International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 13; Issue: 8; August 2026
Website: www.ijrrjournal.com
Research Paper *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Outcomes of Arteriovenous Fistula Creation for Haemodialysis Access: A Prospective Cohort Study

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DOI: https://doi.org/10.52403/ijrr.20260852

ABSTRACT

Arteriovenous fistula (AVF) is the preferred long-term vascular access for chronic haemodialysis because of its durability and low complication rate, yet primary failure remains common. This prospective cohort study evaluated outcomes of AVF creation and factors affecting maturation at the Department of Urology, Rajarajeswari Medical College and Hospital (RRMCH), Bengaluru, between July 2024 and January 2026. Seventy-five patients with end-stage renal disease (ESRD) underwent AVF creation after preoperative duplex ultrasonographic vascular mapping, with venous diameter reassessed at 8 weeks. Sixty fistulas (80%) were brachiocephalic and fifteen (20%) radiocephalic. Two patients died during follow-up; of the remaining 73, 57 (78.1%) achieved successful maturation and 16 (21.9%) had primary failure. Radiocephalic fistulas failed more often than brachiocephalic fistulas (71% vs 11%, p=0.045). Preoperative vein distensibility below 50% (OR 0.1, p=0.010) and vein diameter below 2mm (OR 6.9, p=0.005) independently predicted failure; a receiver operating characteristic curve identified a preoperative vein diameter cut-off of 2.25mm (AUC 0.741) for predicting successful maturation. Preoperative duplex ultrasonographic vascular mapping is a valuable, low-cost tool for optimising AVF outcomes, particularly for radiocephalic fistulas.

Keywords: *Arteriovenous fistula; Haemodialysis; Vascular access; Primary failure; Duplex ultrasonography*

INTRODUCTION

Patients with end-stage renal disease (ESRD) requiring chronic haemodialysis have been increasing in number in India, along with growth in dialysis centres and access to treatment. Effective haemodialysis depends on a reliable vascular access, of which three forms exist: central venous haemodialysis catheters, arteriovenous grafts, and arteriovenous fistulas (AVFs) [1-2].

An AVF is a surgically created anastomosis between an artery and a vein. Following surgery, the vein begins to dilate and arterialise under arterial pressure; the fistula is considered mature once the vein is large and superficial enough to be reliably cannulated. Possible configurations include radiocephalic, brachiocephalic, brachiobasilic (forearm or transposed), and lower-extremity AVFs [2-3].

Recognised risk factors for primary AVF failure include predialysis hypotension, smoking, significant vascular abnormalities such as arteriosclerosis, comorbidities including diabetes mellitus, and older age [4]. Vessel diameter is a key determinant of maturation success even in patients with substantial comorbidity [5], while poor vein

anatomy and repeated venipuncture trauma further increase failure risk [6].

For an AVF to be usable for dialysis it must support a blood flow of at least 500-700ml/min, offer a relatively straight cannulation segment of 8-10cm, sit within 5-6mm of the skin surface, and be reliably and repeatedly accessible with the patient comfortably seated. Meeting these criteria depends heavily on appropriate preoperative vessel selection, which is where clinical examination and adjunctive imaging, particularly duplex ultrasonography, play a central role. Despite the recognised importance of these factors, no prior study had examined AVF outcomes or their determinants at our institution, and institution-specific failure rates and predictors are necessary to guide preoperative patient selection and reduce reliance on central venous catheters, which carry higher infection and mortality risk.

The aim of this study was to determine the outcome of AVF creation, defined by successful functional maturation versus primary failure, and the objectives were to: (i) determine the overall rate of successful AVF maturation and primary failure among ESRD patients undergoing AVF creation at RRMCH; (ii) compare outcomes between brachiocephalic and radiocephalic configurations; and (iii) identify which demographic characteristics, comorbidities, and preoperative vascular mapping parameters were independently associated with primary failure, so as to inform preoperative counselling and vessel selection protocols going forward.

LITERATURE REVIEW

The AVF is the preferred long-term haemodialysis access because of its superior primary patency, fewest required interventions, and lowest morbidity and mortality among access types, which in turn lowers the healthcare costs associated with vascular access procedures and their complications. Vascular access failure remains a major driver of hospitalisation and cost in haemodialysis populations, with one estimate attributing over 20% of hospitalisations and more than $1 billion in annual costs in the United States to access-related procedures and complications [7].

Primary failure is defined as an AVF that has never been usable for dialysis, or that fails within three months of creation, generally reflecting failure of maturation [8-9]. Reported primary failure rates vary widely, from 10-60% across randomised studies [7,10]. The Hemodialysis Fistula Maturation Study reported a 40% failure rate [11], a 43-study meta-analysis reported 23% [12], a 2-year Mayo Clinic series of 317 AVFs reported 37.1% [13], and a 10-year Nigerian series of 80 AVFs reported only 7.5%, with diabetes and thrombosis as the leading contributors to failure [14]. Radiocephalic fistulas have consistently shown the highest failure rates and brachiobasilic transpositions the lowest among fistula types; Hakaim et al. reported failure rates of 70%, 27%, and 0% for radiocephalic, brachiocephalic, and brachiobasilic fistulas respectively [15-17].

The literature on patient-level predictors of failure is inconsistent. Some studies report age as an independent negative predictor of AVF success [18], while others find no age-related difference [3]; US Renal Data System figures show only modest variation in failure rate across age bands (32-40%) [19], and Woods et al. found AVFs in patients over 65 years had a 24% lower risk of failure than grafts [20]. No consensus minimum arterial or venous diameter threshold exists, though a 2mm threshold is most frequently cited; a radial artery diameter below 1.5mm has been linked to high primary failure [21], and a combined cephalic vein/radial artery diameter below 1.6mm to early failure [6]. Vein distensibility on preoperative duplex ultrasonography has been shown to be a stronger predictor of eventual AVF diameter than the resting diameter itself [22].

Diabetes does not appear to independently worsen AVF outcomes once vessel calibre is accounted for [2,23], whereas peripheral arterial disease and associated intimal hyperplasia have been linked to higher failure rates, particularly in older, more

diabetic patients [24-25]. Maturation is generally apparent within four to six weeks of creation [8], with measurable increases in blood flow and cross-sectional area as early as two weeks [26], and venous diameter and flow largely plateauing by the second postoperative month [27].

A recurring theme across this literature is that fistula configuration and preoperative vessel quality, rather than any single demographic factor, are the dominant determinants of maturation success. This has practical implications for surgical planning: where physical examination alone is equivocal, particularly in the forearm, preoperative duplex ultrasonographic vascular mapping allows more objective vessel selection than examination alone, and may permit a higher proportion of radiocephalic fistulas, generally preferred as the most distal and access-conserving option, to be attempted safely rather than defaulting to a more proximal brachiocephalic configuration.

MATERIALS & METHODS

This was a prospective cohort study of adult patients with ESRD who underwent AVF creation for haemodialysis at the RRMCH Urology Department between July 2024 and January 2026 (18 months). Patients with chronic kidney disease approaching ESRD, as well as those already on haemodialysis via tunnelled central venous catheters, were recruited from the RRMCH Renal Unit after informed consent. Inclusion required referral for AVF creation; exclusion criteria were vessels below 1.5mm on physical examination and Doppler ultrasound, limb swelling or central venous stenosis on prior catheter use, age under 18 years, unavailability for follow-up, and terminal illness.

Sample size was calculated using Fisher's formula ($Z=1.96$, expected success proportion 95%, precision 0.05), yielding a minimum of 73 patients; allowing for an estimated 5% loss to follow-up, a final target of 77 patients was set. Convenience sampling was used, recruiting consecutive eligible referrals until the target was reached; 75 patients ultimately underwent AVF creation within the study period.

Preoperative assessment included history, physical examination (arterial pulses, inter-arm blood pressure difference, modified Allen test, venous outflow and distensibility), and duplex ultrasonographic vascular mapping of arterial and venous diameters where physical examination was inconclusive. Fistula type and site were selected based on these findings. Intraoperatively, arterial and venous internal diameters were recorded before anastomosis, and presence of a thrill was noted immediately after fistula creation. Patients were followed up at 4, 8, and 12 weeks, with duplex ultrasonography repeated at 8 weeks to reassess venous diameter, and timing of first successful cannulation, dialysis duration, and achieved blood flow rates recorded.

An AVF was considered mature if venous internal diameter exceeded 4.0mm at 8 weeks with blood flow above 500ml/min, permitting successful cannulation and dialysis; primary failure was defined as an AVF never usable for dialysis or failing within three months of creation. Ethical approval was obtained from the RRMCH Ethics and Research Committee, and patient confidentiality was maintained throughout.

Statistical Analysis

Data were analysed using SPSS version 23. Categorical variables were summarised as frequencies and percentages and continuous variables as means/medians with standard deviation/interquartile range. Associations between patient/vascular characteristics and outcome were assessed using the chi-square test, with significant variables carried forward to univariate logistic regression (odds ratios with 95% confidence intervals; $p<0.05$ considered significant). Receiver operating characteristic (ROC) analysis was used to identify a predictive vein diameter cut-off.

RESULT

Seventy-five AVFs were created in 75 patients; two died during follow-up. Fifty patients (66.0%) were male and 25 (34.0%) females, with a mean age of 49.6 years (SD 14.4; range 25-77). The most represented age band was 61-70 years (29%). Hypertension was the leading cause of ESRD (60.5%, n=45), followed by diabetes mellitus (27.2%, n=20), glomerulonephritis (9.3%, n=7), obstructive uropathy (2.6%, n=2), and polycystic kidney disease (1.3%, n=1). Sixty-eight patients (90.6%) were already on haemodialysis via a central venous catheter prior to AVF creation. Seventy-one percent (n=53) had no clinical comorbidity beyond their ESRD aetiology; diabetes mellitus accounted for 26.3% (n=20) as a comorbidity, and obesity and congestive cardiac failure each accounted for 1.3% (n=1).

All patients had normal arterial pulses on examination. Inter-arm blood pressure difference was normal (<10mmHg) in 80% (n=60), abnormal (>20mmHg) in 10.6% (n=8), and marginal in 9.4% (n=7). Good venous outflow and distensibility (>50% of resting diameter) was present in 92% (n=69). On preoperative duplex mapping, mean brachial artery diameter was 4.2mm (SD 1.0) and mean radial artery diameter 2.7mm (SD 0.5).

Preoperative vein diameters clustered predominantly in the 2.0-2.9mm range for both configurations (59.9% of brachiocephalic and 73.3% of radiocephalic fistulas), while preoperative artery diameters were generally larger for brachiocephalic fistulas, with 25.3% in the 3.5-3.9mm band compared with the radiocephalic group, in which two-thirds of arteries measured below 3.0mm. Sixty fistulas (80%) were brachiocephalic and 15 (20%) radiocephalic, all fashioned in the left upper limb. A thrill was present immediately postoperatively in 96% (n=72); the three without a thrill (one brachiocephalic, two radiocephalic) all had preoperative vein diameters below 2.0mm. At 8 weeks, mean venous diameter overall was 6.4mm (SD 0.9; range 3.5-17.5mm), and was higher for brachiocephalic than radiocephalic fistulas (7.6mm [SD 2.7] vs 5.4mm [SD 1.3]); the majority of brachiocephalic fistulas achieved a diameter of 6.1-8.0mm at 8 weeks, whereas most radiocephalic fistulas plateaued lower, in the 4.1-6.0mm range.

Excluding the two deaths, 57 of 73 fistulas (78.1%) achieved successful maturation and functional dialysis, while 16 (21.9%) had primary failure. Failure was significantly more common among radiocephalic than brachiocephalic fistulas (10/14, 71% vs 6/59, 11%; OR 0.4 for brachiocephalic vs radiocephalic, p=0.045). On univariate analysis, vein distensibility below 50% (OR 0.1, 95% CI 0.03-0.6, p=0.010) and preoperative vein diameter below 2mm (OR 6.9, 95% CI 1.8-27.1, p=0.005) were significant predictors of failure. Age (≤40 years OR 1.4, p=0.593; 41-60 years OR 1.2, p=0.751), female gender (OR 1.5, p=0.388), diabetes (OR 0.9, p=0.887), prior haemodialysis vascular access (OR 2.3, p=0.437), inter-arm blood pressure difference, and preoperative artery diameter below 2mm (OR 6.1, p=0.056) were not statistically significant. ROC analysis of preoperative vein diameter against outcome yielded an area under the curve of 0.741 (SE 0.057, 95% CI 0.629-0.853, p<0.001), identifying an optimal cut-off of 2.25mm (sensitivity 74.7%, 1-specificity 33.3%).

DISCUSSION

This prospective cohort provides the first institutional data on AVF outcomes at RRMCH and one of few such datasets from a single Indian tertiary urology unit using systematic preoperative duplex mapping for every patient rather than physical examination alone. The prospective design, standardised 8- and 12-week follow-up, and use of both chi-square screening and univariate logistic regression strengthen the reliability of the associations identified, even within a moderate sample size.

The overall primary failure rate of 21.9% observed in this cohort falls within the wide range reported internationally (10-60%) [7,10-

[13], and is comparable to several moderate-sized single-centre series. As in prior work comparing fistula configurations, radiocephalic fistulas failed substantially more often than brachiocephalic fistulas in this study (71% vs 11%, p=0.045), a difference reaching statistical significance and consistent with Hakaim et al.'s finding of markedly higher failure among radiocephalic compared with brachiocephalic and brachiobasilic fistulas [15]. The reduced calibre of forearm vessels relative to those at the elbow or upper arm is the most plausible explanation for this consistent finding.

The mean venous diameter achieved at 8 weeks (6.4mm, SD 0.9) and the observation that all three fistulas with a diameter below 4mm were considered failures mirror findings by Robbin et al., who similarly identified a minimum venous diameter of approximately 4.0mm as necessary for dialysis adequacy [27].

Consistent with the inconsistent literature on age as a risk factor [3,18], age was not a significant predictor of failure in this cohort, though patients above 60 years trended toward higher failure than younger groups. The male-predominant referral pattern observed here mirrors national data showing higher rates of ESRD among men [19]; female gender trended toward higher failure risk but did not reach significance, consistent with the mixed findings reported elsewhere for gender as a predictor. Diabetes mellitus was not associated with increased failure risk (OR 0.9), in keeping with evidence that vessel calibre, rather than diabetic status itself, drives outcomes [2,23].

Over 90% of patients referred for AVF creation were already dialysing via a central venous catheter, underscoring the continued reliance on catheters pending fistula creation in this setting; earlier, elective referral by nephrologists could reduce catheter-associated morbidity and mortality [28]. Prior haemodialysis vascular access trended toward higher failure risk in this cohort, consistent with data linking prior temporary catheter use to increased fistula failure [29].

Vein distensibility of at least 50% and a preoperative vein diameter above 2mm were the strongest, statistically significant predictors of successful maturation, corroborating Malovrh et al.'s observation that distensibility predicts eventual AVF calibre more reliably than resting diameter alone [22]. While no universally accepted minimum diameter threshold exists [6], the ROC-derived cut-off of 2.25mm identified here offers a practical, institution-specific benchmark for preoperative vessel selection. Systematic preoperative duplex ultrasonographic mapping allowed exclusion of patients with inadequate vessels before fistula creation and likely contributed to containing the overall failure rate, while also enabling more radiocephalic fistulas to be attempted with confidence in cases where physical examination alone was inconclusive.

Artery diameter below 2mm showed a similar direction of effect to vein diameter (OR 6.1) but did not reach statistical significance, likely reflecting the small number of patients with such small arteries (n=3) rather than a true absence of association; arterial diameter thresholds have similarly shown a real but less consistently significant association with early failure elsewhere [21]. Taken together, these findings support prioritising venous mapping parameters, diameter and distensibility together, over arterial diameter alone when counselling patients and planning fistula configuration, while still confirming adequate arterial inflow before proceeding to surgery.

This study has limitations. It was a single-centre design with a moderate sample size and an 18-month recruitment and follow-up window, which restricts assessment to primary maturation and does not capture longer-term secondary patency, need for revision, or late failure beyond 12 weeks. Duplex ultrasonography itself is operator-dependent and offers limited visualisation of deep or heavily calcified vessels, which may have led to under- or over-estimation of true vessel quality in a minority of patients, and is

unable to dynamically predict long-term maturation with complete accuracy.

Based on these findings, future work at this institution should prioritise two directions: strengthening early nephrology-to-urology referral pathways so that AVF creation can be planned well ahead of dialysis initiation, reducing reliance on central venous catheters and their associated infective and thrombotic risks; and longer-term, ideally multi-centre, follow-up studies to characterise secondary patency, re-intervention rates, and durability of AVFs created using this preoperative mapping protocol beyond the initial maturation window studied here. Prospective validation of the 2.25mm vein diameter cut-off identified in this cohort in a larger, independent population is recommended to confirm its generalisability as a preoperative selection benchmark.

CONCLUSION

AVF creation at RRMCH achieved outcomes broadly comparable to international series, with an overall primary failure rate of 21.9%. Radiocephalic fistulas failed significantly more often than brachiocephalic fistulas. Preoperative vein distensibility of at least 50% and a vein diameter above the derived cut-off of 2.25mm were the strongest predictors of successful maturation, while age, gender, diabetes, and prior vascular access, though trending toward higher failure risk, were not statistically significant. Systematic preoperative duplex ultrasonographic vascular mapping is an accessible and valuable tool for optimising patient selection and AVF outcomes, particularly when radiocephalic fistulas are being considered.

Declaration by Authors

Ethical Approval: Approved

Acknowledgement: None

Source of Funding: None

Conflict of Interest: No conflicts of interest declared.

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How to cite this article: Vishal Muttappa Gulappagol, Prathvi Shetty, N Srinath, Vinay. Outcomes of arteriovenous fistula creation for haemodialysis access: a prospective cohort study. *International Journal of Research and Review*. 2026; 13(8): 502-508. DOI: *https://doi.org/10.52403/ijrr.20260852*

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