



Research Article

Doppler Ultrasound–Driven Insights into Early Maturation of Radiocephalic AV Fistulas: Decoding the Impact of Anastomotic Configuration

Dr. Vijaykumar N¹; Dr. Mohan G Kakola²; Dr. Chandrashekar³; Dr. Saikumar P⁴

¹ Professor & Head, Department of Plastic, Reconstructive Surgery and Burns Mysore Medical College and Research Institute Mysore, Karnataka, India

² Professor, Department of Plastic, Reconstructive Surgery and Burns Mysore Medical College and Research Institute Mysore, Karnataka, India

³ Assistant Professor, Department of Plastic, Reconstructive Surgery and Burns Mysore Medical College and Research Institute Mysore, Karnataka, India

⁴ Postgraduate, Department of Plastic, Reconstructive Surgery and Burns Mysore Medical College and Research Institute Mysore, Karnataka, India

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Corresponding Author:

Dr. Saikumar P

Postgraduate, Department of Plastic, Reconstructive Surgery and Burns Mysore Medical College and Research Institute Mysore, Karnataka, India

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ABSTRACT

BACKGROUND: Arteriovenous fistula (AVF) is the preferred vascular access for hemodialysis owing to superior patency and lower complication rates compared with grafts or catheters. The optimal anastomotic configuration—End-To-Side (ES) versus Side-To-Side (SS)—remains debated. This study compared early Doppler ultrasound (DUS) findings, maturation rates, and complications between ES and SS Radiocephalic AVFs.

METHODS: A prospective observational study was performed at a tertiary care centre between January 2024 and May 2025. Eighty adult patients requiring AVF creation underwent preoperative DUS mapping. Based on vascular anatomy, patients received either ES (n = 40) or SS (n = 40) anastomosis. Postoperative assessments at day 1, 1 week, 3 weeks, and 6 weeks included clinical and DUS evaluation of AVF diameter, flow volume, and maturation. Statistical analyses employed Fisher's exact test, independent t-test, ANOVA, and logistic regression.

RESULTS: Maturation occurred in 92.5% of SS and 90% of ES fistulas (p = 0.026). SS fistulas had a larger mean diameter on day 1 (4.455 mm vs. 4.185 mm; p = 0.045). Flow volumes increased progressively in both groups without significant difference. Causes of failure included failure to mature (n = 2), hematoma (n = 2), partial thrombosis (n = 2), and total thrombosis (n = 1).

CONCLUSION: Both ES and SS AVFs showed high maturation rates and satisfactory early hemodynamics. SS offered a modest early maturation advantage, potentially supporting earlier cannulation. DUS was effective for both preoperative planning and postoperative surveillance.

Keywords: Arteriovenous fistula, Hemodialysis, Doppler ultrasound, End-to-side, Side-to-side, Vascular access.

INTRODUCTION

End-stage renal disease (ESRD) patients require lifelong renal replacement therapy—either dialysis or renal transplantation—to sustain life. Following the development of the Scribner shunt in 1960, Brescia et al. described, in 1966, the creation of a subcutaneous arteriovenous fistula (AVF) between the radial artery and an adjacent vein, now known as the Cimino fistula, which remains the preferred vascular access for hemodialysis (HD) ^[1,2]

In India, recent estimates indicate that more than 364,000 patients are on chronic dialysis, corresponding to a prevalence of approximately 257 per million population, with an annual growth rate of 10–20% ^[3]. An autogenous AVF remains the procedure of choice for venous access in HD, with an overall success rate of about 84% ^[4]

Several anastomotic configurations are available for AVF creation: end-to-end anastomosis; terminal vein stump to the lateral wall of the artery (end-to-side, ES); lateral artery wall to lateral vein wall (side-to-side, SS); and side-to-side with distal vein ligation. ES and SS remain the most commonly employed [5].



Figure 1: A-End to Side anastomosis , B- Side to Side anastomosis

Preferred sites include radiocephalic AVF at the wrist, brachiocephalic or brachio basilic AVF at the elbow, and, in selected cases, forearm AV grafts [5]. A functional and mature AVF typically exhibits a flow rate of 350–400 mL/min [6], while common complications include thrombosis, venous hypertension, steal syndrome, aneurysm, bleeding, and seroma formation [7].

The use of Doppler ultrasound (DUS) has transformed vascular access surgery by enabling accurate preoperative mapping of arteries and veins, improving the feasibility of native vessel AVFs, and enhancing postoperative monitoring for early detection of complications [8].

DUS can be applied in three main contexts:

1. Preoperative vascular mapping – to assess vessel calibre, patency, wall characteristics, and distensibility.
2. Assessment of AVF maturation – to confirm readiness for cannulation, particularly in slow-maturing or clinically ambiguous cases.
3. Postoperative surveillance – to identify complications and monitor long-term patency.

➤ Preoperative vascular mapping

Traditionally, vessel selection relied solely on physical examination, which provides adequate information on superficial veins but limited data on arterial anatomy and flow [9,10,11]. DUS uniquely combines B-mode imaging with color and spectral Doppler, allowing simultaneous evaluation of vessel morphology (diameter, wall thickness, trajectory, stenosis) and function (blood flow, reactivity).

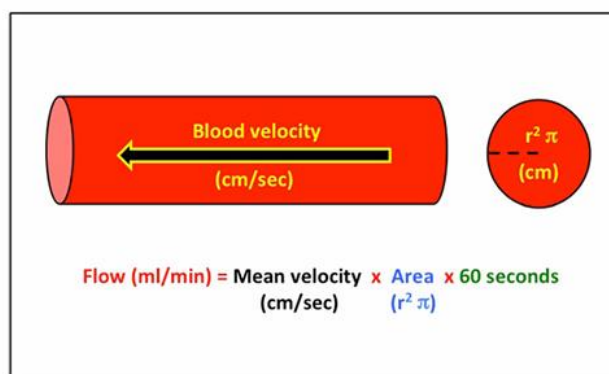
For venous mapping, transverse scans of the cephalic vein from the wrist to its junction with the deep system are performed, with assessment of wall thickness, patency, caliber, depth (<6 mm preferred), compressibility, and linearity of course [9,12].

AVF maturation

Maturation refers to the development of anatomical and hemodynamic characteristics permitting repeated cannulation with large-gauge needles [13]. According to KDOQI's "Rule of 6s" [13], a mature fistula should have a flow volume ≥ 600 mL/min, an outflow vein diameter ≥ 6 mm, and a depth ≤ 6 mm from the skin surface.

DUS assists in distinguishing **slow maturation from failure-to-mature (FTM)** by measuring serial flow volumes—preferably in the brachial artery to avoid underestimation in distal fistulas where ulnar artery inflow contributes via the palmar arch [14,15].

AVF FLOW VOLUME CALCULATION



Measurement of blood flow is now considered the best means of surveillance for a vascular access^[8]; reduced flow volumes or values that decrease over time are predictive of thrombosis for both native and prosthetic AVFs^[12, 13, 14].

Despite its widespread use, the optimal AVF anastomotic technique remains debated.

ESVS guidelines suggest a preference for ES anastomosis, but supporting evidence is limited^[13,15]. This study was designed to compare ES and SS techniques in terms of maturation, complications, primary patency, incorporating preoperative DUS mapping and postoperative surveillance.

METHODS

Study design and setting

This was a single-centre, prospective observational study conducted in the Department of Plastic Surgery at a tertiary care centre between January 2024 and May 2025. Patients were recruited consecutively during the study period, and data were collected from preoperative DUS mapping, operative notes, and structured follow-up visits.

Inclusion criteria

- Age > 18 years
- Pre-dialysis or dialysis-dependent patients requiring ES or SS AVF for HD
- No history of venipuncture or intravenous infusion in the proposed limb within the preceding two weeks
- Controlled systolic blood pressure > 100 mmHg

Exclusion criteria

- Previous AVF in the same elbow or more proximal site
- Forearm arteriovenous grafts
- Prior AVF revisions
- History of deep venous thrombosis
- Non-compliance with follow-up visits
- Intraoperative failure to construct the AVF

Patient grouping and surgical techniques

Eighty eligible patients were assigned to two groups based on surgical technique:

- **ES group** – proximal end of a transected cephalic vein anastomosed to the lateral wall of the radial artery.
- **SS group** – lateral wall of the radial artery anastomosed to the lateral wall of the cephalic vein.

Preoperative assessment

Preoperative DUS mapping evaluated vessel calibre, patency, with optimal arterial diameter ≥ 2 mm with a patent palmar arch. The reactive hyperaemia test was used to assess arterial distensibility.

Surgical site selection

Surgery was preferentially performed on the non-dominant wrist. The dominant limb was chosen only in cases of unfavorable distal anatomy, prior distal AVF on the non-dominant side. All procedures were performed by the same surgical team to ensure technical consistency.

Surgical Technique

All procedures were conducted under Local Anaesthesia, with the patient positioned supine and the operative limb placed on an arm board. After routine antiseptic preparation and draping, the target vessels identified during preoperative Doppler ultrasound mapping were exposed through a S shaped skin incision. Careful dissection was performed to mobilize the artery and vein over an adequate length to allow a tension-free anastomosis.

In the end-to-side (ES) configuration, the proximal end of a divided vein was spatulated and anastomosed to a longitudinal arteriotomy on the lateral wall of the artery using continuous 7-0 polypropylene or 8-0 ethilon sutures under loupe magnification.

In the side-to-side (SS) configuration, matching longitudinal arteriotomies and venotomies were created, followed by side-to-side anastomosis between the two lateral walls using continuous 7-0 polypropylene or 8-0 ethilon sutures. The size of anastomosis was measured between 10 to 15 mm in case of radiocephalic SS anastomosis. Vessel clamps were released sequentially, and haemostasis was secured.

Intraoperative assessment of flow was performed by palpating the thrill and observing venous distension. In cases where flow was suboptimal, the anastomosis was inspected for technical issues such as narrowing, kinking, or torsion, which were corrected immediately. Thorough haemostasis is achieved and the skin incision is closed in two layers. Non-compressive dressings applied.

Limb was elevated postoperatively to minimize oedema. Patient is advised not to apply pressure over the operated site, not to allow blood collection from the operated upper limb. Hand exercises using a soft ball are demonstrated and patient is asked to follow the same in postoperative period. Wound dressing is checked on second postoperative day and patient is discharged.

Follow-up

Follow-up assessments, including clinical examination and DUS, were performed at POD1, 1 week, 3 weeks, and 6 weeks to evaluate flow volume, AVF diameter, maturation and patency.

The primary exposure of interest were the preoperative arterial and venous diameters nearest to the planned AVF anastomosis and the brachial artery blood flow, whereas the primary outcomes were postoperative ultrasound measurements of AVF diameter and blood flow.

Statistical Analysis

IBM SPSS Statistics software, version 20 (IBM Corp., Armonk, NY, USA), was used for all analyses. Demographic variables were summarised as frequencies, means, and standard deviations. Associations between demographic or clinical characteristics and the two operative techniques were evaluated using Fisher's exact test for categorical variables, while outcomes of the two surgical techniques were compared using the independent Student's *t*-test for continuous variables.

Complete datasets—including patient demographics, comorbidities, preoperative and postoperative Doppler findings, and clinical AVF outcomes—were available for all study participants. Rates of AVF maturation were calculated for each subgroup and compared using the chi-squared test.

Continuous variables were assessed using analysis of variance (ANOVA). Multivariable logistic regression was performed to evaluate the association between patient clinical characteristics, preoperative ultrasound measurements, and AVF maturation. A *p*-value < 0.05 was considered statistically significant.

RESULTS

A total 80 patients were included in the study. Forty patients were divided equally in ES and SS groups. Demographic and preoperative data were compared in Table-1.

Age and gender distribution between ES and SS group were statistically non-significant. 25 patients (62.5%) in ES group had hypertension as compared to 28 (70.0%) in SS group (*p*=0.478), 13 (32.5 %) patients in ES group suffered from diabetes whereas 16 (40.0 %) patients in SS group suffered with diabetes (*p*=0.485). 7(17.5%) patients in ES and 6 (15.0%) patients in SS group were having previously diagnosed cardiac disease(*p*=0.762).

	ES (n=40)	SS (n=40)	P VALUE
AGE (IN YEARS)	47.34 ± 10.43	46.84 ± 11.56	0.839
GENDER			
Male	21 (52.5%)	23 (57.5%)	0.653
Female	19 (47.5%)	17 (42.5%)	
COMORBIDITIES			
Hypertension	25 (62.5%)	28 (70.0%)	0.478
Diabetes Mellitus	13 (32.5%)	16 (40.0%)	0.485
Cardiac Disease	7 (17.5%)	6 (15.0%)	0.762

Table 1: Analysis of demographic and pre- operative data between groups

Pre-op vessel diameter	End to Side group [Mean ±SD]	Side to Side group [Mean ±SD]	P Value
Arterial diameter	2.26±0.17	2.27±0.19	0.78
Vein diameter	2.03±0.15	1.97±0.21	0.11

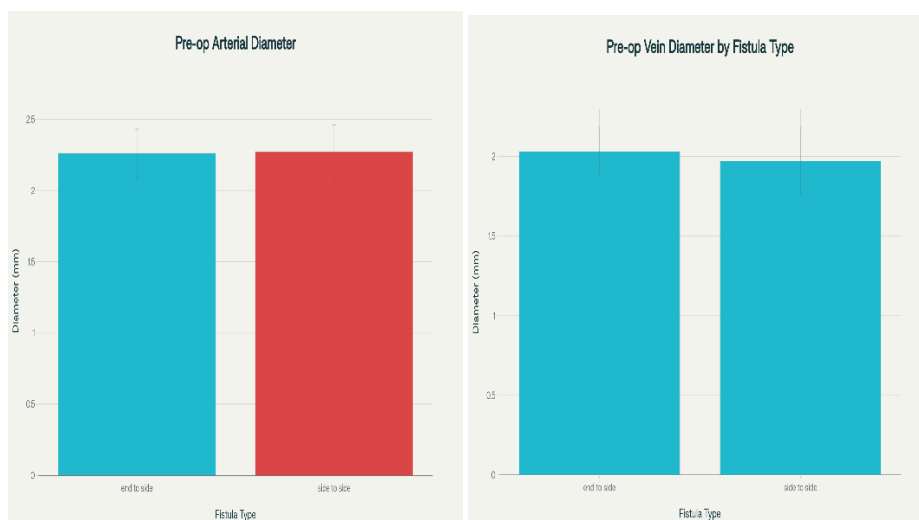


Table 2 and Chart 1 & 2: Pre-operative Mean Vessel diameters in both groups

- Pre-operative mean arterial diameters is 2.2mm in both groups
- Pre-operative mean vein diameters in SS group is 1.97mm and in ES group is 2.03mm; but the comparison isn't statistically significant

Post-op Flow Volume	End to Side group [Mean $\pm$ SD]	Side to Side group [Mean $\pm$ SD]	P Value
Day 1	662.43 $\pm$ 55.56	652.77 $\pm$ 23.28	0.313
Week 1	708.146 $\pm$ 75.90	717.42 $\pm$ 31.9	0.477
Week 3	964.92 $\pm$ 18.31	1023 $\pm$ 27.22	0.05
Week 6	1060 $\pm$ 21.9	1148 $\pm$ 65.2	0.017

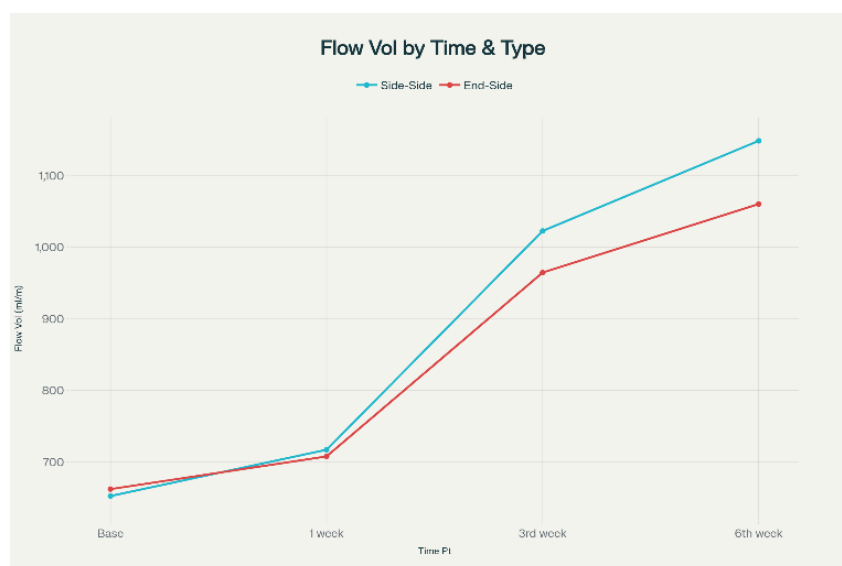


Table & Chart 3: Analysis of Post-operative Flow Volume in both groups done at constant intervals

- There is a trend of increasing flow volume in both groups with the SS group consistently exhibiting slightly higher values.
- This graphical representation compares the hemodynamic performance between the two types of anastomosis across the post-op period.

Post-op Vein diameter	End to Side group [Mean $\pm$ SD]	Side to Side group [Mean $\pm$ SD]	P Value
Day 1	4.19 $\pm$ 0.79	4.46 $\pm$ 0.30	0.045
Week 1	4.29 $\pm$ 0.79	4.45 $\pm$ 0.37	0.024
Week 3	4.58 $\pm$ 0.31	4.34 $\pm$ 0.78	0.07
Week 6	4.46 $\pm$ 0.79	4.72 $\pm$ 0.76	0.05

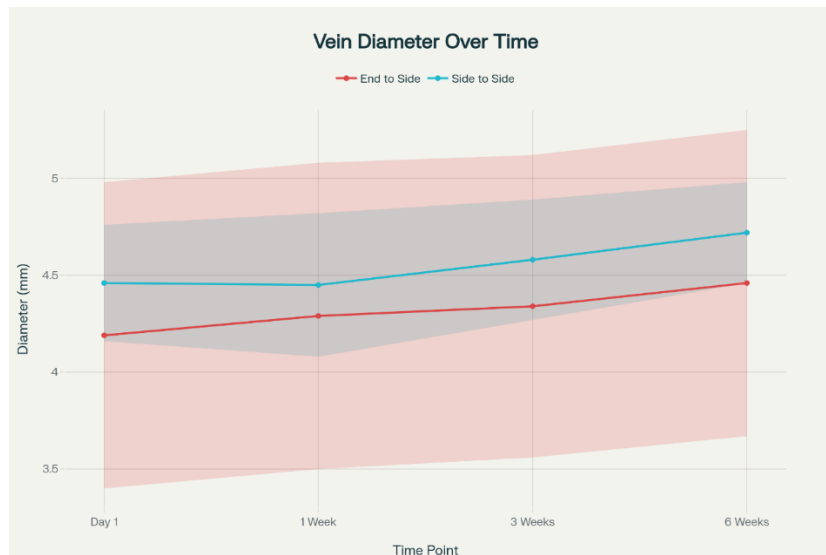


Table & Chart 4: Analysis of Mean Vein diameter in postoperative period between two groups

- The SS group consistently has larger mean vein diameters at each post-op time point compared to the ES group.
- The difference between the two groups appears to gradually widen over time, with the SS anastomosis tending towards greater vein dilation.

Post-op AVF diameter	End to Side group [Mean ±SD]	Side to Side group [Mean ±SD]	P Value
Day 1	4.18 ±0.78	4.45±0.29	0.045
Week 1	4.28±0.78	4.45±0.36	0.241
Week 3	4.33±0.77	4.57±0.30	0.071
Week 6	4.46±0.78	4.71±0.25	0.056

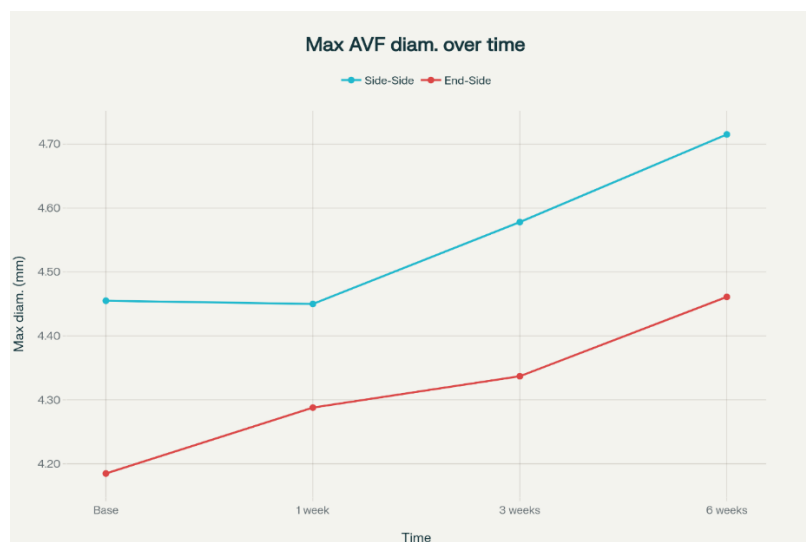


Table &Chart 5: Analysis of Maximum AVF diameter between the study groups in postoperative period

- There is a trend of increasing flow volume in both groups with the SS group consistently exhibiting slightly higher values.

AVF Maturation Vs Fistula type						
Maturation		Fistula type			Total	
	Matured		Count	37	36	73

		%	92.5%	90%	91.25%
	Not Matured	Count	3	4	7
		%	7.5%	10%	8.75%
Total		Count	40	40	80
		%	100.0%	100.0%	100.0%
a. p=0.026 sig (Fisher's exact test)					

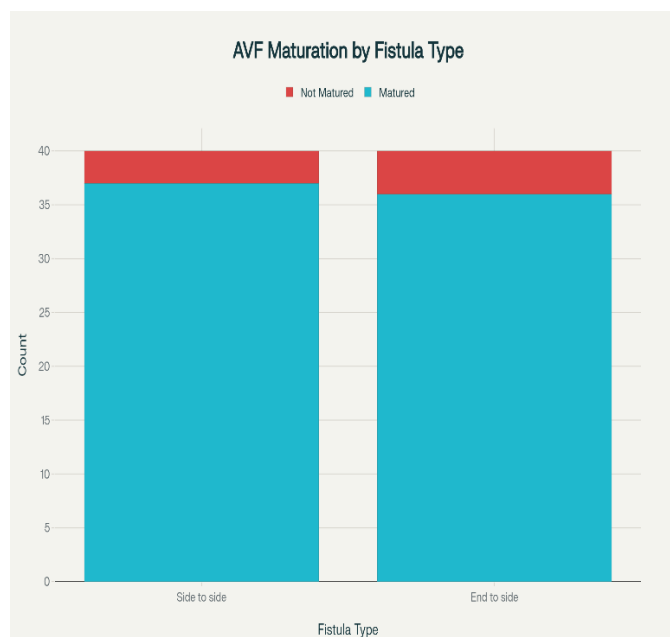


Table & Chart 6: shows the distribution of clinically matured versus non-matured AVF's according to the anastomosis technique.

- Clinical maturation was achieved in 92.5% of side-to-side AVFs and 90% of end-to-side AVFs, with the difference reaching statistical significance ($p = 0.026$, Fisher's exact test).

Table 7: causes of failure for AVF maturation in the study group

CAUSES OF FAILURE	NUMBER OF SUBJECTS
FAILED TO MATURE	2
HEMATOMA	2
PARTIAL THROMBOSIS	2
TOTAL THROMBOSIS	1

Key findings from the DUS assessments at various postoperative intervals (baseline, 1, 3, and 6 weeks) showed:

- SS group consistently has significantly larger mean vein diameters at each post-op time point compared to the ES group
- Flow volume increased over time in both groups with SS group consistently exhibiting slightly higher values which is statistically significant at week 3 and week 6 [$p=0.05$ and $p=0.017$ respectively]
- The maximum AVF diameter at postoperative day 1 was significantly larger in the SS group compared to the ES group ($p=0.045$), suggesting SS group tend to have larger vein diameter than the ES group, particularly immediately after surgery
- Fistula maturation rates were similarly high in both groups—92.5% in SS and 90% in ES—with a statistically significant difference favoring SS ($p=0.026$).

DISCUSSION

This prospective observational study compared end-to-side (ES) and side-to-side (SS) anastomosis techniques in radio cephalic arteriovenous fistula (RCAVF) creation, using serial Doppler ultrasound (DUS) to track hemodynamic changes and maturation. Both groups demonstrated high maturation rates (>90%) and significant improvements in flow volume, vein diameter, and AVF diameter over the 6-week follow-up.

The SS technique was associated with a significantly larger maximum AVF diameter on postoperative day 1 and a marginally higher maturation rate, although long-term hemodynamic parameters were comparable.

Comparison with previous literature

Our findings closely parallel those of Anil et al. (2021)^[16], who in a retrospective series reported no significant difference in long-term patency between ES and SS RCAVFs, but found that SS allowed greater early vein caliber expansion.

Similarly, Zamboli et al^[17], in their prospective clinical trial found that SS AVFs demonstrated greater early diameter gains without compromising patency, and that both techniques achieved satisfactory maturation rates when performed on vessels with adequate preoperative caliber. These parallels reinforce our finding that both techniques are viable, with SS potentially offering an early advantage in cases requiring rapid maturation.

The work of Ann O'Banion et al^[18] also supports this interpretation; in their comparative study of RCAVF techniques, early postoperative flow was higher in SS configurations, although long-term outcomes did not differ significantly. They emphasized that the choice of configuration should be dictated by intraoperative anatomy and surgeon experience—an approach consistent with our study's conclusions.

Physiological considerations and predictive factors

The slightly larger POD1 diameter observed in SS AVFs may be explained by bidirectional flow through the parallel anastomotic opening, which facilitates rapid venous distension. Over time, vascular remodeling and hemodynamic stabilization likely attenuate these early differences, as reflected in the similar parameters at later follow-ups.

Predictive factors described by Farrington et al^[19]—including adequate arterial diameter, higher preoperative systolic blood pressure, and preserved left ventricular ejection fraction—may partially explain the uniformly high maturation rates in both groups in our series. All patients underwent strict preoperative DUS mapping, ensuring optimal vessel selection in line with these criteria.

Clinical implications

Both ES and SS techniques are effective for RCAVF creation in appropriately selected patients. The modest early advantage in vessel diameter and maturation seen with SS suggests it may be beneficial in patients with smaller vein diameter and those requiring earlier cannulation, such as those with urgent dialysis needs.

CONCLUSION

In summary, the SS anastomosis group even with smaller vein diameter though not statistically significant demonstrated a slightly larger initial AVF diameter and marginally higher maturation rate compared to ES group. While both techniques are effective, SS may provide some advantage in early fistula development as assessed by DUS parameters.

This study highlights the utility of DUS for objective monitoring of AVF maturation and supports the use of SS anastomosis as a potentially favorable surgical technique for AVF creation in hemodialysis patients

Study limitations

Our study is limited by its single-center design, short follow-up, and non-randomized allocation, which may limit generalizability. The absence of patient-reported outcomes, such as cannulation ease or satisfaction, also limits the scope of our conclusions.

Future research

Further randomized multicenter trials with extended follow-up are needed to clarify whether the early advantages of SS AVFs translate into improved long-term patency. Studies integrating patient-centered outcomes and cost-effectiveness analyses could further refine surgical decision-making.

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