PROSPECTIVE EVALUATION OF ARTERIOVENOUS FISTULA MATURITY & SUCCESS: SERIAL FOLLOW-UP USING PREOPERATIVE & POSTOPERATIVE DUPLEX ULTRASOUND (1ST WEEK, 3RD WEEK, & 6 WEEKS)

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ABSTRACT

Background: Arteriovenous fistula (AVF) is the preferred vascular access for hemodialysis. Early maturation and patency are critical for successful dialysis, but outcomes are influenced by patient factors, vessel characteristics, and comorbidities.
Objective: To prospectively evaluate AVF maturation and success using duplex ultrasound in patients undergoing RC-AVF, BC-AVF, and BB-AVF, with serial assessments at 1, 3, and 6 weeks postoperatively.
Methods: Sixty-nine patients undergoing AVF creation at CMH Lahore from January to July 2025 were included. Demographics, comorbidities (diabetes mellitus, hypertension, ischemic heart disease), and fistula type were recorded. Preoperative and postoperative vessel diameters and AVF flow rates were measured using duplex ultrasound. Statistical analysis was performed.
Results: Among the 69 patients, BC-AVFs consistently exhibited the highest mean flow rates and diameters across the postoperative period. Thrombosis occurred in 7–9% of AVFs, predominantly among patients with smaller preoperative vessel diameters and those with diabetes mellitus, consistent with significant negative correlations between vessel size and postoperative flow ($p < 0.05$). Serial duplex assessments at 1st, 3rd, and 6th weeks enabled early identification of suboptimal flow, allowing timely intervention to optimize AVF maturation.
Conclusion: AVF maturation is influenced by fistula type, preoperative vessel diameter, and patient comorbidities. BC-AVFs demonstrate higher early flow rates, whereas RC-AVFs with smaller vessels are more prone to thrombosis. Older age, diabetes, and ischemic heart disease further increase the risk of early AVF failure.

Keywords: Arteriovenous fistula, Hemodialysis, Duplex ultrasound, AVF maturation, Thrombosis, Vascular access

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INTRODUCTION

Arteriovenous fistula (AVF) remains the gold standard for vascular access in patients requiring hemodialysis, owing to its superior long-term patency and lower complication rates compared to central venous catheters and synthetic grafts.[1,2] Successful AVF function depends on adequate vessel size, blood flow, and maturation, as well as patient-related factors including age and comorbidities such as diabetes mellitus, hypertension, and ischemic heart disease.[3,4]

Despite advances in surgical technique, early AVF failure remains a significant clinical problem, often resulting from thrombosis or inadequate maturation.[5] Duplex ultrasound has emerged as a reliable non-invasive tool to assess

preoperative vessel suitability and monitor postoperative AVF development, allowing early identification of dysfunction and timely intervention.[6,7]

This study aimed to prospectively evaluate RC-AVF, BC-AVF, and BB-AVF maturation and success over a 6-week follow-up period using serial duplex ultrasound assessments, while analyzing the impact of patient demographics, comorbidities, and vessel characteristics on outcomes.

METHODS

This was a prospective observational study conducted at the Department of Vascular Surgery, CMH Lahore, over a period of six months from 1st January 2025 to 31st July 2025. Patients undergoing AVF creation (RC-AVF, BC-AVF, BB-AVF) for hemodialysis access were included. Patients with prior vascular access surgery, active infection, or incomplete follow-up data were excluded. A total of 92 patients were enrolled. Demographic variables (age, sex) and comorbidities (diabetes mellitus, hypertension, ischemic heart disease) were recorded. The type of AVF created was documented.

Preoperative assessment: Preoperative vessel diameters (radial/brachial artery, cephalic/basilic vein) were measured using duplex ultrasound. Vessel suitability criteria included artery diameter ≥2 mm and vein diameter ≥2.5 mm.

Surgical procedure: All AVFs were created under local anesthesia using standard surgical techniques. RC-AVFs, BC-AVFs, and BB-AVFs were performed according to established protocols.

Postoperative assessment: Serial duplex ultrasound evaluations were performed at 1 week, 3 weeks, and 5–6 weeks postoperatively to measure AVF diameter and blood flow (ml/min). The presence of thrill, patency, and thrombosis was recorded.

Variables and statistical analysis: Categorical variables included sex, presence of comorbidities, and thrombosis (yes/no). Quantitative variables included age, vessel diameters, AVF diameter, and flow rates. Descriptive statistics (mean, median, frequencies) and inferential associations were calculated using Microsoft Excel. Thrombosis rates were analyzed in relation to patient age, comorbidities, and preoperative vessel diameter.

Descriptive statistics were calculated for all preoperative and postoperative variables. Continuous variables (e.g., AVF diameter and flow) are presented as mean ± SD, and categorical variables (e.g., sex, comorbidities, AVF type) as counts and percentages.

To evaluate associations between preoperative patient characteristics and postoperative outcomes (AVF diameter, flow, and thrombosis at 1st, 3rd, and 6th weeks), Spearman's correlation was used for continuous variables, and point-biserial correlation for binary outcomes. AVFs with thrombosis or no thrill were included, with diameter and flow recorded as 0.

A p-value < 0.05 was considered statistically significant, and significant correlations were highlighted to identify factors influencing AVF outcomes.

RESULTS

A total of 69 patients undergoing arteriovenous fistula (AVF) creation were included in the study. The mean age was 58.1 years (range 14–84 years), with a predominance of males (50, 72.5%) compared to females (19, 27.5%). Comorbidities were common, with diabetes mellitus present in 42 patients (60.9%), hypertension in 38 patients (55.1%), and ischemic heart disease in 20 patients (29%). The AVF types created were radial-cephalic (RC-AVF) in 25 patients, brachial-cephalic (BC-AVF) in 31 patients, and brachial-basilic (BB-AVF) in 13 patients. This cohort represents a typical patient population undergoing AVF formation, allowing for evaluation of preoperative and postoperative outcomes**. (Table 1)**

Table 1 – Summary of patient demographics

Variable	Category / Measure	N (%) or Value
Age (years)	Mean ± SD	58.2 ± 12.4
	Median (IQR)	59 (52 – 65)
	Range	14 – 84
Sex	Male	50 (72.5%)
	Female	19 (27.5%)
Diabetes Mellitus	Yes	38 (55%)
	No	31 (45%)
Hypertension	Yes	36 (52%)
	No	33 (48%)
Ischemic Heart Disease	Yes	22 (32%)
	No	47 (68%)
AVF Type	RC (Radiocephalic)	25 (36%)
	BC (Brachiocephalic)	28 (41%)
	BB (Brachio-basilic)	16 (23%)

Among the 69 patients, BC-AVFs consistently exhibited the highest mean flow rates and diameters across the postoperative period. At 1 week, mean flow (± SD) was 307 ± 183 ml/min for BC-AVFs, 212 ± 123 ml/min for BB-AVFs, and 248 ± 155 ml/min for RC-AVFs. By 3 weeks, flows increased to 430 ± 226 ml/min (BC), 371 ± 178 ml/min (BB), and 313 ± 165 ml/min (RC). At 6 weeks, BC-AVFs achieved the highest maturation with mean flows of 506 ± 276 ml/min, followed by BB-AVFs (423 ± 198 ml/min) and RC-AVFs (345 ± 180 ml/min).

Thrombosis occurred in 7–9% of AVFs, predominantly among patients with smaller preoperative vessel

diameters and those with diabetes mellitus, consistent with significant negative correlations between vessel size and postoperative flow ($p < 0.05$). Serial duplex assessments at 1st, 3rd, and 6th weeks enabled early identification of suboptimal flow, allowing timely intervention to optimize AVF maturation.

Table 2 – Co-relation between variables

AVF Type	Pre-op Variable	1st Week Diameter r (p)	1st Week Flow r (p)	1st Week Thrombosis r (p)	3rd Week Diameter r (p)	3rd Week Flow r (p)	3rd Week Thrombosis r (p)	6th Week Diameter r (p)	6th Week Flow r (p)	6th Week Thrombosis r (p)
RC	Age	0.12 (0.34)	0.10 (0.41)	-0.15 (0.29)	0.11 (0.38)	0.09 (0.44)	-0.17 (0.23)	0.13 (0.32)	0.10 (0.41)	-0.16 (0.26)
RC	Sex	0.08 (0.52)	0.07 (0.56)	-0.05 (0.65)	0.09 (0.48)	0.06 (0.59)	-0.07 (0.55)	0.08 (0.51)	0.05 (0.66)	-0.06 (0.60)
RC	DM	-0.21 (0.12)	-0.18 (0.18)	0.25 (0.08)	-0.19 (0.15)	-0.17 (0.20)	0.23 (0.10)	-0.18 (0.17)	-0.15 (0.25)	0.22 (0.11)
RC	HTN	-0.14 (0.27)	-0.12 (0.33)	0.18 (0.19)	-0.13 (0.30)	-0.11 (0.36)	0.16 (0.22)	-0.12 (0.33)	-0.10 (0.41)	0.15 (0.25)
RC	IHD	-0.10 (0.41)	-0.09 (0.44)	0.12 (0.34)	-0.11 (0.38)	-0.08 (0.51)	0.13 (0.32)	-0.09 (0.48)	-0.07 (0.55)	0.12 (0.34)
RC	Pre-op Diameter	0.52 (0.002)	0.49 (0.004)	-0.38 (0.02)	0.54 (0.001)	0.50 (0.003)	-0.36 (0.03)	0.56 (0.001)	0.52 (0.002)	-0.34 (0.04)
BC	Age	0.08 (0.55)	0.06 (0.62)	-0.12 (0.34)	0.10 (0.43)	0.07 (0.57)	-0.14 (0.27)	0.11 (0.38)	0.08 (0.52)	-0.13 (0.32)
BC	Sex	0.05 (0.65)	0.04 (0.70)	-0.03 (0.76)	0.06 (0.60)	0.05 (0.66)	-0.04 (0.70)	0.05 (0.66)	0.03 (0.78)	-0.05 (0.65)
BC	DM	-0.20 (0.14)	-0.18 (0.19)	0.22 (0.11)	-0.21 (0.13)	-0.16 (0.23)	0.20 (0.15)	-0.19 (0.15)	-0.14 (0.27)	0.18 (0.19)
BC	HTN	-0.12 (0.33)	-0.10 (0.41)	0.15 (0.25)	-0.14 (0.27)	-0.09 (0.44)	0.16 (0.22)	-0.13 (0.30)	-0.08 (0.51)	0.14 (0.27)
BC	IHD	-0.08 (0.52)	-0.06 (0.60)	0.11 (0.38)	-0.09 (0.48)	-0.05 (0.66)	0.12 (0.34)	-0.07 (0.55)	-0.04 (0.70)	0.10 (0.41)
BC	Pre-op Diameter	0.47 (0.004)	0.45 (0.006)	-0.35 (0.03)	0.50 (0.003)	0.47 (0.005)	-0.33 (0.04)	0.52 (0.002)	0.50 (0.003)	-0.31 (0.05)
BB	Age	0.09 (0.48)	0.07 (0.56)	-0.10 (0.41)	0.11 (0.38)	0.09 (0.48)	-0.12 (0.34)	0.13 (0.32)	0.10 (0.41)	-0.14 (0.27)
BB	Sex	0.04 (0.70)	0.03 (0.76)	-0.05 (0.65)	0.05 (0.66)	0.04 (0.70)	-0.06 (0.60)	0.06 (0.60)	0.05 (0.66)	-0.07 (0.55)
BB	DM	-0.22 (0.11)	-0.20 (0.14)	0.24 (0.09)	-0.21 (0.13)	-0.19 (0.15)	0.23 (0.10)	-0.20 (0.14)	-0.17 (0.20)	0.21 (0.13)
BB	HTN	-0.14 (0.27)	-0.12 (0.33)	0.16 (0.22)	-0.13 (0.30)	-0.11 (0.36)	0.15 (0.25)	-0.12 (0.33)	-0.10 (0.41)	0.14 (0.27)
BB	IHD	-0.10 (0.41)	-0.09 (0.44)	0.11 (0.38)	-0.09 (0.48)	-0.08 (0.51)	0.10 (0.41)	-0.08 (0.51)	-0.07 (0.55)	0.09 (0.48)
BB	Pre-op Diameter	0.50 (0.003)	0.48 (0.004)	-0.36 (0.03)	0.52 (0.002)	0.50 (0.003)	-0.34 (0.04)	0.55 (0.001)	0.52 (0.002)	-0.32 (0.05)

Correlation analysis between preoperative patient characteristics and postoperative AVF outcomes at 1st, 3rd, and 6th weeks revealed significant associations. Higher preoperative radial artery diameter was positively correlated with postoperative AVF flow at 1st week ($r = 0.45$, $p = 0.002$), 3rd week ($r = 0.48$, $p =$

0.001), and 6th week ($r = 0.51$, $p < 0.001$). Similarly, preoperative cephalic vein diameter showed a positive correlation with AVF flow at 3rd week ($r = 0.39$, $p = 0.01$) and 6th week ($r = 0.42$, $p = 0.008$). Thrombosis occurrence was negatively correlated with both radial artery diameter ($r = -0.41$, $p = 0.005$) and cephalic vein diameter ($r = -0.36$, $p = 0.01$), indicating smaller vessels were more prone to thrombosis. Age, DM, HTN, and IHD showed no significant correlations with AVF flow or diameter at any postoperative interval.

These findings suggest that preoperative vessel diameter is a key determinant of early AVF maturation and patency, while patient comorbidities had limited impact on early postoperative outcomes. (Table – 02)

Thrombosis occurred in 8 patients (8.7%). Thrombosis was more common in BB-AVF (16%) and patients with diabetes (14.3%). Older age (>60 years) and diabetes also showed higher rates of thrombosis.(table 03)

Table 3. Break down of details of patients with thrombosis

Variable	Category	No of Patients with Thromb-osis	Total in Category	% with Thrombosis
Age	≤60	5	36	13.9%
	>60	3	33	9.1%
Sex	Male	6	50	12%
	Female	2	19	10.5%
Diabetes	Yes	6	42	14.3%*
	No	2	27	7.4%
Hyper-tension	Yes	4	38	10.5%
	No	4	31	12.9%
IHD	Yes	2	20	10%
	No	6	49	12.2%
AVF Type	RC-AVF	4	25	16%
	BC-AVF	3	31	9.7%
	BB-AVF	1	13	7.7%

* Significant

DISCUSSION

This prospective study evaluated 69 patients undergoing AVF creation, with serial duplex ultrasound assessments at 1, 3, and 6 weeks postoperatively. The majority of patients were male (72.5%), with a mean age of 58.6 years (range 14–84 years). Common comorbidities included diabetes mellitus (60.9%), hypertension (59.4%), and ischemic heart disease (21.7%). (table 1)

Our results showed progressive maturation of AVFs over time. The mean diameter and flow of all AVF types increased from the first to the sixth week, indicating successful vascular remodeling and hemodynamic adaptation. Similar results were noted by other studies as well. [8]

BC-AVFs had the highest mean flow rates, followed by BB-AVFs and RC-AVFs. Previous studies have shown that proximal AVFs, especially brachiocephalic fistulas, exhibit higher blood flow rates compared with distal radiocephalic fistulas, consistent with our findings.[9-11]

Thrombosis occurred in 10.9% of patients, primarily in those with smaller preoperative vessels and diabetes mellitus. This aligns with published evidence that smaller preoperative vessel diameters and the presence of diabetes mellitus are significant predictors of early AVF failure.[5] RC-AVFs, BC-AVFs, and BB-AVFs exhibited thrombosis rates of 16%, 9.7%, and 7.7%, respectively, reflecting the influence of AVF type (table 2) and vessel characteristics on early failure as also noted by others.[10]

Thrombosis (Table 3) was more frequently observed in patients with diabetes and smaller preoperative AVF diameters, underscoring the impact of systemic vascular disease and vessel size on fistula patency. These findings are consistent with previous studies identifying diabetes and comorbid vascular disease as significant risk factors for early AVF failure.[5,10]

Duplex ultrasound provided valuable quantitative assessment of both diameter and flow, enabling early detection of AVF dysfunction.[11,12] Our study demonstrates that serial evaluation can guide timely interventions to optimize maturation and reduce thrombosis rates.

Limitations include the single-center design, relatively small sample size, and short follow-up period. Longer-term follow-up would provide further insights into fistula patency and functional outcomes for dialysis.

CONCLUSION

Serial duplex ultrasound evaluation of AVFs is a reliable and effective method for monitoring maturation and detecting early complications. BC-AVFs showed the highest mean flow rates, while RC-AVFs demonstrated slightly lower thrombosis rates compared to BC- and BB-AVFs. Thrombosis was more common in patients with smaller preoperative vessel diameters, diabetes mellitus, ischemic heart disease, and older age. Early postoperative assessment enables timely detection and management of suboptimal AVF maturation or thrombosis, which may improve long-term patency and overall AVF success.

ETHICAL APPROVAL

Ethical approval of article was granted by the Institutional Review Board of Combined Military Hospital (CMH) vide reference No. 756

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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AUTHOR'S CONTRIBUTIONS

FS: Conceived idea, study design, manuscript writing,
MIK: Data collection, data analysis
HKP: Manuscript writing, data analysis
ARA: Manuscript writing, critical review
IS: Data analysis, review of manuscript
All Authors: Approval of the final version of the manuscript to be published

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