Can Pre and Postoperative Vein Diameter and Postoperative Flow Velocities Influence the Patency of Vascular Access in Hemodialysis Patients?

Venu Manne, Vedamurthy Reddy Pogula, Mallikarjuna Reddy Nalubolu, Vijayabhaskar Reddy Gouru, Ranadheer Byram, Sudeep Bodduluri
Department of Urology and Renal Transplantation, Narayana Medical College and Hospital, Nellore, Andhra Pradesh, India

Abstract

Introduction: All end-stage renal disease patients have to undergo renal replacement therapy or renal transplantation. Patients require vascular access for hemodialysis. Autologous arteriovenous fistula (AVF) is the gold standard to maintain vascular access for hemodialysis. Methods: This is a prospective study. A total of 187 patients were evaluated in this study. Correlation with pre- and postoperative vein diameter and flow velocities on the outcomes of the AVFs was studied. Pre- and postoperative vein diameter and postoperative flow velocities were measured on the 1st-postoperative day in vein and across anastomosis using duplex Doppler study. Results: Flow velocities across the anastomosis and the vein were significant in both radiocephalic (RC) and brachioccephalic (BC) group. \( P = 0.010 \) and 0.013 for RC and 0.046 and 0.004 for the BC group, respectively. Increase in the postoperative vein diameter between functioning and nonfunctioning group was significant, with \( P = 0.029 \) in the BC group. Flow velocities in vein and across anastomosis between functioning and failure group were significant in brachiobasilic (BB) fistulas with \( P = 0.0220 \) and 0.0143, respectively. Increase in the postoperative vein diameter between functioning and nonfunctioning group is not significant, with \( P = 0.446 \). Conclusion: The increase in vein diameter after anastomosis predicts the success of fistula in BC AVF. Flow velocities in vein and across anastomosis have strong prediction in RC, BC, and BB AVF.

Keywords: Brachiobasilic arteriovenous fistula, brachiocephalic arteriovenous fistula, flow velocities across anastomosis, radiocephalic arteriovenous fistula, vein diameters

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 brachioccephalic 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.

METHODS

This is a prospective study done on patients who underwent fistula surgery in this hospital from April 2015 to October 2016. 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 preoperatively. Postoperatively, the vein diameter and the flow across the anastomosis on the 1st-postoperative day were measured. Primary failure is

Address for correspondence: Dr. Vedamurthy Reddy Pogula, E-mail: pgreddy@yahoo.co.in

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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 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 \( P = 0.067 \).

**DISCUSSION**

It was suggested that duplex imaging should be used to evaluate all patients before the creation of an AVF. Duplex scanning is a

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

|          | Total | Functioning | Failure |
|----------|-------|-------------|---------|
| RC       | 93    | 80          | 13      |
| BC       | 82    | 75          | 7       |
| BB       | 12    | 8           | 4       |

RC: Radiocephalic, BC: Brachiocephalic, BB: Brachiobasilic

**Table 2: Vein diameters and flow velocities in brachiobasilic arteriovenous fistula group**

|                          | Functioning | Failure |
|--------------------------|-------------|---------|
| Preoperative vein diameter (mm) | 1.5-5.0     | 1.5-3.6 |
| Artery diameter (mm)      | 3.0-4.7     | 3.0-5.7 |
| Postoperative vein diameter (mm) | 2.5-6.8    | 2.5-4.1 |
| Flow velocity in vein (cm/s) | 120-548    | 0-300   |
| Flow velocity across anastomosis (cm/s) | 200-620    | 0-440   |

**Table 3: Vein diameters and flow velocities in brachiobasilic arteriovenous fistula group**

|                          | Functioning | Failure |
|--------------------------|-------------|---------|
| Preoperative vein diameter (mm) | 1.5-5.0     | 1.5-5.0 |
| Artery diameter (mm)      | 3.0-4.7     | 1.5-4.0 |
| Postoperative vein diameter (mm) | 3.6-5.8    | 2.0-6.1 |
| Flow velocity in vein (cm/s) | 100-460    | 0-300   |
| Flow velocity across anastomosis (cm/s) | 200-560    | 0-480   |

**Table 4: Vein diameters and flow velocities in radiocephalic arteriovenous fistula group**

|                          | Functioning | Failure |
|--------------------------|-------------|---------|
| Preoperative vein diameter (mm) | 1.5-3.5     | 1.4-2.9 |
| Artery diameter (mm)      | 1.2-4.1     | 1.0-4.1 |
| Postoperative vein diameter (mm) | 2.5-5.5    | 1.4-5.1 |
| Flow velocity in vein (cm/s) | 120-415    | 0-270   |
| Flow velocity across anastomosis (cm/s) | 170-620    | 0-480   |
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 >2.5 mm and smaller veins that dilated up to 2.5 mm with a placement of a tourniquet were equally suitable for AVF formation.[3]

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.[1] 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.[11] In this study, few patients underwent AVF creation with 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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**Conflicts of interest**

There are no conflicts of interest.
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