Predictive Diameter of Cephalic Vein and Brachial Artery in Relation to Long Term Patency of Brachiocephalic Arteriovenous Fistula

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Abstract

Objective: To find out the mean perianastomotic venous and arterial diameters cutoff values in relation to long term patency of brachiocephalic access.

Material and Methods: All patients fulfilling the inclusion criteria underwent vascular mapping preoperatively to find out mean diameter of cephalic vein and brachial artery. Kaplan-Meier survival analysis was done to analyze the effect of vascular diameters on patency of the access and find out the predictive values. Cox regression analysis was performed to identify the independent predictors of access failure.

Results: A total of 100 brachiocephalic accesses were analyzed with a minimal follow-up of 2 years. Mean age was 54.2 ± SD 5.71 years with male to female ratio of 1.8:1. Advancing age (P-value: 0.001); diabetes mellitus (P-value: 0.001), coronary artery disease (P-value: 0.000) and congestive cardiac failure (P-value: 0.001) had a strong negative association with long term patency of access. Mean brachial artery diameter less than 4mm (SE 2.050; CI: 0.000-0.005; P value: 0.000) and mean venous diameter of cephalic vein less than 3.5mm (SE 1.155; CI: 5.66-525.2; P value: 0.001) are strong negative predictors of patency of brachiocephalic access.

Conclusion: Mean cephalic vein of <3.5mm and brachial artery of <4mm diameters are associated with high fistula failure rates.

Keywords: Brachiocephalic, Fistula, Diameter, Failure.

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Introduction

Chronic renal failure is a prevalent condition affecting more than 800 million individuals worldwide which is almost 10% of the total population.[1] Although autologous arteriovenous fistula (AVF) is the gold standard in treatment of patients with end stage renal disease, due to multiple factors high rates of failure is noted in almost 60% of the patients.[2,3] Along with other multiple factors, the role of diameter of the afferent artery and efferent vein on maturation and long term patency of the target AVF has been widely discussed[4,5]. Preoperative ultrasound mapping is a recommended tool which helps in deciding the site of AVF creation based on the diameter and flow velocities of the artery and veins.[6,7] The results of the studies looking at effect of vessels diameter in terms of fistula maturation and failure are conflicting and no standardized guidelines are available.[4,5] There is little consensus regarding the diameters in relation to a particular site of AVF.

Keeping in view the conflicting evidence and results in literature, we aim to assess the role of diameter of vein and artery in patency of AVF in our local population cohort. Since the diameter of vessels vary according to site and including different sites may create a potential

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bias, we chose only the brachiocephalic fistula to assess the influence of varying arterial and venous diameters on their maturation and long term patency.

Material and Methods

All consecutive patients referred to vascular surgery clinic for creation of an AVF were included in the study. The study was approved by the local ethical review committee (ref 523/ERC/CMH/LMC dated 20/03/2023). Patients underwent preoperative Doppler imaging using 10MHz linear vascular probe (LOGIQ Book, GE Medical Systems, Milwaukee, WI, USA). The Doppler was performed while patient was in sitting position. The cephalic vein was mapped from cubital fossa to its termination in clavipectoral fascia for any stenosis or thrombosis. If found clear, a tourniquet was applied in upper arm and then internal diameter of the vein was measured from cubital fossa to at least 10cm proximally at 1cm intervals. For brachial artery, the internal diameter of the artery was measured from its bifurcation 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 creation of the AVF.

AVF was created under local anesthesia using plain Lignocaine by a trained Vascular Surgeon with at least 5 years of experience. All patients received 2500 units of intravenous un-fractioned heparin before application of arterial clamps. A standard end to side anastomosis was made using continuous Prolene 6/0 suture. Any tributary of the cephalic vein within the operative field if found, was 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.[8] 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 lesions of more than 50% underwent venoplasty to salvage the access.

The outcome of the study was measured in terms of primary patency, secondary patency and access failure. Primary and secondary patency was defined as per Society of Vascular Surgery guidelines.[9] Primary patency was defined as patency from the time of fistula creation until its thrombosis or ligation or any intervention done to maintain/restore patency. Secondary patency was defined as time from access placement until the time of its abandonment. Access failure is defined according to American Society of Nephrology Kidney Heath Initiative as inability of AVF to be used for successful dialysis for a period of 1 month.[10]

The data was analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0 software (SPSS Inc., Chicago, IL, USA). 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 relative influence of diameter of brachial artery and cephalic vein on fistula maturation and patency, dichotomized cut points were determined using the log rank test to find out the strongest predictive outcome of continuous variables. The generated dichotomized cut point for secondary patency was considered most predictive of fistula maturation over time hence this was applied for the assessment of both primary and secondary patency rates. Cox regression analysis was performed to see the association of different variables with failure of fistula. Time-to-event estimations for primary and secondary patency were done using Kaplan-Meier survival analysis. P-value (two-tailed) of ≤ 0.05 was considered to be statistically significant.

Results

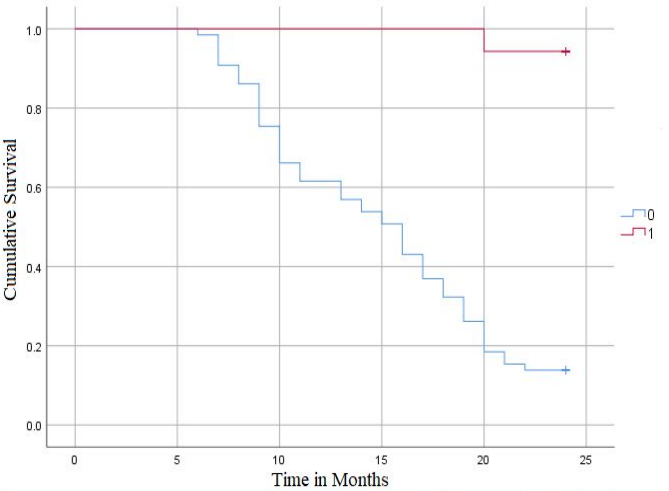
A total of 150 consecutive patients from January 2020 to January 2021 were included in this study. Of these, 23.3% (n=35) patients expired from systemic diseases unrelated to fistula access complications and 10% (n=15) did not complete the mandatory follow-up of 24 months; hence they were excluded. The total number of patients included in this study is 100. Mean age of the patients at the time of presentation was 54.2 (SD ± 5.71, Range 41-65) years. There were 65 males with a male to female ratio of 1.8:1. 68 AVF were made in left and 32 in right cubital fossa. In terms of atherosclerotic risk factors; 80% had diabetes mellitus as major risk factor, followed by hypertension in 20%, hyperlipidemia in 20% and smoking in 15%. There were 42% cases with more than one major risk factors positive, however 14% patients had none of the major risk factors. In terms of cardiac disease, 20% had ischemic heart disease and 5% had congestive cardiac failure. Peripheral vascular disease was present in 25% cases. At the time of fistula creation, 95% cases were already on hemodialysis and had either

a double lumen catheter or tunneled catheter in place. It is worth nothing that 35% patients had a previously failed fistula which either did not mature or failed later on. Cox regression analysis of these variables is shown in table 1. Advancing age (P value: 0.001); diabetes mellitus (P value: 0.001), coronary artery disease (P value: 0.000) and congestive cardiac failure (P value: 0.001) have a strong negative association with long term patency of AVFs.

The primary patency of AVF was 100% at 6 months. It reduced to 50% at 1 year. However 25 patients underwent salvage procedure i.e. Venoplasty, hence the cumulative secondary patency at 1 year was 75%. The final cumulative secondary patency dropped down to 42% by the end of the study period of 2 years.

Cox Regression Analysis showed that 86.1% (n=56/65) patients with brachial artery diameter less than 4mm failed to survive (SE 0.705, CI: 13.6-16.3). However with the diameter of the brachial artery greater than 4mm, only 5.7% (n=2/35) failed to survive (SE: 0.157, CI: 23.4-24.0). The difference in the survival based on the diameter of brachial artery is statistically significant (SE 2.050; CI: 0.000-0.005; P value: 0.000). Figure 1 shows the results of the Kaplan-Meier analysis of arterial diameters in a cumulative form in relation to patency of fistulae over the study period of 2 years. Less than 4mm diameter was coded 0 on analysis (blue curve). It shows progressive loss of patency of AVF starting after 6 months to a cumulative patency of only 13.8% by the end of 2 years. Diameter more than 4mm was coded 1 (red curve), which stays horizontal till about 20 months followed by sum drop to 94.3% patency by the end of 24 months. The difference in final patency between two groups is significant (P value: 0.000).

In terms of venous diameters, 84% (n=21/25) patients with cephalic vein diameter less than 3.5mm failed to survive (SE 1.216, CI: 13.1-17.9). However when the diameter of the cephalic vein was greater than 3.5mm, only 49.3% (n=37/75) failed to survive (SE: 0.69, CI: 17.5-22.2). The difference in the survival based on the diameter of cephalic vein is statistically significant (SE 1.155; CI: 5.66-525.2; P value: 0.001). There is persistent drop in the cumulative survival and only 16% cases (venous diameter < 3.5mm) were patent by the end of 24 months (Figure 2). Other group shows less gradual drop to a final patency of 50.7% by the end of study period.



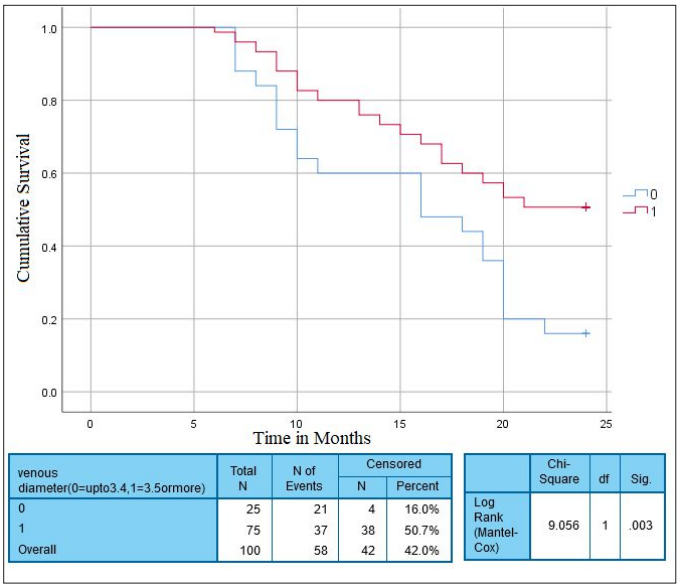
brachialartdia(lessthan4=0,else1)	Total N	N of Events	Censored N	Censored Percent
0	65	56	9	13.8%
1	35	2	33	94.3%
Overall	100	58	42	42.0%

	Chi-Square	df	Sig.
Log Rank (Mantel-Cox)	56.856	1	.000

Figure-1. *Kaplan-Meier Analysis showing cumulative patency stratified by arterial diameter [Log-rank (Mantel Cox), Chi-Square 56.85; P value 0.000].*

Table 1: *Cox Regression Analysis for Brachiocephalic Fistulae*

Variable	[n]	Standard Error (SE)	95.0% CI		P Value
			Lower	Upper	
Age [Mean]	54.2	.088	.625	.882	0.001
Gender [Male / Female]	65 / 35	1.100	.004	.272	0.002
Diabetes Mellitus	80	1.227	6.119	750.358	0.001
Hypertension	20	.801	.377	8.710	0.458
Smoking	15	.945	.014	.563	0.010
Hyperlipidemia	20	1.151	1.399	127.237	0.024
Coronary Artery Disease	20	1.390	.000	.061	0.000
Congestive Cardiac Failure	5	2.631	.000	.022	0.001
Peripheral Vascular Disease	25	.658	.589	7.776	0.248



venous diameter(0=upto3.4,1=3.5ormore)	Total N	N of Events	Censored	
			N	Percent
0	25	21	4	16.0%
1	75	37	38	50.7%
Overall	100	58	42	42.0%

	Chi-Square	df	Sig.
Log Rank (Mantel-Cox)	9.056	1	.003

Fig-2. *Kaplan-Meier Analysis showing cumulative patency stratified by venous diameter [Log-rank (Mantel Cox), Chi-Square 9.056; P value 0.003]*

Discussion

Creation of AVF has been recognized as an optimal approach for hemodialysis in patients with end-stage renal disease because of higher patency rates and lower risk of complications such as stenosis and thrombosis as compared to central venous catheters or arteriovenous grafts[11,12]. However, AVFs are prone to failure due to various factors affecting their maturation. Preoperative techniques for the guidance of the surgeon have resulted in an increased number of fistulas placed and improvement in the selection of suitable functional vessels for successful vascular access. However, the role of preoperative vascular mapping varies in literature. Many studies advocate the role of preoperative mapping in identifying the cutoff values for vascular diameters in relation to maturation of AVF.[13-15] On the other hand; for instance according to Brazilian Society of Angiology and Vascular Surgery guidelines, there is no conclusive evidence (level 2C) of effectiveness of preoperative vascular mapping for AVF creation.[16]

In the creation of an AVF, venous diameter is considered as one of the predictors of successful maturation.[17] In literature, there is no scientific agreement on the ideal venous diameter for successful maturation, however, it is considered to vary between 2.5mm to 4mm.[17] In our study, 84% of the patients with a venous diameter less than 3.5mm failed to survive. This finding is in accordance with previously done studies such as by Lauvao et al.[18] They concluded that vein diameter was a sole independent predictor of fistula maturation, with maturation rate for brachiocephalic AVF (BC-AVF) of diameter greater than 4mm being 81%. Gjorgjievski et al concluded that a cephalic venous diameter of more than 3.12 mm (P = 0.018) positively predicts the success of an AVF14. In another study vein diameter of less than 2.5mm is considered to be inadequate for fistula creation.[17] The maturation of the fistula was unsuccessful in only 49.3% of the patients with cephalic venous diameter >4mm. However In contrast there are many studies which concluded otherwise. In a study of 135 patients with BC-AVF, Kakkos et al concluded that minimum venous diameter of the cephalic vein was not a predictor of AVF patency.[13] Similarly, in another observational cohort study of 602 participants, the venous diameter was inconclusive and non-linear in the prediction of the development of early thrombosis[19]. These inconsistencies in literature may be due to variance in the selection of patients, comorbidities and functional factors. In our study, a brachial artery diameter of greater than 4mm was a positive predictor of AVF survival, with only 5.7% of the patients with a diameter greater than 4mm failing to survive over a study period of 2 years. Gjorgjievski et al concluded that brachial artery diameter of more than 4.78 mm (P = 0.001) positively predicts the success of an AVF[14]. Maya et al reported a significantly lower mean arterial diameter in fistulas which failed to mature as compared to those without failure.[20] In that study, a brachial artery diameter of less than 4.4mm (SD ± 0.9) was predictive of primary failure. Kakkos et al concluded that brachial artery diameter of < 4.1mm is an independent negative predictor for AVF maturation (P = 0.017).[13] In another cohort study, an arterial diameter of >2mm was found to be associated with a successful and functional AVF (P =0.037)4. Farrington et al in his study with 2 years follow-up, concluded that arterial diameter was an important independent predictor of AVF failure with only 20% access loss when artery diameter was >5mm compared to 75% when it was 3-5mm.[21] In US, such studies have led to a shift of creation site of AVF from wrist to more proximally at elbow.

In diabetic individuals, there is endothelial dysregulation because of reduced vasodilatory substances such as nitric oxide, increased aggregation of platelets and an overall imbalance between the protective factors and the mechanisms which produce vascular injury[22]. All

these ongoing derangements of the vessel wall can lead to various progressive microvascular and macrovascular abnormalities in diabetic individuals which may affect the long term patency of AVFs. In the current study, diabetes was a key factor in predicting the failure of the fistula (P value 0.001) which is in accordance with results in previously done studies which concluded diabetes to be a positive predictor of early AVF failure.[23]

Our study has some limitations. Firstly, there is a potential for selection bias in the participant cohort. Certain characteristics of the individuals may prevent the generalizability of the findings to a broader population. Additionally, the design of the study may have introduced some information bias which may affect the overall robustness of the results. Lastly, the follow-up period in our study was only two years, which may affect the ability to have adequately captured the long-term outcomes or changes over an extended period of time.

Conclusion

Brachial artery diameter of <4mm and cephalic vein diameter of <3.5mm are independently associated with loss of cumulative patency of brachiocephalic arteriovenous fistula.

Conflict of Interest: *None*

Funding Source: *None*

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Authors Contribution

RU: Conceptualization of Project
MTK, RU: Data Collection
MN: Literature Search
MFA: Statistical Analysis
MTK, RU: Drafting, Revision
SM: Writing of Manuscript