Distribution and complications of native arteriovenous fistulas in maintenance hemodialysis patients: a single-center study

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ABSTRACT

Background: The aim of this study was to investigate the use of vascular access in maintenance hemodialysis (MHD) patients and the complications of native arteriovenous fistulas (NAVFs) in a Chinese single center.

Methods: Patients (n=376) were recruited in our descriptive cross-sectional study, 350 of them had wrist NAVFs (wrist group), and 18 of them had elbow NAVFs (elbow group). We evaluated the complications associated with NAVFs and the prevalence of high-output cardiac failure between these 2 groups. All statistical analyses were performed with the use of the SPSS software package, version 17.0. Data were expressed as means ± SD; a p value <0.05 was assumed to be statistically significant.

Results: We found 97.87% of patients had NAVFs, among them 93.09% (350/376) of patients had wrist NAVFs, followed by elbow NAVFs 4.79% (18/376), while 1.33% (5/376) had graft AVFs and only 0.80% (3/376) of patients depended on a cuff catheter. The most frequent complications seen in our patients were thrombosis (13.86%), followed by aneurysm (12.23%), anastomotic stenosis (2.17%); arterial steal syndrome (1.63%); infection (0.54%); and venous hypertension (0.27%). Aneurysm was more common in the elbow group (66.67%) than in the wrist group (9.43%) (p<0.01). There were no differences in other complications, patency rate during 1-3 years or Kt/V between the 2 groups. We did not find high-output cardiac failure related to NAVFs in our patients.

Conclusion: The prevalence of complications of NAVFs is high, and greater attention should be paid to the prevention of these complications. Early diagnosis and management of complications related to AVFs is essential to prevent loss of the vascular access. We think the wrist radiocephalic NAVF is the first choice for MHD patients; an elbow NAVF is a reasonable alternative for MHD access when a radiocephalic NAVF is not possible.

Key words: Arteriovenous fistulas, Complications, Hemodialysis

INTRODUCTION

Vascular access is considered the “line of life” for maintenance hemodialysis (MHD) patients. Nephrologists have been searching for the ideal hemodialysis vascular access, which should have a long usable life, deliver an adequate blood flow and have a low rate of complications (1, 2). In the National Kidney Foundation Dialysis Outcomes Quality Initiative (NFK/DOQI) clinical practice guidelines, the order of preference for vascular access is (i) radial artery–cephalic vein arteriovenous fistula (AVF) at the wrist (Brescia-Cimino fistula), (ii) brachial artery–cephalic vein AVF (upper-arm AVF), (iii) arteriovenous graft or transposed brachial artery–basilic vein fistula, and (iv) cuffed tunneled central venous catheters should be discouraged as permanent vascular access (3, 4). Placement of the radiocephalic (Brescia-Cimino) AVF has
been the hemodialysis access of choice for patients with end-stage renal disease (ESRD) receiving MHD because of its reliable patency, low complication rate and preservation of alternate future access sites. However, this procedure is not always easy to perform owing to the poor quality of veins and complications of AVF. Many patients now outlive their first hemodialysis access site and require additional access procedures at different sites. Nephrologists have to search for other kinds of access for these patients. We studied the distribution and complications of different kinds of vascular access in MHD patients in our center.

**Materials and Methods**

**Patients**

Clinical and epidemiological data were obtained from Shanghai First People’s Hospital Affiliated to Jiaotong University, 376 patients were included, there were 204 males (54.26%) and 172 females (45.75%), mean age 56.48 ± 13.06 years. The duration on dialysis ranged from 6 months to 32 years with a mean of 68.91 ± 67.12 months. The time duration from performing the AVF surgery ranged between 6 months to 176 months with a mean of 28.17 ± 30.11 months. Of the patients, 350 had wrist native arteriovenous fistulas (NAVFs) (wrist group), and 18 had elbow arm NAVFs (elbow group). The majority of our patients were scheduled for three 4-hour sessions per week, with an average of 11.4 hours per week. All of our dialysis sessions were performed using biocompatible dialysis membranes, bicarbonate dialysate prepared from reverse osmosis treated water and anticoagulation with heparin. Erythropoietin is prescribed as indicated, according to the National Foundation’s Kidney Disease Outcomes Initiative (K/DOQI) guidelines. The most common cause of renal failure in the study population was chronic glomerulonephritis (68.62%), followed by diabetes mellitus (11.14%) and hypertension (10%) (Fig. 1). There were no significant differences in age, sex, dialysis time or the etiology of ESRD between the wrist and elbow groups.

**Maturation and reinterventions**

We performed brachial artery–cephalic vein, proximal radial artery–cephalic vein NAVF, proximal radial artery–median ante brachial vein or transposed brachial artery–basilic vein fistula at the elbow (Fig. 2). We designated these patients as the elbow group. The access was considered mature if it could be cannulated reproducibly for dialysis with 2 needles with a blood flow $\geq 200$ ml/min for at least 1 month. The dialysis nurses monitored all vascular accesses for clinical evidence of dysfunction such as absent thrill, discontinuous bruit or distal edema; an unexplained decrease in Kt/V on a constant dialysis prescription; or abnormalities of dialysis (difficult cannulation, aspiration of clots or prolonged bleeding from needle sites) (5, 6). Doppler ultrasonography was performed in patients with stenosis, and angioplasty was done only in a few patients.
in our study. An elective surgical revision was performed if the angioplasty was unsuccessful (7).

**Statistical analysis**

All statistical analyses were performed with the SPSS software package, version 17.0. Data were expressed as means ± SD, median and ranges, and values of p <0.05 were assumed to be statistically significant.

**Results**

**Distribution of different kinds of vascular access in study patients**

Of the patients studied, 97.87% (368/376) had NAVFs (Fig. 3); among them 93.09% (350/376) had wrist NAVFs, followed by elbow NAVFs 4.79% (18/376), while 1.33% (5/376) had graft AVFs. Only 0.80% (3/376) of patients depended on a cuff catheter (Fig. 3). If the patients could not be given a wrist or elbow NAVF, they might receive a graft. A cuff catheter was placed only in those patients who were aging and had advanced stage neoplasms or in some patients waiting for a transplant.

**Complications of native arteriovenous fistulas in maintenance hemodialysis patients**

Of the patients, 13.86% (51/368) had an NAVF complicated by thrombosis (Fig. 4), 72.55% (37/51) of those occurred at the anastomosis and 27.45% (14/51) occurred at the site of the puncture; 12.23% (45/368) patients had an aneurysm. The other complications were anastomotic stenosis (2.17%), arterial steal syndrome (1.63%), infection (0.54%) and venous hypertension (0.27%). We did not find high-output cardiac failure relative to either elbow or wrist NAVFs in our patients.

**Complications of native arteriovenous fistulas according to the site of AVF**

Aneurysm was more common in the elbow group (66.67%) than in the wrist group (9.43%) (p<0.01) (Tab. I). There were

<table>
<thead>
<tr>
<th>Complication</th>
<th>Elbow</th>
<th>Wrist</th>
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<tbody>
<tr>
<td>Aneurysm</td>
<td>12/18 (66.67%)*</td>
<td>33/350 (9.43%)</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>3/18 (16.67%)</td>
<td>48/350 (13.71%)</td>
</tr>
<tr>
<td>Anastomotic stenosis</td>
<td>0</td>
<td>8/350 (2.29%)</td>
</tr>
<tr>
<td>Arterial steal syndrome</td>
<td>1/18 (5.56%)</td>
<td>5/350 (1.43%)</td>
</tr>
<tr>
<td>Infection</td>
<td>0</td>
<td>2/350 (0.57%)</td>
</tr>
<tr>
<td>Venous hypertension</td>
<td>0</td>
<td>1/350 (0.29%)</td>
</tr>
<tr>
<td>Blood flow (ml/min)</td>
<td>207.00±14.19</td>
<td>219.55±38.97</td>
</tr>
</tbody>
</table>

*p<0.01, vs. wrist group. AVF = arteriovenous fistula.
no differences in other complications such as thrombosis, venous hypertension, infection, anastomotic stenosis and arterial steal syndrome between the 2 groups. There was no difference in blood flow during hemodialysis sessions between the elbow and wrist groups (207.00 ± 14.19 ml/min vs. 219.55 ± 38.97 ml/min; p>0.05). Elbow NAVFs could deliver an adequate blood flow, too.

**Patency rate of arteriovenous fistulas and dialysis efficiency with different NAVFs**

There was no significant difference in patency rate and Kt/V between the 2 groups (p>0.05) (Tab. II). The patency rate during 1-3 years in the wrist group was 91.34%, 86.47% and 82.38%, respectively; and in elbow group, it was 94.4%, 89.72% and 83.19%, respectively. The equilibrated Kt/V for urea was estimated according to the Daugirdas second-generation equation (8). The Kt/V value was more than 1.2 in all patients; the average in the elbow group was 1.43 ± 0.31 and in the wrist group 1.45 ± 0.54 (p>0.05).

**Discussion**

In our department, 97.87% of patients had NAVFs, and among them 93.09% of patients had wrist NAVFs. Elbow NAVFs were placed only in those patients with a failed wrist fistula or with vessels unsuitable for a wrist fistula. In our study, elbow NAVFs did not increase the risk for primary failure and did not require more interventions to achieve maturation. If the patient was already on dialysis, elbow NAVFs did not entail longer catheter dependence or a higher risk for catheter-related bacteremia. In the last few decades, different countries appear to have different distributions of vascular accesses, such as grafts in the United States and catheters becoming very common in Europe (9). As compared with previous the Dialysis Outcomes and Practice Patterns Study (DOPPS) data, prevalent hemodialysis patients dialyzed via an AVF increased from 24% to only 33% in the United States, whereas use decreased from 80% to 74% in Europe (10, 11). It is possible that problems in cooperating among different professionals involved in the creation of vascular accesses are still unsolved, and a multiprofessional model of vascular access management is still far from being achieved. The management of vascular access by a sole vascular surgeon is the most likely explanation of the high prevalence of grafts in the United States, whereas nephrologist self-sufficiency has been leading to the large-scale utilization of catheters in some European countries (12).

In our center, nephrologists themselves create vascular accesses: they know what the dialysis patient needs and can choose the best access for their patients. There was no significant difference in patency rate during 1-3 years or Kt/V between the 2 groups in our study. Both of these 2 sites for NAVFs could keep a high patency rate and supply adequate blood flow rates to deliver the prescribed dialysis dose. How to deal with primary failure (early thrombosis or lack of maturation) is a big problem. Preoperative vascular mapping has been shown to result in an increased placement of AVFs. In general, 3 modalities (physical examination, ultrasound examination and angiographic evaluation) are available for vascular evaluation. Ultrasound examination of the vessels is an objective assessment. It provides an excellent evaluation of both arteries and veins for creation of an AVF (13). In our center, we examine both arterial as well as venous vessels using physical examination. Ultrasound examination can be used in some obese or poor venous status patients, and angiographic evaluation is seldom used before an operation. Complications of AVFs include thrombosis (early and late), infection, bleeding, increased venous pressure, arterial insufficiency (arterial steal syndrome), aneurysm (true and pseudo), carpal tunnel syndrome, distal ischemia and even heart failure. True aneurysms or pseudoaneurysms are more common in patients with upper-arm AVFs. The most frequent complication of AVFs seen in Iranian hemodialysis patients was aneurysm (51%), followed by venous hypertension (16.7%), infection (4.4%), thrombosis (3.3%) and arterial steal syndrome (1.1%) (14). The most frequent complications seen in our patients was thrombosis (13.86%), followed by aneurysm (12.23%), anastomotic stenosis (2.17%), arterial steal syndrome (1.63%), infection (0.54%) and venous hypertension (0.27%).

**TABLE II**

<table>
<thead>
<tr>
<th>Elbow</th>
<th>Wrist</th>
<th>p Value</th>
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<tbody>
<tr>
<td>Patency rate at 1 year</td>
<td>94.4%*</td>
<td>91.34%</td>
</tr>
<tr>
<td>Patency rate at 2 years</td>
<td>89.72%*</td>
<td>86.47%</td>
</tr>
<tr>
<td>Patency rate at 3 years</td>
<td>83.19%*</td>
<td>82.38%</td>
</tr>
<tr>
<td>Kt/V</td>
<td>1.43 ± 0.31*</td>
<td>1.45 ± 0.54</td>
</tr>
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*p>0.05, vs. wrist group.
elbow group, 66.67% of patients had an aneurysm, which is much more higher than in the wrist group (9.43%). Puncture technique and high arterial pressure can result in an aneurysm. Van Loon et al (15) compared buttonhole needling with rope-ladder technique for hemodialysis AVFs and showed that the buttonhole (BH) method is a valuable technique which causes few complications including hematoma, aneurysm formation and the need for interventions. However, the infections induced by the BH method should not be underestimated. Arteriovenous access-related aneurysms are also related to the site of the AVF. We saw more aneurysms in elbow NAVFs than in wrist NAVFs, which is similar to other reports (16). If a patient had an elbow AVF created, there were shorter veins to cannulate, and the nurse had a tendency to use area puncture. The area puncture technique is probably associated with the worst consequences – i.e., circumscribed dilation, disruption of wall texture and aneurysm formation (17).

Thrombosis included early and late. Early-stage vascular access thromboses are usually related to the technical errors of the surgeon, errors in judging the vessel choice or a period of extreme hypotension. Late-stage thromboses are of multifactorial etiology, with predisposing factors including hypotension, hemoconcentration, hypercoagulable states and repeated puncture (18, 19). The classical histological lesion that appears to be associated with AVF failure is neointimal hyperplasia, including smooth muscle cells, myofibroblasts and endothelial cells within microvessels. Most of the available evidence suggests that detection of stenosis and prevention of thrombosis is valuable. When a test indicates the likely presence of a stenosis, then venography or fistulography should be used to definitively establish the presence and degree of the stenosis. In most but not all cases, angioplasty should be performed if the stenosis is greater than 50% by diameter (20). For treatment of vascular access thromboses, clinical practice guidelines recommend surgical thrombectomy or mechanical or pharmacomechanical thrombolysis, depending on experience, and these tend to show good results (21).

Central venous hypertension occurs in 3%-11% of patients with a dialysis access (22). One of our 69-year-old male patients who had a wrist NAVF created 6 year ago always showed high venous pressure during hemodialysis sessions which was manifested by finger and hand edema, limited motility and livid swollen fingers. However, his fistula remained functional. Bachleda et al reported (23) that the surgical bypass of an obstructed venous segment proximal to a functioning dialysis access site is an acceptable treatment for relieving central venous hypertension symptoms and salvaging functional dialysis access.

Infection is most common with central vein catheter accesses, followed by prosthetic arteriovenous grafts (AVG) and is rare with autogenous fistulas. Two of our patients were allergic to disinfectants, and their skin around the fistula was infected causing an AVF rupture. We ligatured the AVFs and used antibiotics to treat the infection. Graft or fistula infection was suspected if the access site was red, swollen and tender; infection was confirmed by positive wound or blood cultures. Although *Staphylococcus* species are the most common organism to cause infection, early empiric antimicrobial therapy should also include coverage for gram-negative organisms (24).

Two of our patients suffered complications in the form of serious arterial steal syndrome; they always complained of unbearable arm pain, and the distal limb was livid during hemodialysis sessions. After 30 minutes to 1 hour of dialysis, these manifestations increased, and the pain was gradually relieved after ceasing dialysis. One of these patients had a wrist radiocephalic, and the other had an elbow brachiocephalic NAVF. There was no evidence that elbow NAVFs were associated with more steal syndrome than wrist NAVFs in our study.

Many physicians and patients are concerned that an upper-arm fistula could cause high-output cardiac failure. However, we did not find high-output cardiac failure related to NAVFs in our patients. In fact, the relationship between vascular access flow (Qa) of AVFs and cardiac output (CO) is complex. Basile et al (25) found the mean Qa of upper-arm AVFs was higher than that of lower-arm AVFs. Wijnen et al (26) found that Qa was significantly and positively related to cardiac output (CO) and cardiac index (CI), and inversely related to peripheral vascular resistance (PVR). In patients without cardiac failure, CO and CI are significantly higher in patients with elbow/upper-arm access compared with patients with forearm access types. However, only a small percentage of patients with elbow/upper-arm fistulas appeared to be at high risk for development of high-output cardiac failure. We need to enlarge our study sample to investigate this in the future.

The prevalence of complications of NAVFs is high, and greater attention should be paid to the prevention of these complications. The main challenge for the nephrologist today is to minimize the risk of primary failure while attempting to provide most patients with an NAVF. Improving vascular access outcomes is clearly a complex and difficult task and suggests that multidisciplinary management is the most appropriate approach to deal with all of the multifaceted aspects of ESRD care and to increase the likelihood of success (17). We think a wrist radiocephalic NAVF is the first choice.
for long-term hemodialysis. Although wrist NAVF short-term patency rates appear to be comparable, long-term patencies are not as good. So an elbow NAVF is a reasonable alternative for maintenance hemodialysis access when a radiocephalic NAVF is not possible.

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