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Original Research Article

# DO PREOPERATIVE AND POSTOPERATIVE VEIN DIAMETER AND POSTOPERATIVE FLOW VELOCITY AFFECT VASCULAR ACCESS PATENCY IN HEMODIALYSIS PATIENTS?

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## ABSTRACT

**Background:** All End-stage Renal Disease (ESRD) patients are required to undergo renal replacement therapy or renal transplant. To perform hemodialysis, patients will need to be provided vascular access. The autologous arterio-venous fistula (AVF) has been established as the "gold standard" for maintaining vascular access for dialysis. **Materials and Methods:** A total of 187 patients were enrolled in this study as a prospective study. The outcomes of AVFs created from three types of vascular access sites were correlated with the pre-operative and post-operative vein diameters and flow velocity measurements obtained by means of a duplex Doppler study performed on the 1st-post-operative day in both the vein and across the anastomotic site. **Result:** Significance of the flow velocities across the anastomosis and in the vein was found to be present in both the radiocephalic (RC) and brachiocephalic (BC) groups (p= 0.01 & p= 0.013 for RC and p= 0.046 and p= 0.004 for BC). Significant increases in the post-operative vein diameter were noted between functioning and non-functioning groups for the BC group (p = 0.029). For the Brachiobasilic (BB) fistulas, significance of the flow velocities in both the vein and across the anastomosis between the functioning and failure groups was also demonstrated (p = 0.0220 and p = 0.0143, respectively). No significance was found when comparing the post-operative vein diameter between the functioning and failure groups for the BB fistulas (p = 0.446). **Conclusion:** Increased vein diameter post-anastomosis is predictive of successful fistula outcome in the Brachiocephalic (BC) AVF. Flow velocities in vein and across anastomoses are strongly predictive of fistula success in all three AVF configurations; Radiocephalic (RC), Brachiocephalic (BC), and Brachiobasilic (BB).

## INTRODUCTION

An autologous arteriovenous fistula (AVF) is a gold standard to maintain vascular access for hemodialysis. Upper limb fistulas are preferable over a lower limb or any other sites of the body. In an order of preference as given in the KDOQI guidelines, the radiocephalic fistula is the vascular access of preference followed by the brachiocephalic fistula, transposed brachiobasilic fistula, and lastly an arteriovenous synthetic graft.[1]

AVFs are constructed using radial artery and cephalic vein in the forearm and brachial artery and cephalic or basilic vein in the upper arm. The patency rates depend on various factors such as the site of anastomosis, vein and artery caliber used for anastomosis, and the type of anastomosis. Various studies described that loss of patency is due to either thrombosis or stenosis of vascular access. Juxta anastomotic stenosis of a vein is the most common. The aim of this study is to establish correlation with pre and postoperative vein diameter and flow velocities across the anastomosis on the patency of AVFs.

## MATERIALS AND METHODS

This is a prospective study done on patients who underwent fistula surgery in this hospital. A total of 187 patients were enrolled in this study. All patients were subjected to pre and postoperative Doppler study. The vein diameter was evaluated


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preoperatively. Postoperatively, the vein diameter and the flow across the anastomosis on the 1st postoperative day were measured. Primary failure is defined as the loss of patency before cannulation. Early failure is defined as loss of patency within 3 months from the time of fistula surgery. Informed written consent was obtained from all patients.

## RESULTS

Eighty-two (43.8%) patients underwent BC fistulas, 12 (6.4%) patients underwent BB fistulas, and 93 (49.7%) patients underwent RC fistulas. Male patients were 133 (71.1%) and females were 54 (28.9%). Age range was from 8 to 77 years with a mean of 47.8 years.

In this study, out of 82 BC fistulas, 7 failures were noted; out of 12 BB fistulas, 4 failures were noted; and out of 93 RC fistulas, 13 failures were noted. Total functioning fistulas were 163 (87.1%), and total failures were 24 (12.9%) [Table 1].

The preoperative vein diameters in the functioning BC fistulas were 1.5–5 mm. The average size of the vein confirms to 2.81 mm. The preoperative diameter in the failure group was 1.5–3.6 mm with an average of size of 2.7 mm. Postoperative vein diameters in the functioning group ranged from 3 mm to 5.7 mm with an average of 4.32 mm. Flow rates in vein in functioning group ranged from 120 to 548 cm/s with an average of 269.9 cm/s. In the failure group, flow rates in vein range from 0 to 300 cm/s with an average of 171.4 cm/s. Increase in the postoperative vein diameter between functioning and the nonfunctioning group is significant, with P = 0.029 [Table 2]. Flow rates in vein and across anastomosis between functioning and failure group were significant in this BC fistulas with P < 0.046 and 0.004, respectively.

The preoperative vein diameters in functioning BB fistulas range from 1.5 to 5 mm. With an average of 3 mm, postoperative vein diameter ranges from 3.6 to 5.8 mm with an average of 4.75 mm. In the failure group, preoperative vein diameter ranges from 1.5 mm to 5 (same as functioning) mm with an average of 3.13 mm. Postoperative vein diameter of functioning BB fistulas ranges from 2 to 6.1 mm with an average of 4.2 mm. Flow rates in a vein in BB fistula functioning group range from 100 to 460 cm/s with an average of 261 cm/s. In the failure group, the flow rates in vein range from 0 to 380 cm/s with an average of 165 cm/s[Table 3]. Flow velocities in vein and across anastomosis between functioning and failure group were significant in BB fistulas with P = 0.0220 and 0.0143, respectively. Increase in the postoperative vein diameter between functioning and a nonfunctioning group is not significant with P = 0.446.

Preoperative vein diameter in functioning RC fistulas ranges from 1.5 to 3.5 mm with an average of 2.1 mm. The postoperative vein diameter ranges from 2.5 to 5.5 mm with an average of 3.8 mm. In the failure group, preoperative vein diameter ranged from 1.4 to 2.9 mm with an average of 2 mm. Postoperative diameter of the vein in the failure group ranged from 1.4 to 5.1 mm with an average of 3.4 mm. Flow rates in a vein in functioning group ranged from 120 to 415 cm/s with an average of 223.1 cm/s. In the failure group, flow in vein ranges from 0 to 270 cm/s with an average of 163.1 cm/s [Table 4]. Flow rates in vein and across anastomosis between functioning and failure group were significant in RC fistulas with P = 0.010 and 0.013, respectively. Increase in the postoperative vein diameter between functioning and a nonfunctioning group was not significant, with P = 0.067.

**Table 1: Number of cases functioning and failures in each group**

| Type of AVF | Total cases | Functioning | Failure |
|---|---|---|---|
| Radiocephalic (RC) | 93 | 80 | 13 |
| Brachiocephalic (BC) | 82 | 75 | 7 |
| Brachiobasilic (BB) | 12 | 8 | 4 |
| **Total** | **187** | **163** | **24** |

**Table 2: Vein diameters and flow velocities in brachiocephalic arteriovenous fistula (BC AVF) group**

| Parameter | Functioning (Range) | Mean | Failure (Range) | Mean |
|---|---|---|---|---|
| Preoperative vein diameter (mm) | 1.5 – 5.0 | 2.81 | 1.5 – 3.6 | 2.7 |
| Artery diameter (mm) | 2.5 – 6.8 | 4.0 | 2.5 – 4.1 | 4.0 |
| Postoperative vein diameter (mm) | 3.0 – 6.8 | 4.32 | 3.0 – 5.7 | 3.64 |
| Flow velocity in vein (cm/s) | 120 – 548 | 269.9 | 0 – 300 | 171.4 |
| Flow velocity across anastomosis (cm/s) | 200 – 620 | 427.3 | 0 – 440 | 242.8 |

**Table 3: Vein diameters and flow velocities in brachiobasilic arteriovenous fistula (BB AVF) group**

| Parameter | Functioning (Range) | Mean | Failure (Range) | Mean |
|---|---|---|---|---|
| Preoperative vein diameter (mm) | 1.5 – 5.0 | 3.0 | 1.5 – 5.0 | 3.13 |
| Artery diameter (mm) | 3.0 – 4.7 | 4.17 | 1.5 – 4.0 | 3.12 |
| Postoperative vein diameter (mm) | 3.6 – 5.8 | 4.75 | 2.0 – 6.1 | 4.2 |
| Flow velocity in vein (cm/s) | 100 – 460 | 261 | 0 – 380 | 165 |
| Flow velocity across anastomosis (cm/s) | 200 – 560 | 430 | 0 – 480 | 285 |


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**Table 4: Vein diameters and flow velocities in radiocephalic arteriovenous fistula (RC AVF) group**

| Parameter | Functioning (Range) | Mean | Failure (Range) | Mean |
|---|---|---|---|---|
| Preoperative vein diameter (mm) | 1.5 – 3.5 | 2.1 | 1.4 – 2.9 | 2.0 |
| Artery diameter (mm) | 1.2 – 4.1 | 2.29 | 1.0 – 4.1 | 2.32 |
| Postoperative vein diameter (mm) | 2.5 – 5.5 | 3.8 | 1.4 – 5.1 | 3.4 |
| Flow velocity in vein (cm/s) | 120 – 415 | 223.1 | 0 – 270 | 163.1 |
| Flow velocity across anastomosis (cm/s) | 170 – 620 | 367.4 | 0 – 480 | 284.6 |

## DISCUSSION

It was suggested that duplex imaging should be used to evaluate all patients before the creation of an AVF. Duplex scanning is a promising method for establishing certain morphological and functional parameters of peripheral blood vessels because it is noninvasive and safe and may be used in lieu of venography and arteriography at facilities where this modality is available and reliable for venous and arterial assessment. This method has been recently used to visualize and measure arterial and venous vessel diameters and a good correlation between preoperative determination and perioperative findings has shown.

Duplex ultrasound (DUS) is useful in the identification of suitable veins by concluding that veins with a luminal diameter of >2.5mm and smaller veins that dilated up to 2.5 mm with a placement of a tourniquet were equally suitable for AVF formation.[2]

Vessel mapping using ultrasound has become the standard of care for preoperative planning of AV access. The selection of an appropriate venous target is of critical importance. The technical difficulty for the fistula construction is the diameter of the vein. Routine vein mapping provides and improves functionality and patency of AVF as well as primary fistula formation.[3] Malovrh reported that the veins were clinically visible only in 54/116 (46.5%) of patients; among the 62/116 (53.5%) patients with no visible veins, they were detected by ultrasound in 48/62 (77.4%) patients.[4]

In this study, 49.7% patients underwent RC fistula surgery and 43.8% patients underwent BC fistulas. Failures were more with RC fistulas when compared with BC fistulas. In this study, RC primary failure rate is 14.8%, total RC failure rate is 28%, BC primary failure rate is 2.3%, total BC failure rate is 11.9%, overall primary failure rate is 9.37%, and total failure rate is 21.35%. Navuluri and Regalado described primary failures were more with RC fistulas when compared with BC fistulas.[1]

The most accepted reason for failure for Cimino fistulas may be because of poor flow through smaller diameter veins, which are more prone to early thrombosis. The primary factors that determine the resistance to blood flow within a single vessel are as follows: vessel diameter (or radius), vessel length, and viscosity of the blood. Of these three factors, the most important quantitatively and physiologically is vessel diameter. Poiseuille's equation describes vessel resistance (R) which is inversely proportional to the radius to the fourth power (r4). With the decrease in vein diameter, there is an enormous increase in resistance to the flow. Parmar et al. described that the diameter of the radial artery plays an important role in patency of RC AVFs. Radial arteries with a diameter of <1.5 mm had an almost 50% risk of immediate fistula dysfunction as compared with larger radial arteries.[5]

In our study, the primary failure rate is 9.37%. Malovrh demonstrated an immediate patency rate of 92% in patients with a preoperative internal diameter >1.5 mm in the feeding artery, as compared to a maturation rate of 45% in patients with an internal diameter <1.5 mm.[6,7]

In another study by Simon van Hooland et al., preoperative internal arterial diameter of the radial artery ≤1.6 mm has been associated with a higher failure rate in AVFs. The minimal internal venous diameter for successful fistula creation is regarded as 2.5 mm for native AVFs.[8]

Manne et al. in their study concluded that a vein diameter of ≥1.8 mm and the radial arterial diameter ≥2 mm were associated with better patency of RC fistulas.[9] In this study, flow velocities in vein and across anastomosis between functioning and failure group were significant in RC fistulas with P = 0.010 and 0.013, respectively. Increase in the postoperative vein diameter between functioning and a nonfunctioning group is not significant, with P = 0.067.

In the BC fistula group, flow velocities in vein and across anastomosis between functioning and failure group were significant with P = 0.046 and 0.004, respectively. Increase in the postoperative vein diameter between functioning and the nonfunctioning group is significant, with P = 0.029. Flow velocities in vein and across anastomosis between functioning and failure group were significant in BB fistulas with P = 0.0220 and 0.0143, respectively. Increase in the postoperative vein diameter between functioning and the nonfunctioning group is not significant, with P = 0.446.

Mihmanli et al. demonstrated that the primary AVF failure rate was as high as 25% when the preoperative assessment depended on physical examination alone compared to 6% when noninvasive imaging was used. In this study, all the patients underwent preoperative vein mapping, and the primary failure rate was 9.37%.[10] DUS is useful in the identification of suitable veins by concluding that veins with a luminal diameter of >2.5 mm and smaller veins that dilated up to 2.5 mm with a placement of a tourniquet were equally suitable for AVF formation.[2] In this study, few patients underwent AVF creation with


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vein diameter ≤1.5 mm as the patients having poor vascular caliber and other methods of dialysis were not available for the procedure other than hemodialysis.

## CONCLUSION

Color Doppler ultrasound is the most important tool in preoperative vascular mapping in AVF creation in hemodialysis patients. The increase in vein diameter after anastomosis predicts the success of fistula in RC and BC AVF. Flow velocities in vein and across anastomosis on postoperative day 1 correlate with long term fistula patency in RC, BC, and BB AVF. Measuring the flow velocities and assessing the increase in vein diameter rather than initial vein diameter will predict the success rate of fistula. More studies are required to conclude whether flow rates and pre and postoperative vein diameters influence the patency of fistula.

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