Radial artery approach for endovascular salvage of occluded autogenous radial-cephalic fistulae

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Abstract

Background. The endovascular salvage of occluded autogenous radial-cephalic fistulae is a more challenging procedure than that for stenotic fistulae. To obtain an access to the fistula is one of the keys to success. Both retrograde venous approach and brachial artery approach have some disadvantages. The radial artery approach has been used in the endovascular therapy of fistula dysfunction, but few data focused on their feasibility and safety for the totally occluded fistulae.

Methods. We retrospectively reviewed the patients with occluded autogenous radial-cephalic fistulae receiving endovascular salvage via the radial artery approach in our institution. From January 2004 to July 2007, 48 patients fulfilling the above criteria were enrolled. Balloon maceration was used for patients with small clots. Mechanical thrombectomy with an Arrow-Trerotola percutaneous thrombolytic device or an AngioJet rheolytic catheter was used for patients with large clot burden. Outcome variables included anatomic and clinical success, complications and primary and secondary patency.

Results. All the transradial punctures were successful. Anatomic and clinical success was achieved in 96% of the cases. The post-interventional primary patency rates were 92%, 77%, 55% and 44% at 1, 3, 6 and 12 months, respectively. The post-interventional secondary patency rates were 96%, 93%, 89% and 89% at 1, 3, 6 and 12 months, respectively. The 12-month primary patency of the short-segment thrombus group was better than that of the long-segment thrombus group (57% versus 19%, P = 0.005). The complication rate was 4%. No puncture-site-related complications were noted, and all the radial arteries were palpable at follow-up.

Conclusions. An endovascular intervention through the radial artery approach is a safe and feasible strategy choice for restoring occluded autogenous radial-cephalic fistulae.

Keywords: angioplasty; radial artery approach; radial-cephalic fistula; vascular access

Introduction

Autogenous radial-cephalic fistulae are constructed with an anastomosis of the cephalic vein and radial artery. Despite the superior long-term patency compared to synthetic grafts, thrombosis will eventually occur. Although endovascular therapy is technically more difficult in fistulae than grafts, the results are rewarding [1]. One of the challenges is to obtain an access for intervention. Traditionally, the retrograde venous approach or brachial artery approach is used. However, for the totally occluded fistulae, both approach strategies have some disadvantages [2,3].

The transradial approach has become widely accepted in coronary intervention procedures. Recently, the radial artery approach has been employed for endovascular therapy of stenotic radial-cephalic fistulae. However, only very limited cases of occluded fistulae were included in the available literature [4,5]. Herein we describe our institutional experience with endovascular salvage of occluded radial-cephalic fistulae through the radial artery approach.

Patients and methods

Our angiographic unit carries out procedures for patients from our hospital haemodialysis centre and satellite haemodialysis units (~1200 patients). The patients in these haemodialysis units were followed up for clinical signs of access dysfunction according to the following criteria: decreased or absent thrill, increased pulsatility, development of collateral veins, limb swelling, difficulty in cannulation, prolonged bleeding after haemodialysis, high venous pressure during haemodialysis (dynamic venous pressure exceeded threshold levels three consecutive times), decreased haemodialysis flow rate [total fistula blood flow < 500 ml/min with the ultrasound dilution method (Transonic Flow-QC; Transonic Systems, Ithaca, NY, USA) or blood flow decreased by 25% from that at baseline] and abnormal recirculation measurement (>10% with the urea-based method).
the basis of clinical or haemodynamic changes, the patients were referred for diagnostic fistulography and endovascular therapy as appropriate. The exclusion criteria for endovascular therapy were an infected fistula and severe contrast allergy. From January 2004 to July 2007, 79 patients with 88 episodes of totally occluded radial-cephalic fistulae were referred to our institution for endovascular salvage.

Collection of information
We retrospectively reviewed an existing database from our angiographic unit of procedures identified as having all the following criteria: (1) autograft radial-cephalic fistula, (2) totally occluded fistula, (3) endovascular salvage attempted through the radial artery approach. All patients who fulfilled the above criteria were included on an intention-to-treat basis. For subjects who had the procedure performed more than once, only the first one was enrolled for analysis. Existing medical records were reviewed, including dialysis records, hospital medical records, fistulogram and radiology report. An institutional review board approval was not required at our hospital for this type of retrospective analysis.

Transradial arterial puncture technique
Transradial approach is routinely performed in our angiographic unit for patients receiving coronary angiography, and all the interventionists had an at least 2-year experience with this approach. The contraindications to the transradial approach were any of the following: (1) radial artery not palpable, (2) abnormal Allen’s test, (3) radial-cephalic anastomosis located <2 cm proximal to the radial styloid process. Administration of superficial local anaesthesia with 2% lidocaine was given at the selected puncture site, usually at least 2 cm downstream from the radial-cephalic anastomosis. The radial artery was retrograde punctured with a 30 mm 20-G sheathed needle (Terumo, Tokyo, Japan) and then slowly withdrawn to allow for blood purge from the central hub of the needle. After the needle was removed, a 45-cm, 0.025-in hydrophilic guide wire was inserted through the bleeding hub. The 20-G soft sheath was removed and a 6-Fr short sheath (7 cm; Terumo, Tokyo, Japan) was introduced into the radial artery through the guide wire, near but distal to the radial-cephalic anastomotic site. The guide wire was then removed, leaving the sheath in place, and normal saline was flushed into the sheath. The 6-Fr short sheath was then fixed in place. Heparin (5000 IU per intravenous bolus) was routinely given after the sheath was inserted.

Endovascular salvage techniques
All procedures were performed under the use of moderate sedation with midazolam and fentanyl, titrated to effect. Occluded radial-cephalic fistulae were crossed directly by a 0.032-in hydrophilic guide wire (Terumo, Tokyo, Japan) coupled with a 4–6 × 20–40 mm over-the-wire compliant balloon catheter (Wanda, Boston Scientific, Natick, MA, USA). The balloon size was determined by the patient’s previous fistulography/angiography report if available, or the diameter of adjacent normal vein or artery. If the occluded segment was difficult to be crossed, a 6-Fr JR4 catheter (Cook, Bloomington, IN, USA) coupled with a 0.032-in hydrophilic guide wire was used to traverse the occluded segment. The guide wire was then removed, leaving the JR4 catheter or balloon catheter in the venous lumen. A puff of contrast medium was injected through the catheter to confirm the true lumen and visualize the downstream fistula.

The type of thrombectomy procedures was determined at the discretion of the treating interventionists. Thrombectomy was performed with either balloon maceration, Arrow-Trerotola percutaneous thrombolytic device (PTD; Arrow International, Reading, PA, USA), AngioJet rheolytic catheter (AngioJet AVX, Possis Medical, Inc., Minneapolis, MN, USA) or combination of these techniques. In cases with a short plug-like thrombus obstructing, the radial-cephalic anastomosis or nearby downstream vein (‘short-segment thrombus’ group), maceration of the thrombus was tried with angioplasty balloon inflated by low pressure (2 atm) (Figure 1). In cases with large thrombus burden or wall-adherent thrombus that compromised blood flow (‘long-segment thrombus’ group), treatment with either over-the-wire PTD or AngioJet was attempted. If the over-the-wire PTD was crossed, a 7-Fr sheath was exchanged for 6-Fr sheath (Figure 2).

After restoration of flow, diagnostic fistulography was performed along with treatment of the underlying stenosis with balloon angioplasty. Using an inflation device with a pressure gauge, the angioplasty balloon was inflated gradually until the stenosis was eliminated and then kept at the pressure for 60 s. If the waist of stenosis was not eliminated after the maximal inflation pressure for 60 s, either a cutting balloon (Peripheral Cutting Balloon, Boston Scientific, Natick, MA, USA) or a non-compliant high-pressure balloon (Conquest, Bard, Covington, GA, USA) was used to eliminate stenosis [6,7]. For stenosis involving the radial artery adjacent to the radial-cephalic anastomosis site, it was dilated by sequential balloon angioplasty. After the completion of the procedure, diagnostic fistulography was performed from the radial-cephalic anastomosis to central vein.

At the end of the intervention, the short sheath was removed immediately and the puncture site was manually compressed until haemostasis was obtained. A small compressive bandage was placed over the radial puncture site for 4 h to ensure adequate haemostasis. After the procedure was terminated, an antiplatelet agent with aspirin or clopidogrel was given routinely for 3 days, but continuation of heparinization was not routinely performed.

Follow-up
All patients were followed at respective haemodialysis units. Follow-up examinations were the same as those used in the surveillance protocol. When abnormal clinical parameters suggested fistula dysfunction, patients were referred for repeat fistulography and intervention as appropriate. The radial artery patency was checked by physical examination of radial artery pulsation immediately and 6 months after the procedure.
Radial approach for occluded fistulae

Study outcome and definition

According to the reporting standards from the Society of Interventional Radiology (SIR) [8], anatomic success was defined as the restoration of blood flow combined with $<30\%$ minimal residual diameter stenosis at the conclusion of the interventional procedure. Clinical success was defined as the resumption of normal dialysis for at least one session. The procedure time was defined as the time interval from the start of the percutaneous puncture to the final post-treatment angiogram. The post-interventional primary patency was defined as the interval after the intervention until the next access thrombosis or repeated intervention. The post-interventional secondary patency was the interval after the intervention until the access was surgically declotted, revised or abandoned.

Statistical analysis

Statistical analyses were performed using the STATISTICA 7.0 software for Windows (StatSoft, Inc., Tulsa, OK, USA). Comparisons were made between the short-segment thrombus group and the long-segment thrombus group with respect to the patient and fistula characteristics. The Student $t$ test was used for normally distributed continuous variables and the Mann–Whitney $U$-test for the non-normally distributed continuous variables; categorical variables were compared by the $\chi^2$ test with Yates correction or the Fisher exact test when appropriate. Kaplan–Meier analysis was used to determine the primary and secondary patency. The log-rank test was used for normally distributed continuous variables and the non-parametric Wilcoxon–Mann–Whitney test for the non-normally distributed continuous variables. A $P$-value of $<0.05$ was considered to indicate a statistically significant difference.

Results

Patient, fistulae and procedure characteristics (Table 1)

During the study period, 48 patients with the totally occluded radial-cephalic fistulae underwent transradial approach. There were 31 men and 17 women with ages ranging from 30 to 83 years (mean age, 65 years). Occlusion of the fistulae occurred within 24 h of attempted angioplasty in 22 fistulae, between 24 and 48 h in 20 fistulae, and more than 48 h in six fistulae. The fistula age was $20 \pm 28$ months (mean $\pm$ SD). There were seven immature fistulae created for $<1$ month. Fistulae were located on the right side in 6 patients and on the left side in 42 patients. All the interventions using the transradial approach were performed with a 6-Fr sheath initially, but were exchanged to a 7-Fr sheath in 11 cases. Sixteen of the 48 fistulae had large thrombus burden or wall-adherent thrombus that compromised blood flow (long-segment thrombus group); three cases were declotted by AngioJet, 11 were declotted by PTD and the other two were not attempted by mechanical thrombectomy.

Initial success (Table 2)

All the transradial punctures were successful without ultrasound guidance. The average procedure time was $42 \pm 22$ min ($35 \pm 19$ min for the short-segment thrombus group; $53 \pm 24$ min for the long-segment thrombus group). The anatomic success was achieved in 46 of the 48 procedures (96%). All 46 procedures with anatomic success achieved clinical success as well. All seven immature fistulae achieved anatomic and clinical success. After excluding the seven immature fistulae, 39 of the 41 mature fistulae achieved anatomic and clinical success (95%).

In the 32 procedures with short-segment thrombus, both anatomic and clinical success were achieved. In the 16 procedures with long-segment thrombus, technical failure occurred in two of them. One failed because the thrombus was too hard to be passed through. The other one failed because the outflow vein was too small for thrombus clearing. Both the anatomic and clinical success rates of the long-segment thrombus group were 88%.

Complications

Only two complications were noted, and the complication rate was 4%. One of them developed venous rupture at the occluded site with subsequent haematoma, which was compressed by an elastic bandage. The intervention failed and the patient was referred for surgical revision. The other one encountered venous rupture at the distal outflow vein after balloon dilation and was treated with prolonged intraluminal balloon inflation. Hospitalization or blood transfusions were not needed for either of them. There was no radial artery embolization or dissections. All the radial arteries were palpable immediately after the procedures and at follow-up, except for patients who died before the end of the follow-up period. No clinical signs of pulmonary embolism were detected. During the follow-up period, two patients died of causes not related to the procedures: one died from an underlying malignancy 2 months after the procedure and the other died from urosepsis 3 months after the procedure.

Table 1. Patient and fistula characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Short-segment thrombus ($N = 32$)</th>
<th>Long-segment thrombus ($N = 16$)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient characters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>66 ± 15</td>
<td>64 ± 13</td>
<td>0.49</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>21/11</td>
<td>10/6</td>
<td>0.99</td>
</tr>
<tr>
<td>Hypertension</td>
<td>15 (47%)</td>
<td>8 (50%)</td>
<td>0.99</td>
</tr>
<tr>
<td>Smoking</td>
<td>6 (19%)</td>
<td>4 (25%)</td>
<td>0.71</td>
</tr>
<tr>
<td>Fistula characters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fistula age (month)</td>
<td>16 ± 24</td>
<td>29 ± 32</td>
<td>0.13</td>
</tr>
<tr>
<td>Fistula side (left/right)</td>
<td>29/3</td>
<td>13/3</td>
<td>0.39</td>
</tr>
<tr>
<td>Occlusion duration</td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>&lt;24 h</td>
<td>20</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>24–48 h</td>
<td>11</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>&gt;48 h</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Aneurysmal dilatation</td>
<td>1 (3%)</td>
<td>2 (13%)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 2. Initial success and 12-month patency

<table>
<thead>
<tr>
<th></th>
<th>Short-segment thrombus ($N = 32$)</th>
<th>Long-segment thrombus ($N = 16$)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure time (min)</td>
<td>35 ± 19</td>
<td>53 ± 24</td>
<td>0.008</td>
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<tr>
<td>Initial success</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatomic success</td>
<td>100%</td>
<td>88%</td>
<td>0.11</td>
</tr>
<tr>
<td>Clinical success</td>
<td>100%</td>
<td>88%</td>
<td>0.11</td>
</tr>
<tr>
<td>Patency at 12 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-interventional primary patency</td>
<td>57%</td>
<td>19%</td>
<td>0.005</td>
</tr>
<tr>
<td>Post-interventional secondary patency</td>
<td>93%</td>
<td>81%</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Fig. 3. Kaplan–Meier survival curves demonstrate the 12-month post-interventional primary and secondary patency. The numbers above the dash line and the numbers below the solid line denote the numbers at risk at the start of interval.

Fig. 4. Kaplan–Meier survival curves demonstrate the 12-month post-interventional primary patency rate stratified by long-segment or short-segment thrombus groups. The numbers above the dash line and the numbers below the solid line denote the numbers at risk at the start of interval. The error bar means standard error.

Patency (Table 2)
The Kaplan–Meier survival curves are displayed in Figure 3. With inclusion of initial failures, the post-interventional primary patency was calculated as 92%, 77%, 55% and 44% at 1, 3, 6 and 12 months, respectively. Five patients were referred for surgical creation of new fistulae: two due to failed percutaneous interventions, two due to the referring nephrologist’s discretion and the last one due to fistula infection. The post-interventional secondary patency was calculated as 96%, 93%, 89% and 89% at 1, 3, 6 and 12 months, respectively. After excluding the seven immature fistulae, the post-interventional primary patency for the mature-fistulae group was calculated as 93%, 78%, 52% and 41% at 1, 3, 6 and 12 months, respectively; the post-interventional secondary patency for the mature-fistulae group was calculated as 93%, 92%, 90% and 90% at 1, 3, 6 and 12 months, respectively.

When the patency rate was stratified by the short-segment or long-segment thrombus groups, the post-interventional primary patency rates for the short-segment thrombus group were 97%, 84%, 74% and 57% at 1, 3, 6 and 12 months, respectively, and for the long-segment thrombus group, 81%, 63%, 19% and 19% at 1, 3, 6 and 12 months, respectively (Figure 4). The post-interventional primary patency rate of the short-segment thrombus group was significantly better than that of the long-segment thrombus group at 12 months ($P = 0.005$).

Discussion
Preservation of the limited vascular access sites in a haemodialysis patient is important. A matured radial-cephalic fistula is the most durable access for long-term haemodialysis. However, thromboses will eventually occur after a period of fistula dysfunction. Occluded fistulae can be declotted by endovascular therapy, using mechanical methods, pharmacological methods or a combination of both. To obtain a continent access to the fistula is one of the keys to success. Although the radial artery approach has now been widely used for coronary intervention, only very limited cases of occluded fistulae dealing with this approach have been reported [4,5].

The retrograde venous approach has traditionally been the preferred method for occluded fistulae, but this approach has some disadvantages. First, for occluded fistulae, retrograde venous injection of contrast medium did not depict the radial-cephalic anastomosis and afferent radial artery, which are sometimes difficult to cross due to sharp angulations. Second, underlying stenosis is difficult to visualize, which may cause difficulties for the introduction of the sheath. Third, downstream lesions have not been uncommon, which may complicate the clearance of thrombus during the retrograde intervention. Because of these limitations, an antegrade brachial artery approach has been reported by some interventionists [2,3]. The antegrade brachial artery approach offers some advantages over the retrograde venous approach: the puncture is easy and all lesions can be treated via one puncture. However, some arguments have been raised. First, it is relatively difficult to stop bleeding from the brachial artery with higher rates of puncture site complications [9]. Second, it requires a long route to the occluded segment, and the U-turn curve at the anastomosis may cause difficulties in advancing of devices. Third, impairment of the fistula flow may occur during or after the procedures due to brachial artery spasms or haemostasis.

Theoretically, most of the above drawbacks could be avoided by the radial artery approach. First, the radial artery is not compromised at the occluded fistulae and it is relatively easy to puncture. Second, one sheath is usually enough to treat all the downstream lesions at the same time. Third, the radial artery access site is close and straightforward to the occluded segment. There is usually no sharp angle to hamper wiring or device advancing. Fourth, the sheath is kept distal to the radial-cephalic anastomosis site and hence does not interrupt the blood flow of the treated fistula. Fifth, it is relatively easy to stop bleeding from the
radial artery despite the concurrent use of heparin during the procedures. Sixth, the potential risk of distal embolization to the hand could be minimized by the antegrade contrast injection and intervention. Despite the above advantages, some limitations need to be addressed. The first one is the location of radial-cephalic anastomosis. Unless some distance exists between radial-cephalic anastomosis and wrist for sheath insertion, the transradial access is not possible. In addition, it is also not possible for the end-to-end radial-cephalic anastomosis. The second one is the concern about radial artery thrombosis with subsequent hand ischaemia. As a consequence, the procedure should be limited to patients with a normal Allen test. In addition, the effect of radial artery occlusion on the fistula flow still needs to be determined. The third one is spasm of the radial artery; however, this complication was rare in our practice because the sheath was kept distal to the radial-cephalic anastomosis. Finally, an adjuvant venous approach was still needed if large devices passing through an 8- or 9-Fr sheath were necessary.

The necessary skills for the radial artery canalization are similar to those for the brachial artery except that a ‘learning curve’ is likely for interventionists new to this approach [10]. In the present study, all the palpable radial arteries could be successfully canalized without the need of ultrasound guidance. According to the experience from coronary intervention, repeated transradial approach is usually possible because temporary radial artery occlusion occurs in <5% of cases, with persistent occlusion in half of those [10,11]. The adverse effect on the radial artery may be even less in the radial-cephalic fistulae intervention because the sheath was usually kept distal to the anastomosis and the guide wire was placed in the downstream vein for support, rather than in the radial to brachial artery during the retrograde venous approach. Some PTA balloons on 0.018-in the guide wire platform are compatible with 4-Fr sheaths, which may further reduce radial artery complications [3].

Our success rate was similar to other studies in the retrograde venous approach or antegrade brachial artery approach [3,12–15]. According to our experience and previous studies, two-thirds of the occluded fistulae were obstructed by a small plug-like thrombus in the downstream vein near radial-cephalic anastomosis [3,12,16]. After balloon maceration of the occluded segment, the downstream outflow veins were usually free of the thrombus. Thrombectomy procedures were needed in only one-third of cases with large thrombus burden or wall-adherent thrombus, which would correspond to the ‘long-segment thrombus’ described by Hagge et al. [14]. A variety of thrombus-debulking techniques have been reported in the literature, including the pharmacological method with local infusion of thrombolitics through regular needles [17] or pulse-spray catheter [18], and the mechanical method with PTD [15], thromboaspiration catheter [19] or AngioJet [20]. The need for a larger sized sheath for thrombectomy procedures is an important concern for the transradial approach. In our experience, an AngioJet catheter could be advanced through a 6-Fr sheath. If over-the-wire PTD or thromboaspiration catheter was intended, a 7-Fr sheath should be used. Traditionally, the sheath used in transradial coronary intervention is limited to 6-Fr. Some studies in coronary interventions have shown the feasibility of 7-Fr sheath in transradial intervention [21].

Poor 6-month patency results for endovascular treatment were reported in early studies (Vorwerk et al., 50% and Hagge et al., 53%) [14,22]. In recent series, the 6-month primary patency results varied widely (Turmel-Rodrigues et al., 70%; Liang et al., 81%; Rajan et al., 28%; and Shatsky et al., 38%) [8,12,13,15]. A direct comparison between these series is not valid because of the lack of uniform study methods, reporting standards and disparity in thrombus burden. For example, the clot burden in the study of Liang et al. may be quite small because thrombolytic agents were used in only 31% of their procedures [12]. Most of their occluded fistulae would be more similar to the short segment thrombus group of our study. In contrast, only fistulae with large clot burden requiring thrombectomy procedures were included in the study by Shatsky et al. [15]. Their results were similar to our long-segment thrombus group. We separated the patency rate between the long- and short-segment groups for more convincing comparisons to existing and future series.

There were several limitations that need to be addressed. The most significant one is our retrospective nature, which made the results subject to selection bias. Secondly, as a retrospective analysis, we could not provide the exact percentage of fistulae that were applicable for the transradial approach, and we cannot be sure that all the radial artery attempts were recorded in the database. Thirdly, the radial artery patency was checked by physical examination only, which could give false positive pulses [23]. Fourthly, the Allen test is of questionable value when the result is abnormal. However, a normal Allen test, when performed correctly, does imply the adequacy of ulnar collateral supply [24–26].

In conclusion, our study demonstrated that the radial artery approach is a safe and feasible strategy choice for the intervention of totally occluded radial-cephalic fistulae.

References

Residual renal function improves outcome in incremental haemodialysis despite reduced dialysis dose

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Abstract

Background and Methods. The importance of residual renal function is well recognized in peritoneal dialysis but its role in haemodialysis (HD) has received much less attention. We studied 650 incident patients in our incremental high-flux HD programme over a 15-year period. Target total Kt/V urea (dialysis plus residual renal) was 1.2 per session and monitored monthly. Renal urea clearance (KRU) was estimated 1–3 monthly.

Results. KRU declined during the first 5 years of HD from 3.1 ± 1.9 at 3 months to 0.9 ± 1.2 ml/min/1.73 m² at 5 years. The percentage of patients with KRU ≥ 1 ml/min at these

References


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