ORIGINAL ARTICLE

# Predicting Suitable Diameters of Radial Artery and Cephalic Vein for Long Term Patency of Radiocephalic Arteriovenous Fistula

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## ABSTRACT

**Objective**: To find out the cut-off values of vascular arterial and venous diameters effecting patency of arteriovenous fistula (AVF) at wrist.

**Methodology:** In this longitudinal study with non-purposive consecutive sampling, all consecutive patients fulfilling the inclusion criteria and undergoing radiocephalic AVF (RC-AVF) were included. Log-Rank test was applied to find the cut-off points and Kaplan-Meier survival was used to detect vascular diameter effects on cumulative patency of RC-AVF at 2 years.

**Results**: A total of 150 RC-AVF were analyzed. Mean age at presentation was 53.5 (SD ± 4.76, Range 46-64) years. Cardiac (P-value: 0.000) and peripheral vascular arterial disease (P-value: 0.004) had a strong negative association with long term patency of access. Dichotomized cutoff point of radial artery was 2mm and cephalic vein was 2.5mm. Radial artery diameter of less than 2mm (SE 1.155; CI: 5.66-525.2; P value: 0.001) and cephalic vein diameter of 2.5mm (SE 1.155; CI: 5.66-525.2; P value: 0.001) are strongly associated with poor long-term patency of RC-AVF.

**Conclusion**: Cephalic vein of <2.5mm and radial artery of <2mm diameter is associated with statistically significant failure rates of RC-AVF.

**Keywords:** Arteriovenous fistula, Fistula failure, Radiocephalic, Vascular diameter.

Authors' Contribution:
*[1,2]Conception; Literature research; manuscript design and drafting; [1,2]Critical analysis and manuscript review; [1,2]Data analysis; Manuscript Editing.*

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## Introduction

Arteriovenous Fistula (AVF) has less complications, better patency, and low mortality risk when compared to HD catheters and arteriovenous grafts.[1-3] Hence native AVF is a preferred method of vascular access for patients needing hemodialysis. Although radiocephalic AVF (RC-AVF) is a preferred access method and allows further proximal future placement options when needed, they do have a high risk of access failure compared to more proximal AVFs.[4] Many factors including comorbidities and vessel diameters are responsible for loss of AV access.[1-3] Clinicians use examination and vascular Doppler to find out suitability of vein and artery for AVF creation.[5-7] Turbulent shearing forces near the vascular anastomosis may initiate intimal damage leading to hyperplasia induced stenotic segments and thrombosis being primary causes for RC-AVF dysfunction.[8]

Many studies have assessed the relationship of vessel diameter to long term patency of RC-AVF and results are variable.[6,7] Since there are no local studies in our population addressing the association of vessel diameter to patency, we designed this study to find out this association if any, between vascular diameters and long-term patency of RC-AVF in our setting.

## Methodology

In this longitudinal study the sample size (n) was calculated using Open Source Epidemiologic Statistics for Public Heath (Open Epi) sample size calculator [formula: $n= (Z_{1-\alpha/2})^2 \times p\,(1-p)/e^2$]. Here $Z_{1-\alpha/2}$ was standard normal variate [at 5% type 1 error and P<=0.05, it is 1.96]. Absolute error (e) was 0.08 (8%). Prevalence (p) was derived from proportion of population from a previously conducted study.[9] The calculated sample size was 120. All consecutive patients who were referred to Vascular Clinic for creation of an AVF from January 2021 to January 2022 were included. Patients with previously failed AVF at wrists, patients requesting more proximal access and patients who did not consent to be included in study, were excluded. Furthermore, those patients who did not maintain the recommended follow up schedule or those who did not complete a minimum of 2 years follow up were also excluded. Vascular mapping was done by trained Vascular Surgeon in the clinic using 10MHz linear vascular probe (LOGIQ Book: GE Medical Systems; Milwaukee, USA). All patients had vascular mapping done in sitting position. The cephalic vein was mapped from wrist to its termination in clavipectoral fascia for any stenosis or thrombosis. If found clear, a tourniquet was applied in lower arm and internal diameter of the vein was calculated from snuffbox to at least 10cm proximally towards forearm at 1 cm intervals. The internal diameter of radial artery was calculated from wrist crease to 5cm proximally at 1cm interval. Mean Arterial Diameter (MAD) and Mean Venous Diameter (MVD) were then calculated. This mapping was done on both arms and the arm with greater mean diameters was selected for the creation of AVF. AVF was created under local anesthesia using plain Lignocaine by a trained Vascular Surgeon with at least 5 years of operative experience. All patients received 2500 units of intravenous un-fractioned heparin before application of arterial clamps. A standard end-to-side anastomosis was made with continuous Prolene 7/0 suture. Any venous tributaries within the operative field if found, were ligated to prevent diversion of flow. All patients were provided written post-operative instructions about the care of AVF. AVF was considered mature for hemodialysis when it met the KDOQI criteria.[10] All patients were followed up regularly and underwent Doppler scan to assess patency of the access at monthly intervals. All patients in which there was any inability to cannulate, significant flow rate reduction or elevated outflow pressures during hemodialysis; underwent venography. All patients with a stenotic lesion of more than 50% underwent Venoplasty to salvage the access. The outcome of the study was measured in terms of primary and secondary patency and access failure. Patency was defined as per Society of Vascular Surgery guidelines.[11] Primary patency is from the time of fistula creation up to its thrombosis, ligation or any intervention done to maintain or restore it. Secondary patency is time from access placement until its abandonment. Failure of access is defined as an inability of AVF to be used for successful dialysis for a period of 1 month.[12] The data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0 software (SPSS Inc., Chicago, IL, USA) and R version 3.5.1 (R Foundation; Statistical Comp: Vienna, Austria). All continuous variables were expressed as means and standard deviations (SD), whereas categorical variables were expressed as frequency and percentage. In order to find out the influence of diameter of radial artery and cephalic vein on maturation of fistula and patency, dichotomized cut-off points were ascertained with the log rank test. The dichotomized cut-off points for secondary patency were considered most predictive of fistula maturation over time hence used for assessing long term patency of the AVF. Cox regression model was used to assess the association between demographic variables and failure of fistula. Kaplan-Meier survival analysis plots were used to assess time to event estimations of patency rates. P-value (two-tailed) was calculated with Bonferroni method, value of less than or equal to 0.05 was considered significant.

**Ethical approval** of the study was approved by the local Ethical Review Committee of CMH Lahore, Medical and Institute of Dentistry (206/ERC/CMHLMC dated 20/8/20).

## Results

There was total 230 cases: 25.2% (n=58) patients expired from systemic illness unrelated to any complication of AVF while 9.5% (n=22) did not complete the mandatory follow-up of 2 years; hence they were excluded. Therefore, the total number of patients completing the study were 150. Mean age was 53.5 (SD ± 4.76, Range 46-64) years. There were 90 males and 60 females. Out of 150, 70% (n=105) AVFs were made in left and 30% (n=45) in right wrist. In terms of major atherosclerotic risk factors; 70% (n=105) had diabetes mellitus, followed by hypertension in 23% (n=35) cases, smoking in 20% (n=30) and hyperlipidemia in 13% (n=20) patients. However, there were 10% (n=15) patients with no major atherosclerotic risk factor. There were 16.6% (n=25) patients who had congestive cardiac failure and 10% (n=15) had ischemic heart disease. Peripheral vascular arterial disease was present in 13.3% (n=20) cases. Cox regression shows that coronary artery disease (P value: 0.000) and peripheral vascular arterial disease (P value: 0.004) have a strong negative correlation with long term patency of radiocephalic AVFs (Table 1). 73.3% (n=110) had non tunneled double lumen dialysis catheter in neck veins and 6.7% (n=10) had tunneled catheter (PermCath®) in place.

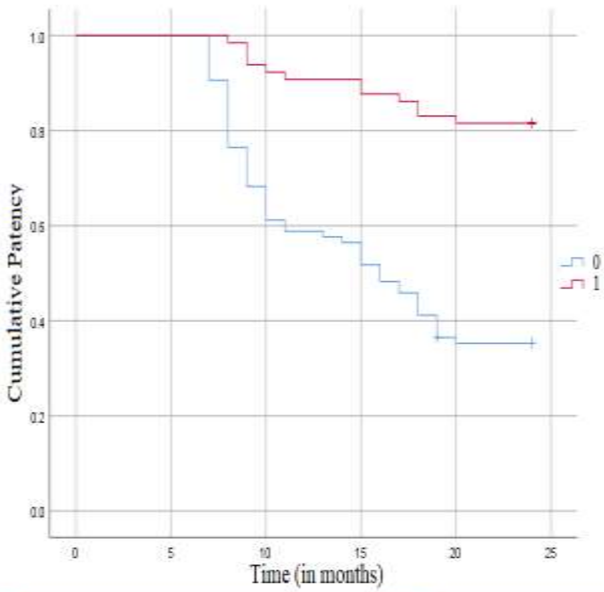
**Table I: Cox Regression analysis showing effect of demographic variables on long term patency of AVF (n=150)**

| Variable | Standard Error (SE) | 95% Confidence Interval (CI) | | P value |
|---|---|---|---|---|
| | | Lower | Upper | |
| Age | 0.054 | 1.024 | 1.263 | 0.017 |
| Gender | 0.330 | 0.265 | 0.966 | 0.039 |
| Diabetes Mellitus | 0.394 | 0.197 | 0.925 | 0.031 |
| Hypertension | 0.351 | 0.641 | 0.322 | 0.205 |
| Smoking | 0.614 | 0.508 | 5.636 | 0.391 |
| Hyperlipidemia | 0.682 | 1.055 | 15.310 | 0.042 |
| Coronary Artery Disease | 0.869 | 3.920 | 118.071 | **0.000** |
| Congestive Cardiac Failure | 0.873 | 0.102 | 3.110 | 0.509 |
| Peripheral Vascular Disease | 1.084 | 0.005 | 0.371 | **0.004** |

All AVFs was patent at 6 months (100%). Primary patency rate dropped to 54.7% at 1 year (n=82). However, 91.1% (n=62/68) patients with failed fistula underwent successful Venoplasty as a salvage procedure. Thus, the cumulative patency rate rose to 75.3% (n=113) at 1 year. Over further course of time, more AVFs failed thus the final cumulative patency dropped down to 55.3% (n=83) by the end of the study period of 2 years.

Mean venous diameter at wrist was 2.6 mm (SD ± 0.29, Range 2.3-3.1). Dichotomized cutoff point [calculated by Log Rank (Mantel Cox) test] for venous diameter at wrist was 2.5mm. Cox Regression Analysis revealed that 64.7% (n=55/85) patients with venous diameter of less than 2.5mm failed to survive (SE 1.216, CI: 13.1-17.9) by the end of 2 years. However, when the diameter of the vein was >= 2.5mm, only 18.4% (n=12/65) failed to survive (SE: 0.69, CI: 17.5-22.2). Based on diameter of vein, survival difference in two groups is statistically significant (SE 1.155; CI: 5.66-525.2; P value: 0.001). When the vein diameter was less than 2.5mm, the drop in the cumulative survival was sharp within 1$^{st}$ year (from 7$^{th}$ month to 11$^{th}$ month).

In this group, 55/85 AVFs FTM by the end of 2 years (blue line – Figure 1) leaving a cumulative patency of 35.3%. In contrast there was a gradual loss of patency starting after 6 months when vein diameter was >=2.5mm and only 12/65 AVFs FTM in this group (red line – Figure 1) leaving a better cumulative patency of 81.5%

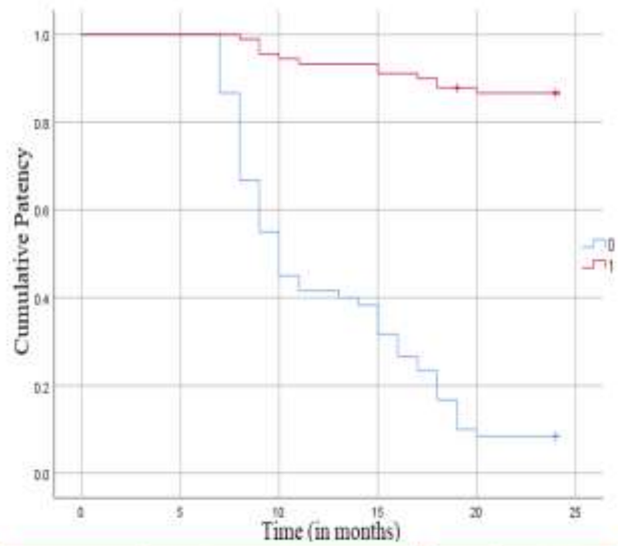



| venousdia less than 2.5=0, else1 | Total N | N of Events | Censored | |
|---|---|---|---|---|
| | | | N | Percent |
| 0 | 85 | 55 | 30 | 35.3% |
| 1 | 65 | 12 | 53 | 81.5% |
| Overall | 150 | 67 | 83 | 55.3% |

| | Chi-Square | df | Sig. |
|---|---|---|---|
| Log Rank (Mantel-Cox) | 32.825 | 1 | .000 |

**Figure 1: Kaplan-Meir Analysis showing effects of diameter of Radial vein on AVF maturation**

Mean diameter of radial artery at wrist was 2.1 mm (SD ± 0.22, Range: 1.9-2.6). Dichotomized cutoff point [calculated by Log Rank (Mantel Cox) test] for radial artery diameter at wrist was 2mm. Cox Regression Analysis revealed that 91.6% (n=55/60) patients with arterial diameter of <= 2mm failed to survive (SE 1.216, CI: 13.1-17.9) by the end of 2 years. However, when the diameter of the artery was >2mm, only 13.3% (n=12/90) failed to survive (SE: 0.69, CI: 17.5-22.2). The survival difference in two groups based on arterial diameter was statistically significant (SE 1.155; CI: 5.66-525.2; P value: 0.001). Similar to vein, there was steep loss of AVFs within 1st year (from 7th month to 11th month) in cases where radial artery diameter was <=2mm (blue line – Figure 2). In this group, 55/60 AVFs FTM by the end of 2 years (blue line – Figure 2) leaving a cumulative patency of only 8.3%. In contrast there was a much lesser loss of patency starting after 6 months when artery diameter was >=2.1mm and only 12/90 AVFs FTM in this group (red line – Figure 2) leaving a significantly better cumulative patency of 86.7%




| radial art dia less than 2.1=0, else 1 | Total N | N of Events | Censored | |
|---|---|---|---|---|
| | | | N | Percent |
| 0 | 60 | 55 | 5 | 8.3% |
| 1 | 90 | 12 | 78 | 86.7% |
| Overall | 150 | 67 | 83 | 55.3% |

| | Chi-Square | df | Sig. |
|---|---|---|---|
| Log Rank (Mantel-Cox) | 115.595 | 1 | .000 |

**Figure 2: Kaplan-Meir Analysis showing effects of diameter of Radial artery on AVF maturation**

## Discussion

The dimensions of preoperative veins and arteries significantly impact the maturation process and long-term viability of autologous AVF. Despite knowing that vessel anatomy affects fistula outcomes, the impact of vessel diameters on fistula maturation and long-term patency varies greatly.[13,19] These differences occur due to variations in the way patients are chosen for studies, measurements are taken, patients are followed up and results are reported. Some studies only look at people getting their first AVF,[15-18] while others don't include people who already had one on the same side.[20] Additionally, most of the studies are about radio-cephalic and/or brachio-cephalic AVFs, some focus exclusively on radio-cephalic AVFs.[15-17] We exclusively enrolled patients with initial RC-AVF, irrespective of their anatomical placement. This decision was made because individuals with secondary AVFs on the same side might present with altered anatomy that could affect vascular diameters. For this reason, patients with prior unsuccessful AVFs in their wrists or those seeking more proximal access were excluded from our study, although it may be labelled as selection bias.

Studies examining vein and artery diameter reveal significant variability in findings. Misskey at el revealed that early thrombosis incidences were less frequent in AVFs formed using vein diameters exceeding 3 mm.[17] Nevertheless, fistula success rates displayed a bi-modal distribution pattern, with greater failures observed in 2-3 mm category and decreased failure noted among patients with cephalic vein diameters below 2 mm or exceeding 3 mm. Some investigators employ MVD as a metric, indicating that an MVD < 2.7 mm is associated with Failure to Mature (FTM) within six months.[1,3] Similarly, an MVD < 3 mm is linked to early thrombosis or FTM in 5% and 26% of cases.[14-17] Moreover, FTM rates range from 19.8% to 45% when vein diameter measures 2–3 mm.[13-17] Notably, successful outcomes are observed when vein diameter measures up to 4 mm, with reported success rates ranging between 76-89%.[19] According to Wong et al, AVFs featuring venous access will inevitably fail where the diameter was <=1.6mm.[21] Additionally, Ferring et al. noted significantly higher access maturation (76% vs. 16%) in fistulae constructed using vein >2 mm diameter.[22] Similarly, Kordzadeh et al suggested a higher FTM rate where venous diameter exceeded 1.5 mm reaching 86%.[19] The result of our study is comparative to this literature. We calculated the dichotomised cutoff point for MVD as 2.5mm and 64.7% (n=55/85) patients with MVD of less than 2.5mm failed when compared to only 18.4% (n=12/65) failure rate when MVD was 2.5mm or more.

Currently few guidelines regarding the impact of vessel diameter on fistula maturation are available. The ESVS recommends a vessel diameter of at least 2 mm below elbow and 3 mm above elbow,[6] while KDOQI 2019 suggests diameter of 2 mm for artery and 2.5 mm for vein.[10] Our study reveals similar outcome with significant differences observed in terms of survival based on the diameter of artery to 2 mm and of vein to 2.5 mm. A recent metanalysis by Feng et al (80 articles) recommended that venous diameter of less than 2 mm is a strong negative predictor for fistula patency however they did not find any difference between primary secondary patency rate over a period of 1 year.[14]

Recommending the strategy of utilising larger arterial and venous vessels (over 2 mm) to improve fistula success might constrain options, especially for younger patients requiring long-term renal support. Embracing smaller veins in younger patients, along with vigilant monitoring, could broaden native options, particularly if patients are referred promptly and AVF creation precedes dialysis commencement. Conversely, for elderly patients already undergoing dialysis with limited life expectancy, selecting elbow options with adequate vessel size might provide more predictable success rate and fewer complications.

Although we found similar cutoff values of vascular diameters in our population when compared across the world, yet we acknowledge the limitations of our study. We did not assess other anatomical factors such as vein compliance and arterial calcification. There was potential risk of selection bias because of pattern of referral and favourable anatomy. For those reasons we recommend further multicentre studies with larger patient pool to adequately assess the effect of vascular diameters on long term patency of radiocephalic AVF in our population. The dimensions of preoperative veins and arteries significantly impact the maturation process and long-term viability of autologous AVF. Despite knowing that vessel anatomy affects fistula outcomes, the impact of vessel diameters on fistula maturation and long-term patency varies greatly.[13-19] These differences occur due to variations in the way patients are chosen for studies, measurements are taken, patients are followed up and results are reported. Some studies only look at people getting their first AVF,[15-18] while others don't include people who already had one on the same side.[20] Additionally, most of the studies are about radio-cephalic and/or brachio-cephalic AVFs, some focus exclusively on radio-cephalic AVFs.[15-17] We exclusively enrolled patients with initial RC-AVF, irrespective of their anatomical placement. This decision was made because individuals with secondary AVFs on the same side might present with altered anatomy that could affect vascular diameters. For this reason, patients with prior unsuccessful AVFs in their wrists or those seeking more proximal access were excluded from our study, although it may be labelled as selection bias.

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Although we found similar cutoff values of vascular diameters in our population when compared across the world, yet we acknowledge the limitations of our study. We did not assess other anatomical factors such as vein compliance and arterial calcification. There was potential risk of selection bias because of pattern of referral and favourable anatomy. For those reasons we recommend further multicentre studies with larger patient pool to adequately assess the effect of vascular diameters on long term patency of radiocephalic AVF in our population.

## Conclusion

Radial artery of <2mm and vein of <2.5mm diameter at the wrist is associated with statistically significant loss of patency of radiocephalic arteriovenous fistula.

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