5 mm showing significantly higher AVF maturation rates (67.5%) compared to those with <0.5 mm (11.7%). Additionally, peak systolic velocity ≥30 cm/s was strongly associated with successful AVF maturation (42.5%) compared to <30 cm/s (36.7%). These results emphasize the role of preoperative vascular assessment in predicting AVF outcomes.

Table 4: Receiver operator curve analysis of preoperative parameters in assessing successful maturation of arteriovenous fistula (n=120)

Parameter	AUC	95% CI	P-Value
Radial artery diameter	0.582	0.442 - 0.732	0.321
Cephalic vein diameter	0.629	0.497 - 0.765	0.098
Vein distensibility	0.663	0.519 - 0.805	0.067
Peak systolic velocity	0.578	0.438 - 0.723	0.082

The receiver operating characteristic (ROC) analysis examined the predictive power of preoperative Doppler parameters for AVF maturation success. The cephalic vein diameter demonstrated a moderate area under the curve (AUC) value of 0.629 (95% CI: 0.497–0.765, p = 0.098), indicating its predictive significance. Vein distensibility had a higher AUC of 0.663 (95% CI: 0.519–0.805, p = 0.067), suggesting a strong correlation with AVF maturation. The radial artery diameter and peak systolic velocity had lower predictive values, with AUCs of 0.582 and 0.578, respectively. These results reinforce the importance of vein distensibility as a key determinant in AVF maturation success, further validating its role in preoperative vascular assessments.

Adverse events were recorded in 18 (15.0%) patients. Among these, hypotension was observed in three patients, while thrombosis occurred in five cases and stenosis in four cases. Additionally, five patients experienced postoperative limb edema, and one patient developed a hematoma. Despite these complications, the overall success rate of AVF maturation was high, demonstrating the effectiveness of Doppler ultrasound in preoperative assessment and postoperative monitoring.

Figure -1

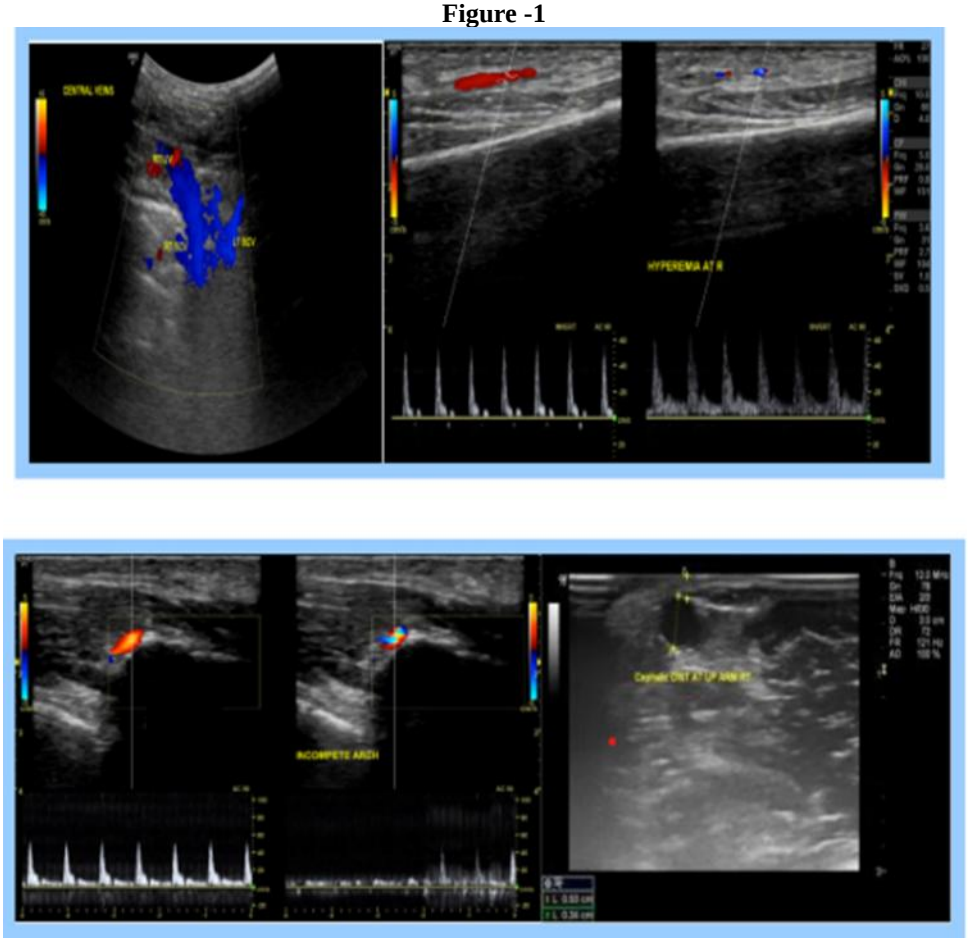

Fig. 1. Vascular mapping for normal arterial and venous duplex study with bilateral incomplete palmar arch of Female Patient 45 years old with CRF. (a) Patent central veins. (b) Normal arterial hyperemia response. (c) Duplex Allen test shows bilateral incomplete palmar arch. (d) patent compressible cephalic vein with average diameter 5 mm.

Figure-2

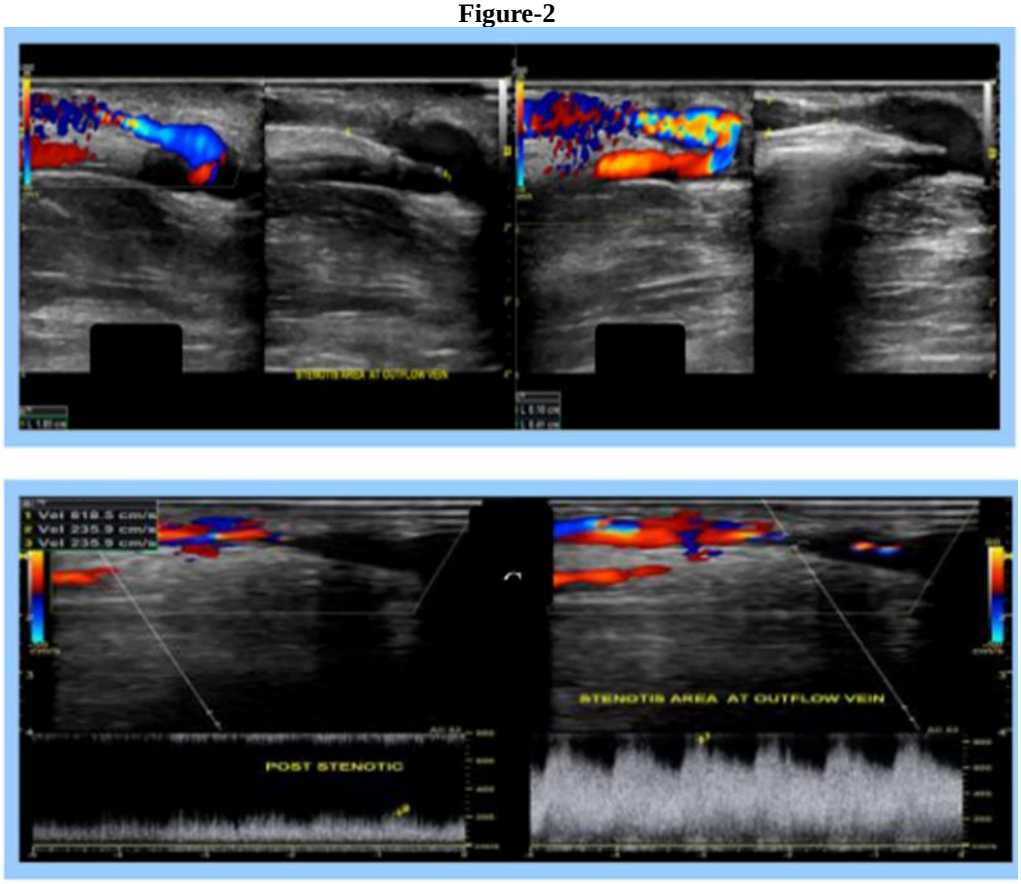

Fig. 2. Significant Juxta-anastomotic stenosis of right radio-cephalic fistula of Female patient 16 years old had right radio-cephalic fistula. (a) cephalic vein which show diameter reduction < 50 % with distance about 2 cm from the anastomosis at (juxta- anastomotic area) and measures about 1.6 mm at the narrowest area . (b) Focal aliasing and visible colour bruit artifact at juxta anastomotic area (the most common stenotic area) (c) Doppler study reveals monophasic low resistant flow with markedly elevated velocity measure 820 cm/s at stenotic area while post stenotic velocity measure 235 cm/s having a velocity ratio.

IV. Discussion

The current study explored the effectiveness of Doppler ultrasound (DUS) in forecasting arteriovenous fistula (AVF) maturation and its association with clinical outcomes in patients undergoing hemodialysis. The results indicate that specific preoperative Doppler parameters—especially vein distensibility and peak systolic velocity—play a crucial role in AVF maturation success.

Comparison with Earlier Research

Our findings are consistent with prior research that highlights the value of vascular measurements in predicting AVF maturation. For instance, studies by Wong et al. (1996) and Silva et al. (1998) demonstrated that a radial artery diameter (RAD) of at least 1.6 mm and a cephalic vein diameter (CVD) of 2.0 mm or more are favorable for successful maturation. Tessitore et al. (2016) also confirmed a strong relationship between vessel diameter, Doppler-measured blood flow, and AVF patency. Notably, our study underlines the importance of vein distensibility (VD), echoing Kim et al. (2011), who found that higher VD enhances vein dilation and long-term access functionality.

Conversely, Lockhart et al. (2004) observed lower maturation rates using similar Doppler parameters, potentially due to variation in patient selection or surgical techniques. Nonetheless, our results further support the consensus that comprehensive vascular evaluation before surgery—such as that proposed by Agarwal et al. (2019)—improves AVF outcomes.

Functional Versus Anatomical Maturation

We observed that 79.2% of AVFs satisfied the "Rule of Six" for anatomical maturation. However, a larger percentage (87.5%) met the criteria for functional maturation, defined as successful two-needle

cannulation with adequate blood flow (>250 mL/min) during six dialysis sessions. This disparity suggests that anatomical measures alone may not fully reflect access usability. Lee et al. (2020) made similar observations and recommended incorporating flow dynamics into AVF maturity assessments for a more holistic evaluation.

Importance of Vein Distensibility

One of the standout findings in this research is the significant influence of vein distensibility on AVF outcomes. Patients with VD ≥0.5 mm had a substantially higher chance of successful maturation (OR = 7.92, p = 0.008), confirming the importance of this parameter. This aligns with the conclusions of Kim et al. (2011), who reported that enhanced vein compliance contributes to better dilation and long-term function of AVFs. Therefore, VD should be considered a key metric during preoperative evaluation.

Doppler Indicators and Dialysis Efficiency

The study also identified a positive association between higher peak systolic velocity in the radial artery and improved AVF performance. This is consistent with findings by González et al. (2019), who showed a strong link between Doppler-assessed blood flow and dialysis effectiveness, measured through Kt/V and the urea reduction ratio (URR). Utilizing Doppler ultrasound in AVF planning may thus help ensure more effective dialysis, reduce access complications, and enhance overall patient outcomes.

Study Limitations and Future Prospects

1. **Limited Sample Size**: Although this study included 120 participants, a larger sample would strengthen the statistical reliability of the findings.
2. **Brief Follow-up Duration**: The study did not assess AVF patency beyond six weeks, limiting insights into long-term outcomes.
3. **Absence of Randomization**: A randomized controlled trial design could provide stronger evidence for causality.

Future investigations should aim to evaluate long-term AVF performance, refine the predictive value of Doppler ultrasound parameters, and assess new therapeutic strategies—such as the use of vasodilator agents—to enhance fistula maturation and durability.

V. Conclusion

This research reinforces the clinical value of using Doppler ultrasound as a non-invasive tool for predicting arteriovenous fistula maturation before surgery. Among the parameters assessed, vein distensibility (VD) and radial artery peak systolic velocity (PSV-RA) showed the highest predictive power for successful outcomes.

- Favorable Doppler thresholds—RAD ≥1.6 mm, CVD ≥2.0 mm, VD ≥0.5 mm, and PSV-RA ≥30 cm/s—were strongly associated with higher maturation success rates.
- Functional maturation (87.5%) surpassed anatomical maturation (79.2%), suggesting that current success criteria should incorporate hemodynamic performance.
- Routine use of Doppler-based vascular evaluation can enhance access planning and improve long-term dialysis outcomes.

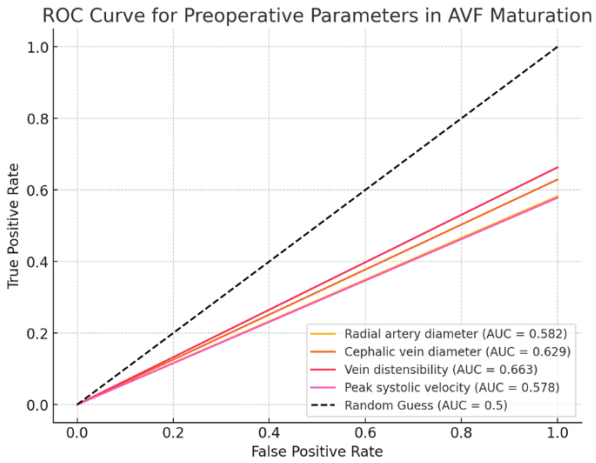

Figure 4: ROC curve analysis of preoperative parameters in assessing successful maturation of arteriovenous fistula (n = 120). ROC = Receiver-operator-curve, RAD = Radial artery diameter, CVD = Cephalic vein diameter, PSV = Peak systolic velocity

References

[1] Tessitore, N., Bedogna, V., Poli, A., Mantovani, W., &Sandrini, M. (2016). Prognostic Significance Of Doppler Ultrasound In Hemodialysis Vascular Access. American Journal Of Kidney Diseases, 67(1), 104-112. DOI:10.1053/J.Ajkd.2015.08.022

[2] Allon, M., &Robbin, M. L. (2002). Hemodialysis Vascular Access Monitoring: Current Strategies And Future Directions. Kidney International, 62(6), 2203-2213. DOI:10.1046/J.1523-1755.2002.00681.X

[3] Sidawy, A. N., Spergel, L. M., Besarab, A., Allon, M., Jennings, W. C., Padberg, F. T., ...& Work, J. (2018). The Society For Vascular Surgery Clinical Practice Guidelines For The Surgical Placement And Maintenance Of Arteriovenous Hemodialysis Access. Journal Of Vascular Surgery, 67(1), 2-35. DOI:10.1016/J.Jvs.2017.06.067

[4] Agarwal, A. K., Haddad, N. J., Vachharajani, T. J., &Asif, A. (2019). Innovations In Vascular Access For Hemodialysis. Kidney International Reports, 4(3), 281-296. DOI:10.1016/J.Ekir.2018.10.011

[5] Lee, T., Mokrzycki, M., Moist, L., Maya, I., Vazquez, M., Lok, C. E., & Sands, J. J. (2020). Standardized Definitions For Hemodialysis Vascular Access. Kidney International, 97(5), 1067-1080. DOI:10.1016/J.Kint.2020.01.037

[6] González, A. M., Georgopoulos, C., Kamper, L., &Schmieder, R. E. (2019). Assessment Of Arteriovenous Fistulas With Doppler Ultrasound: Correlation With Dialysis Adequacy Parameters. Nephrology Dialysis Transplantation, 34(1), 89-96. DOI:10.1093/Ndt/Gfy134.

[7] Wong V, Ward R, Taylor J, Selvakumar S, How TV, Bakran A. Factors Associated With Early Failure Of Arteriovenous Fistulae For Haemodialysis Access. Eur J Vascendovasc Surg. 1996;12(2):207-213.

[8] Silva MB Jr, Hobson RW 2nd, Pappas PJ, Jamil Z, Araki CT, Goldberg MC, Et Al. A Strategy For Increasing Use Of Autogenous Hemodialysis Access Procedures: Impact Of Preoperative Noninvasive Evaluation. J Vasc Surg. 1998;27(2):302-307.

[9] Lockhart ME, Robbin ML, Allon M. Preoperative Sonographic Radial Artery Evaluation And Correlation With Subsequent Radiocephalic Fistula Outcome. J Ultrasound Med. 2004;23(2):161-168.

[10] Kim JT, Chang WH, Oh TY, Jeong YK. Venous Distensibility As A Key Factor In The Success Of Arteriovenous Fistulas At The Wrist. Ann Vasc Surg. 2011;25(8):1094-1098. Doi:10.1016/J.Avsg.2011.07.011.