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Original Article

The Relationship Between Proximal Radiocephalic Arteriovenous Fistula Flow Rate at the First and Third Months After Construction and Function of AVF in a One-Year Follow-Up

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Abstract

A proximal radiocephalic arteriovenous fistula (PRCAVF) could be beneficial for multiple reasons. First, this configuration can increase the chance of creating a functional autogenous AVF while preserving future upper arm options. In addition, PRCFs have theoretically fewer complications compared to brachiocephalic fistulas (BCFs) because of hemodynamic effects. We investigated whether PRCF flow measured by ultrasound 30 days as well as 3 months postoperative predicted successful hemodialysis (HD). In this prospective study, color Doppler ultrasound was used to measure cephalic vein outflow volume at 1 and 3 months, postoperatively. Out of 175 patients screened for feasibility of PRC-AVF by physical examination and ultrasound arterial and vein mapping, 160 were considered suitable for construction of PRC AVF. 2 patients died and 4 patients refused further participation during the study. Out of 154 patients who had a forearm PRC-AVF, 130 (84.4%) proceeded to successful AVF dialysis, and 24 (15.6%) ceased function within the first 30 days postoperatively. The mean flow at 30 days for patent fistulas was 716 SD204 mL/min, and by the third month had increased to 733 SD222 mL/min. At the 1st month, 95/130 (73%) patients had a flow rate >500 mL/min and 35/130 (27%) patients had a flow rate <500 mL/min. All patients were advised to do hand exercise and followed for 2 months. At the 3rd month, 98/130 (75.3%) patients had a flow rate >500 mL/min. 32/130 (24.7%) patients had a flow rate <500 mL/min. 60% of the low flow fistulas in the 1st month and 88% percent of high-flow fistulas in 1st month had successful patency within 1 year. A PRC-AVF flow rate >500 mL/min in the 1st month predicted more successful HD than a flow rate <500 mL/min (88% vs. 60%). Without intervention, low flow AVFs do not improve significantly. We recommend ultrasound imaging for all patients at 30 days to identify and promptly correct stenosis in those with low flow rates.

Keywords: Arteriovenous fistula, Color doppler ultrasonography, Fistula blood flow, Fistula patency

Introduction

There are three options available for vascular access in hemodialysis patients: arteriovenous graft, arteriovenous catheter, and arteriovenous fistula (AVF). Among the three, arteriovenous fistulas are the preferred method of vascular access for hemodialysis [1, 2]. Comparing with AV grafts and central catheter, AVF fistula after maturation demonstrate lower complication rate, lower infection, better long-term survival, and lesser intervention for maintaining long-term patency [2]. Current recommendation, [3-5], is to first create radiocephalic fistula, followed by brachiocephalic fistula, and then, brachiobasilic fistula. Distal radiocephalic fistulas (DRCF) placed at the wrist has higher non-maturation rate than brachiocephalic fistulas placed in the upper arm [6]. Brachiocephalic fistula is more prone to steal syndrome, high output cardiac failure, and hand edema. An alternative option is to create a proximal radiocephalic arteriovenous fistula (PRCF) between the proximal radial artery and the cephalic vein [7]. Created proximal forearm fistula by anatomizing proximal radial artery and cephalic vein, while [8] created PRCF by anastomosis of proximal radial artery to perforating branch of median cubital or cephalic vein end to side fashion. Thrombosis and stenosis, which are the main factors behind AVF failure, will increase patients' economic burden and lower their quality of life [9]. With the help of proper monitoring, thrombosis and stenosis can be early detected and

timely treated, which extends the life of fistula and increases patient's survival rate [10]. Color Doppler ultrasound is widely used in clinical imaging [11-14] and is recommended as the best way to monitor AVF, since it is noninvasive and radiation-free, has a low price, and provides real-time access to AVF anatomical and hemodynamic information [15, 16]. In this paper, we aim to investigate, whether and to what extent, AVF flow rates predict successful HD. To this end, we measure AVF flow rate at 30 days and 90 days, and find the relationship between flow rates and AVF maturity. Additionally, we assess the impact of early identification of low-flow fistulas and possibly required interventions for maturity.

Materials and Methods

In this prospective study, all adult patients undergoing PRC-AVFs over a 1- year period were included from August 2019 to August 2020. All the patients underwent preoperative Doppler ultrasound to measure the size of radial artery, size of cephalic vein, and flow rate at wrist and elbow. All patients were advised to preserve cephalic vein on the forearm by avoiding any venae puncture prior to fistula creation. Inclusion criteria for creation of PRCF were: Radial artery <2 mm at wrist, Radial artery flow rate <40 mL/sec at wrist, cephalic vein <2.5 mm at wrist, and previously failed AVF at wrist. All surgeries were done by a single vascular surgeon using local infiltration anesthesia with 2% lidocaine. A 3 to 4 cm longitudinal incision was made one inch below the cubital fossa crease in the interval between brachioradialis and flexor carpi radialis. Brachial artery and proximal Radial artery were identified, followed by identification of cephalic vein or median antebrachial vein. If median antebrachial vein were present, they were preferred. Side to side anastomosis was done by back wall first technique between proximal of radial artery and cephalic or median antebrachial vein. Once anastomosis is completed, any leak from the anastomosis was identified. Patency of fistula is confirmed by palpable thrill. Skin was closed with an interrupted 3-0 nylon. Using color scan Doppler ultrasound Hitachi EUB-525 (DUS), radiocephalic vein outflow was estimated on the forearm at the 1-month and 3-month postoperative follow-up appointments. Flow was measured 5 cm above the AVF communication. DUS measured the average lumen diameter of the outflow cephalic vein. AVF maturity was defined as an average cephalic luminal diameter ≥5 mm and outflow vein volume blood flow ≥500 mL/min via DUS. 154 patients were examined at 2 weeks, 1 month, 3 months, 6 months, 9 months and 1year post operation. Patients received endovascular surgical procedures during this time period if they were identified to have either 50% stenosis or a drop in cephalic vein outflow <350 mL/min. Endovascular procedures included balloon angioplasty with/without stenting. All patients included in this study were encouraged to perform exercises at home to encourage proper arm movements. AVF-sustained patency was defined as successful consecutive HDs via AVF after AVF being deemed mature.

Statistical Analysis

Data were analyzed using R (version 4.1.2). Quantitative data were tested by paired t-test. Categorical data were presented as counts and proportions and were tested by Chi-square test. With a significance level of 95%, p-value<0.05 was considered statistically significant in our analysis.

Results

Out of 175 patients screened for feasibility of PRC-AVF by physical examination and ultrasound arterial and vein mapping, 160 were considered suitable for construction of PRC-AVF. 2 patients died, and 4 patients refused further participation during the study. Out of 154 patients, 97 patients (63%) were male and 57 patients (37%) were female, whose ages were in the range of 22 to 84 years with an average age of 52 SD16 years. 110 patients (68.75%) were hypertensive, 67 patients (43.5%) were diabetic, 54 patients (35%) used aspirin, 16 patients (9.37%) used Plavix, and 24 patients (15.5%) were smoker≥20 pack years. 130 patients (84.4%) proceeded to successful AVF dialysis and 24 (15.58%) ceased function within the first 30 days' post operation. AVF failure was defined as AVF that clotted or was not suitable for HD. Patients who had a patent fistula were divided into two groups based on cephalic vein outflow measured via DUS at 1 month. Among the 130 patent fistulas, 95 had vein outflow ≥500 mL/min, and 35 had vein outflow <500 mL/min at the 1st month. The mean flow at 30 days for patent fistulas was 716 SD204 mL/min. By the third month, 98 had vein outflow ≥500 mL/min, 32 had vein outflow <500 mL/min, and fistula mean flow

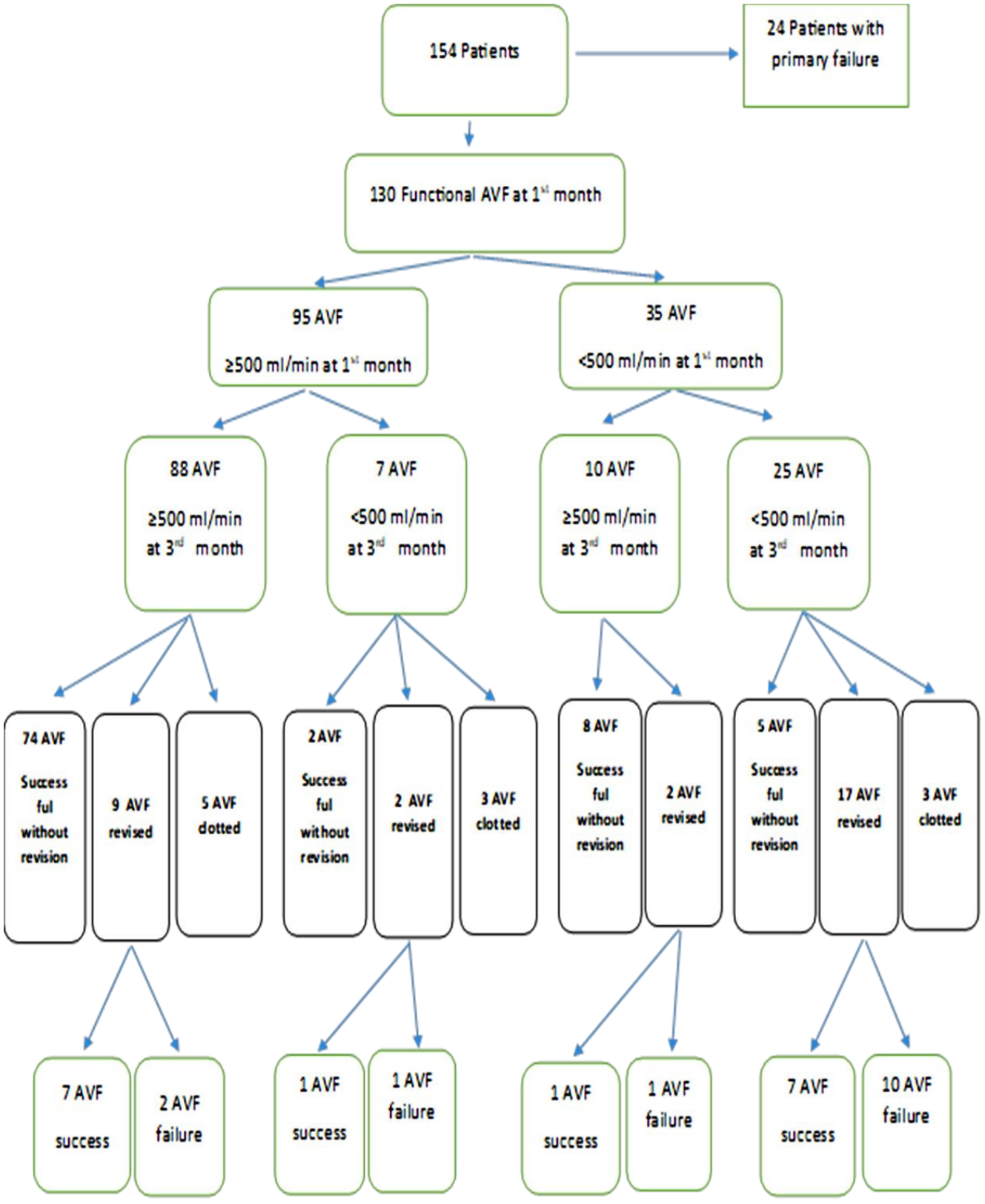

Figure1. 154 patients who underwent PRC-AVF

statistically significant differences in change of flow from month 1 to month 3 between the 2 groups (≥ and <500 mL/min) (p-value≈0.36). Among patients with fistula mean flow ≥500 mL/min at third month, 82 (83.6%) underwent successful HD without interventions, 5 (5.1%) clotted, and 11 (11.22%) underwent endovascular revisions during the year of observation. Among those with endovascular revisions, 8 led to successful HD whereas 3 led to a failed HD. Out of 32 patients with fistula mean flow <500 mL/min at the 3rd month, 7 (21.87%) underwent successful HD without interventions, 6 (18.75%) clotted, and 19 (59.37%) underwent endovascular revisions during the year of observation. Among those with endovascular revisions, 8 resulted in successful HD, whereas 11 led to a failed HD. Both the patients with clotted AVF and failed intervention underwent HD via central vein catheters (CVC). Overall, 84 (88.42%) patients with high flow at month 1 underwent successful HD and 11 (11.57%) had clotted AVF or failed intervention, and 21 (60%) patients with low flow at month 1 underwent successful HD, and 14 (40%) had clotted AVF or failed intervention. 105 out of the 154 (68.18%) patients sustained patency over 1 year follow up. 24 (15.58%) had primary failure, 25 (16.2%) had secondary failure. 88% of patients with high flow rate sustained patency over a year, while only 60% of the low-flow group sustained patency over a year (p-value<0.05). Among those high-flow fistulas at the 1st month that were patent over a year, only 9.5% needed intervention, while 38% of fistulas with low flow at the 1st month needed intervention to stay patent over a year (p-value<0.05). Fig. 1 summarizes the results.

Discussion

Multiple studies and national guidelines clearly emphasized numerous advantages of using autogenous access over prosthetic grafts and CVCs for HD [17-22]. These recommendations also suggest that a distal forearm AVF (Brescia-Cimino) should be attempted first, if anatomically possible, followed by an upper arm AVF. However, upper arm AVFs, due to high-flow volumes, can result in potential complications such as arm swelling, steal syndrome, pseudoaneurysm, cephalic arch stenosis and heart failure [23, 24]. Using the proximal radial artery as inflow may mitigate these risks, and thus, should be a more routinely considered AVF configuration if a distal forearm option is not available. We have demonstrated an overall 105 (68.18%) of 154 PRC-AVF functional patency over a 1-year follow-up. For patients whose AVF did not clot in less than 1 month, 80.7% underwent successful HD. Compared to prior studies, [25, 26], our study demonstrated a better annual AVF patency (36%–60%). Earlier studies have tried to assess functional maturity using DUS on preoperative artery and vein diameters [27]. They found no differences in AVF maturity considering preoperative artery and vein diameters or radial artery flow rates greater or less than 500 mL/min. By increasing AVF prevalence within the HD population, more efforts should be made to understand how to better predict AVF patency and when to intervene for successful HD. Waiting for a prolonged time hoping for AVF maturation may result in greater reliance on CVC use, which increases morbidity and mortality from catheter-associated line infections and central vein stenosis [21, 28, 29].

Our study focused on 1-month postoperative vein outflow to predict AVF HD maturation because there was not a significant increase in fistula flow rate between the 1st month and 3rd month. Dividing our patients into two groups of ≥ and <500 mL/min, we found that 88.4% of patients in the high-flow group, compared to only 60% in the low-flow group, achieved successful HD. In contrast with [30], we observed that 1-year patency was better in the high flow group (88.4% vs 81%), which may be due to the fact that we chose a higher flow end point in our study (500 mL/min vs 400mL/min). In our study, 1-year patency in the low-flow group was 60% at the 1st month and 47% at the 3rd month, both of which were lower than those in [30]. This observation implies that delayed intervention for low-flow (<500mL/min) fistula results in lower 1-year patency. 8/11 (72.7%) of revisions led to successful HD in the high-flow group, whereas only 8/19 (42.1%) had successful HD after revisions in the low flow group. Overall, more than 80% of patients who did not clot within the 30 days had a 1-year fistula patency. Successful maturation greater than 50% in either group demonstrates that the candidates for PRC-AVF were selected appropriately (according to our criteria), leading to better fistula maturation outcomes compared to prior studies [31]. Our study included more participant than the similar study in [30] and consisted of both males and females. To the best of our knowledge, this study

is the first to solely assess proximal radiocephalic AVF patency based on vein outflow obtained from postoperative ultrasound. A limitation of our study was that all of our patients were older than 22 years, preventing us from extending our results to younger patients. Our patients were selected with a cephalic vein greater than or equal to 3mm preoperatively, favoring a better patency outlook. However, we did not use intraoperative fluoroscopic venogram which could improve AVF success rate. In our study, there was one vascular surgeon who did all the AVF creations and surgical interventions postoperatively. One ultrasound technician was responsible for all vein mapping done postoperatively to further reduce variability in reporting vein outflow. Prior studies have shown that exercise programs increase AVF maturation postoperatively, and the use of endovascular interventions improves stenosis [32, 33]. Both exercise programs and endovascular procedures were utilized to optimize AVF maturity and patency in our study. Comparing vein outflow at month 1 and month 3 indicated no significant changes in mean vein outflow rate or between the high and low groups similar to the prior study in [30].

Our findings show that earlier assessment can be made at 30 days as there were no significant changes between the flow rate of the first and third month post operation. Therefore, if a patient has low flow, earlier interventions are required to improve chances of AVF maturation. We recommend patients who have a 1-month postoperative vein outflow <500 mL/min to have early interventions.

Conclusion

At month 1, PRC-AVF flows of ≥500 mL/min accurately predict successful HD (88.4% vs. 60%). Low flow rates do not change significantly, and maturation is unlikely to happen without intervention. We recommend all patients undergo monitoring by DUS at 30 days after creation of PRC-AVF to early identify and promptly correct stenosis in those with flow rate <500mL/min.

Author contribution

Authors declare no conflicts of interest.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical declaration

There was no ethical declaration.

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