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Autogenous radiocephalic hemodialysis access in patients with small caliber cephalic veins after expansion with a Fogarty catheter

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ABSTRACT. Autogenous arteriovenous fistula (AVF) is the first choice for hemodialysis access in renal failure with uremia. However, AVF cannot be performed in some patients due to small and narrow veins in the forearm. In this study, a Fogarty catheter was used to establish autogenous radiocephalic hemodialysis access in patients with small caliber cephalic veins, and the patency rate and complications of this method were observed. Sixty-seven patients with uremia were divided into a treatment group (40 cases, caliber of cephalic veins <2.5 mm) and a control group (27 cases, caliber of cephalic veins ≥2.5 mm). According to ultrasound results, the treatment group received AVF after expansion with a Fogarty catheter, and the control group received traditional AVF. The fistula patency rate and complications were observed during follow-up. All patients were followed up for an average period of 18 months (range = 3-36 months). AVF was successfully used in 58 patients for hemodialysis, with primary access failure in 9 cases (5 cases in the treatment group and 4 cases in the control group) due to

early thrombosis. The primary and secondary patency rates 12 months after surgery in the treatment group were 64 and 72%, respectively, and those in the control group were 60 and 76%, respectively. Patients with small caliber cephalic veins can be treated with radiocephalic fistula after the caliber of cephalic veins is expanded to more than 2.5 mm with a Fogarty catheter. The long-term patency rate awaits observation in a longer follow-up period.

Key words: Hemodialysis; Catheter; Autogenous radiocephalic access

INTRODUCTION

Chronic hypertension and diabetes are the major causes of renal failure. Hemodialysis, a procedure to remove excess water, toxic chemicals, and waste from the blood, is required treatment for renal failure with uremia. Many patients who undergo long-term hemodialysis need to establish a permanent vascular access for hemodialysis. Autogenous arteriovenous fistula (AVF), a prosthetic vascular graft, and a central venous catheter, have all been used in clinics for hemodialysis access. Among the three types, AVF is the first choice for hemodialysis access with a good patency rate and less complications. AVFs, such as radiocephalic fistula or brachiocephalic fistula, have been recommended by the National Kidney Foundation-Kidney Disease Outcomes Quality Initiative guidelines (NFK/KDOQI, 2006). However, AVF cannot be performed in patients who have small and narrow veins in the forearm. In addition, some patients cannot afford the cost of prosthetic vascular grafts. Therefore, the development of an affordable hemodialysis method that can be used in small caliber veins is necessary. In this study, a Fogarty catheter was used to establish autogenous radiocephalic hemodialysis access in patients with small caliber cephalic veins, and the patency rate and complications of this method were observed.

MATERIAL AND METHODS

Subjects

This study was conducted with approval from the Ethics Committee of the Qingpu Branch of the Zhongshan Hospital, Fudan University (Shanghai, China). Sixty-seven patients (39 males and 28 females) were enrolled in this study at the Department of Nephrology, Qingpu Branch of the Zhongshan Hospital, Fudan University from January 2007 to December 2010. Written informed consent was obtained from all patients. All patients were diagnosed with uremia according to NFK/KDOQI criteria. The average age of the patients was 56 years (range = 24-78 years). There were 25 patients with chronic glomerulonephritis, 18 patients with diabetic nephropathy, 15 patients with hypertensive nephrosclerosis, 2 patients with polycystic kidney disease, 1 patient with obstructive nephropathy, 2 patients with IgA nephropathy, and 4 patients with unknown causes (Table 1). All patients received AVF for the first time and underwent vein mapping using ultrasound examination before AVF. They were divided into a treatment group and a control group. The treatment group comprised 40 cases, 27 males and 13 females, with an average age of 58 years (range = 24-78 years), and the caliber of cephalic

veins was <2.5 mm. The control group comprised 27 cases, 12 males and 15 females, with an average age of 54 years (range = 24-78 years), and the caliber of cephalic veins was ≥2.5 mm. According to ultrasound results, the treatment group received AVF after expansion with a Fogarty catheter, and the control group received traditional AVF.

Table 1. Etiology of renal disease in patients.

Diseases	Research group (N = 40)	Control group (N = 27)
Chronic glomerulonephritis	16 (40%)	9 (33.3%)
Diabetic nephropathy	11 (27.5%)	7 (25.9%)
Hypertensive nephrosclerosis	7 (17.5%)	8 (29.7%)
Polycystic kidney disease	1 (2.5%)	1 (3.7%)
Obstructive nephropathy	1 (2.5%)	0
IgA nephropathy	2 (5%)	0
Others	2 (5%)	2 (7.4%)

Methods

All patients underwent routine physical examinations including blood, urine, and feces tests, X-ray chest film, liver and kidney functions, electrocardiogram, and blood clotting tests. The blood supply of the radial and ulnar arteries was examined by using the Allen's test and ultrasonography, and the branches and diameters of the cephalic veins were also examined by ultrasonography. Brachial plexus anesthesia was selected, accompanied by 0.75% lidocaine administered locally as needed. An incision parallel to the cephalic vein was made at the wrist. The cephalic vein (3 cm) and radial artery (2 cm) were exposed and tied distally. If the diameter of the cephalic vein was less than 2.5 mm, or a stenosis was identified in the cephalic vein in the forearm, a 3F Fogarty catheter was applied to expand the vein. The Fogarty catheter was inserted into the cephalic vein 30 cm proximally, and was inflated with 0.1-0.2 mL heparinized saline. Each 1 cm length of the cephalic vein was expanded with the inflated balloons. The caliber of the cephalic veins was dilated by 2- to 2.5-fold using an inflated Fogarty balloon with a 5 mm in diameter when filled with 0.2 mL solution. If the diameter of the cephalic veins was more than 2.5 mm, or no stenosis was identified in the cephalic vein in the forearm, a traditional radiocephalic AVF was constructed with an end-to-end anastomosis after being washed with heparinized saline. Doppler ultrasound was used to measure the internal vessel diameter in the treatment group. The cephalic vein caliber was measured immediately using Doppler ultrasound after surgery.

All patients were followed up with an average follow-up period of 18 months (range = 3-36 months). The maturation time, patency rate, complications, and secondary interventions were recorded during follow-up.

Statistical analysis

A paired Student *t*-test was used to assess the statistical significance between preoperative and postoperative variables. The life table method was applied to plot the patency rate curve, and to evaluate the difference in the patency rate between groups. Probability values less than 0.05 were considered to be statistically significant. The statistical analysis was performed using the SPSS 15.0 software.

RESULTS

All 40 patients in the treatment group received AVF with a Fogarty catheter, and the diameter of cephalic veins increased from preoperative (2.15 ± 0.61 mm; range = 1.5-2.5 mm) to postoperative (3.74 ± 0.66 mm; range = 3.0-5.0 mm) ($P < 0.05$). The average diameter of the cephalic veins increased by approximately 1.74-fold after expansion with the inflated Fogarty balloon. The preoperative average diameter of the cephalic veins in the control group (3.54 ± 0.81 mm; range = 2.5-5.0 mm) was significantly larger than that of the treatment group (2.15 ± 0.61 mm; range = 1.5-2.5 mm) ($P < 0.05$). There was a statistically significant difference in the diameter of radial arteries between the treatment group (2.71 ± 0.56 mm; range = 2.0-4.0 mm) and the control group (3.74 ± 0.68 mm; range = 2.0-5.0 mm) ($P < 0.05$).

Among the 67 patients who received AVF, 2 patients died due to heart failure, 2 patients died due to cerebral hemorrhage, 1 patient died from multiple organ failure, and 1 patient died from stomach cancer. Fifty-eight patients used the fistula for hemodialysis with a flow rate between 200 and 300 mL/min 2-3 times per week (a total of 10 h). The average AVF maturation time (the interval between the creation and the first use) was 46 days (range = 25-65 days) for the treatment group, and was 48 days (range = 16-70 days) for the control group ($P > 0.05$). Primary access failure occurred in 9 cases (5 cases in the treatment group and 4 cases in the control group) due to early thrombosis. No other early complication (e.g., infection or digital ischemia) was found. Late complications occurred in 7 cases due to venous aneurysm (2 cases), heart failure (1 case), excessive branches of the cephalic vein (1 case), and thrombosis (3 cases). The late complications occurred in 5 (12.5%) of the 40 patients in the treatment group and in 2 (7.4%) of the 27 patients in the control group ($P < 0.05$). Surgical interventions were performed in 5 patients in the treatment group, including thrombectomy (2 patients), venous aneurysm removal (2 patients), and ligation of branches of the cephalic vein (1 patient), and in 4 patients in the control group, including thrombectomy (3 patients) and encircling constriction of the cephalic vein to reduce blood overflow (1 patient). The primary and secondary patency rates in the 12-month follow-up period were 64 and 72%, respectively, in the treatment group, and were 60 and 76% in the control group, respectively (Figures 1 and 2). There was no significant difference in patency rates between the two groups ($P > 0.05$).

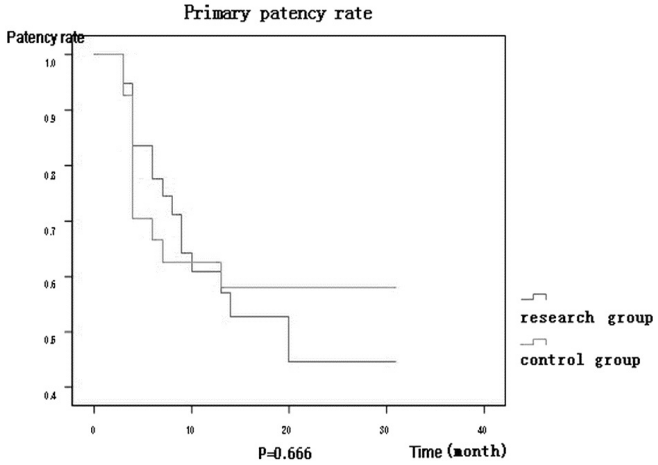

Figure 1. Overall survival curves of primary patency rate in the two groups.

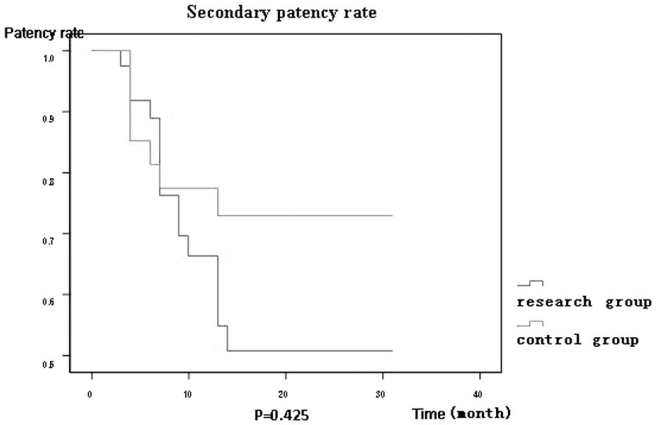

Figure 2. Overall survival curves of secondary patency rate in the two groups.

DISCUSSION

In 1960, Quinton and Scribner first invented an arteriovenous shunt using a U-shaped Teflon tube to shunt the blood from the artery to the vein. Shortly after that, Brescia and Cimino first described the AVF, which is the longest lasting hemodialysis access method used to date (Bagolan et al., 1998). Three types of hemodialysis access methods have been recommended by the NFK/KDOQI (2006), including autogenous AVF, a prosthetic vascular graft, and a central venous catheter. Autogenous AVF is the first choice of hemodialysis access, including radiocephalic fistula, brachiocephalic fistula, and brachiobasilic fistula, followed by vascular draft and central venous catheter. Since autogenous AVF has a higher patency rate than grafts and catheters in the long-term, the NFK/KDOQI recommended that AVF be used in prevalent hemodialysis patients to a minimum of 65%. AVF has many advantages, such as its ease of construction, long-term use time of more than 2 years, less complications, ease of use for maintaining blood flow at 200-300 mL/min, low cost of construction and maintenance, normal blood supply in distal extremities, and no influence on daily life and work for the patient (Perera et al., 2004; Turmel-Rodrigues and Bourquelot, 2006; Weale et al., 2008; Hsieh et al., 2009). Radiocephalic fistula is the first choice of hemodialysis access in clinics (Papanikolaou et al., 2009). To successfully construct a radiocephalic fistula, the diameter of radial arteries must be at least 1.6 mm with the existence of a palm arch, and the diameter of the cephalic veins must be at least 2.5 mm with no stenosis or constriction of the central vein (Pirozzi et al., 2010; Kakkos et al., 2011).

However, the use of radiocephalic fistula is limited by the poor quality of the distal cephalic vein resulting from multiple prior venipunctures and cannulations in uremia patients undergoing long-term treatment. Wong et al. (2011) reported that radiocephalic fistula was not suitable for hemodialysis access in patients with cephalic veins <1.6 mm in diameter (Tordoir, 2011; Wong et al., 2011). Therefore, patients with poor or narrow cephalic veins at the wrist had to use other hemodialysis access methods including the brachiocephalic fistula or the arteriovenous graft, which were more expensive and traumatic to patients (Fitzgerald et al., 2004). AVF is generally difficult to create in uremic patients with diabetes and hypertension because

these patients often have collapsed, thin, and narrow cephalic veins. The failure of AVF is largely due to the lack of good, shallow veins and low blood flow in the veins after surgery. Although some veins expand in response to arterial pressure, an increase in fistula maturation time and a decrease in maturation rate often occur. Primary failure in some patients is associated with narrow cephalic veins. Rooijens et al. (2005) reported that 10-24% of patients with radiocephalic fistulae are complicated with thrombosis, poor function, and delay in maturation time, and fail to mature. Unlike the saphenous vein, which is mechanically expanded by heparinized saline in bypass surgery, the cephalic vein will often not effectively expand during traditional AVF surgery because the stenosis or collateral circulation of the cephalic vein is not located within the surgical field. In addition, vascular spasms often occur during radiocephalic fistula, especially in cephalic veins. Vasospasms cannot be avoided by gentle operation techniques, and usually cannot be relieved by warm normal saline and lidocaine treatment.

We used the Fogarty balloon catheter to expand the cephalic vein to effectively construct radiocephalic fistulae. The Fogarty balloon is soft and smooth, and its volume and pressure can be adjusted according to the vascular caliber, thus producing fewer injuries to the vascular endothelium. In addition, the Fogarty catheter can expand the vascular wall uniformly and mechanically during thrombectomy, and does not affect the patency of the vessel after surgery. Although using non-compliant balloons may have more advantages, such as the accuracy of the expansion pressure and diameter (Turmel-Rodrigues et al., 2009; Natário et al., 2010), our emphasis here was developing a more affordable method, which is why the Fogarty, rather than a standard angioplasty balloon, was used. One 3F Fogarty balloon costs 500 RMB and a resident's medical insurance will pay 85% of the cost; in other words, the patients only need to afford 15%. In contrast, a GoreTex artificial vascular graft costs 4000 RMB, which patients have to pay for themselves. In addition, the cost of a standard angioplasty balloon (5000-6000 RMB) must also be paid for by the patients themselves. Therefore, low-income patients could not afford such treatment. Thus, our original intention was focused on the Fogarty balloon.

In this study, the diameter of the cephalic vein was significantly smaller in the treatment group (2.25 mm) than in the control group (3.54 mm) before the expansion with the Fogarty balloon, and was similar after the operation. There were no significant differences in the surgery success rate, primary success rate, maturation time, and secondary intervention rate between the treatment group and the control group. However, the treatment group showed a higher complication rate than the control group. There were no significant differences in the primary and accumulated patency rates between the two groups immediately after surgery or at 6 months and 12 months of follow-up ($P > 0.05$). The patency rates within the 12-month postoperative period were similar between two groups. The patency rates in the control group were maintained at a steady plateau of approximately 60% between 12 and 24 months. However, the patency rates in the research group gradually declined after 12 months, and were significantly smaller than those in the control group after 20 months. The decrease in the long-term patency rate in the treatment group may have resulted from the intimal hyperplasia in response to the intimal injury after the Fogarty catheter treatment. In addition, only 5 patients were followed up for more than 20 months in the treatment group. The small sample size in the treatment group may have caused analysis errors. The patients will be followed up in the future to further study the patency rate after 20 months. The patency rates greatly increased in the control group, but not in the treatment group, after secondary interventions of thrombolysis, thrombectomy, and vasodilation.

In conclusion, patients with cephalic veins of small caliber can undergo radiocephalic fistula after the diameter of cephalic veins is expanded to more than 2.5 mm with a Fogarty balloon. The patency rate in AVF with a Fogarty catheter in the early stage (<12 moths) is similar to that of traditional AVF. However, the long-term patency rate (>20 months) needs to be further observed in extended follow-up.

REFERENCES

Bagolan P, Spagnoli A, Ciprandi G, Picca S, et al. (1998). A ten-year experience of Brescia-Cimino arteriovenous fistula in children: technical evolution and refinements. *J. Vasc. Surg.* 27: 640-644.

Fitzgerald JT, Schanzer A, Chin AI, McVicar JP, et al. (2004). Outcomes of upper arm arteriovenous fistulas for maintenance hemodialysis access. *Arch. Surg.* 139: 201-208.

Hsieh LC, Wang HJ, Chen YP, Lin JJ, et al. (2009). Radial arterial approach with adjunctive urokinase for treating occluded autogenous radial-cephalic fistulas. *Cardiovasc. Intervent. Radiol.* 32: 1202-1208.

Kakkos SK, Haddad GK, Stephanou A, Haddad JA, et al. (2011). Routine preoperative venous and arterial mapping increases both, construction and maturation rate of upper arm autogenous arteriovenous fistulae. *Vasc. Endovascular. Surg.* 45: 135-141.

Natário A, Turmel-Rodrigues L, Fodil-Cherif M, Brillet G, et al. (2010). Endovascular treatment of immature, dysfunctional and thrombosed forearm autogenous ulnar-basilic and radial-basilic fistulas for haemodialysis. *Nephrol. Dial. Transplant.* 25: 532-538.

NKF/KDOQI (2006). Clinical practice guidelines for vascular access: 2006 Updates. *Am. J. Kidney. Dis.* 48: S1-S322.

Papanikolaou V, Papagiannis A, Vrochides D, Imvrios G, et al. (2009). The natural history of vascular access for hemodialysis: a single center study of 2,422 patients. *Surgery* 145: 272-279.

Perera GB, Mueller MP, Kubaska SM, Wilson SE, et al. (2004). Superiority of autogenous arteriovenous hemodialysis access: maintenance of function with fewer secondary interventions. *Ann. Vasc. Surg.* 18: 66-73.

Pirozzi N, Apponi F, Napoletano AM, Luciani R, et al. (2010). Microsurgery and preventive haemostasis for autogenous radial-cephalic direct wrist access in adult patients with radial artery internal diameter below 1.6 mm. *Nephrol. Dial. Transplant.* 25: 520-525.

Rooijens PPGM, Burgmans JPL, Yo TI, Hop WCJ, et al. (2005). Autogenous radial-cephalic or prosthetic brachial-antecubital forearm loop AVF in patients with compromised vessels? A randomized, multicenter study of the patency of primary hemodialysis access. *J. Vasc. Surg.* 42: 481-486.

Tordoir J (2011). Commentary. Factors associated with early failure of arteriovenous fistulae for haemodialysis access. *Eur. J. Vasc. Endovasc. Surg.* 42 (Suppl 1): S55-S56.

Turmel-Rodrigues L and Bourquelot P (2006). Regarding "autogenous radial-cephalic or prosthetic brachial-antecubital forearm loop AVF in patients with compromised vessels? A randomized multicenter study of the patency of primary hemodialysis access". *J. Vasc. Surg.* 43: 1315-1316.

Turmel-Rodrigues L, Boutin JM, Camiade C, Brillet G, et al. (2009). Percutaneous dilation of the radial artery in nonmaturing autogenous radial-cephalic fistulas for haemodialysis. *Nephrol. Dial. Transplant.* 24: 3782-3788.

Weale AR, Bevis P, Neary WD, Boyes S, et al. (2008). Radiocephalic and brachiocephalic arteriovenous fistula outcomes in the elderly. *J. Vasc. Surg.* 47: 144-150.

Wong V, Ward R, Taylor J, Selvakumar S, et al. (2011). Reprinted article "Factors associated with early failure of arteriovenous fistulae for haemodialysis access". *Eur. J. Vasc. Endovasc. Surg.* 42 (Suppl 1): S48-S54.