Peripheral Vascular Disease

The Feasibility of Transradial Artery Approach for Angioplasty of Central Vein Stenosis in Hemodialysis Patients

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Purpose: To evaluate the feasibility of transradial (TR) intervention for central vein stenosis (CVS) in hemodialysis patients.

Methods: This study retrospectively reviewed 41 consecutive TR endovascular procedures for CVS. Patient baseline characteristics and long-term outcomes were recorded and analyzed, and the primary patency rate was analyzed by the Kaplan-Meier method.

Results: The 41 patients in our study consisted of 19 males and 22 females with a mean age of 62.8 ± 12.1 years. There were 21 cases of right-sided CVS and 20 cases of left-sided CVS. Of the procedures performed, 12 were arteriovenous grafts and 29 were native arteriovenous fistulas. Initial fistulography revealed 14 occluded lesions (34.1%) and 27 stenotic lesions (65.9%). During intervention, thrombosis was found in 8 cases (19.5%) and CVS was combined with other lesions in 21 cases (51.2%). The TR approach achieved a technique success rate of 90.2%. The median primary patency time was 8.4 months, and the primary patency rates at 3, 6, 9, and 12 months were 81%, 64%, 57%, and 45%, respectively. There were no adverse events caused by radial artery occlusion.

Conclusion: TR intervention is a feasible alternative to conventional intervention in selected CVS cases, particularly those combined with lesions located at arterio-venous or arterio-graft anastomotic areas (within 2 cm to anastomosis).

Key Words: Central vein stenosis • Hemodialysis • Transradial

INTRODUCTION

Central vein stenosis (CVS) is a potentially trouble-
morbidity in end-stage renal disease patients. In recent years, percutaneous interventions, including angioplasty and stenting, have become a popular alternative to surgical treatment due to decreased complications and morbidity.\textsuperscript{7-12}

In clinical practice, transdialysis access combined with a transfemoral vein approach is the primary method of endovascular intervention for CVS.\textsuperscript{10,13,14} However, this approach may be associated with prolonged hemostasis, and even the need for sand bag compression after transfemoral approach, especially after thrombolytic agents and large-sized sheath insertion. A transradial (TR) endovascular approach for the management of dysfunctional dialysis access offers some benefits over the conventional approach, such as lesions can be clearly visualized from radial artery to central vein, one access site is enough for all downstream lesions, easy hemostasis, and no disturbance of blood flow in the hemodialysis system. These benefits are particularly in cases where lesions are totally occluded or there are more than two lesions.\textsuperscript{15,16}

Therefore, this study retrospectively reviewed endovascular interventions for CVS performed using a TR approach, and assessed the clinical outcomes. The purpose of this study was to clarify the feasibility, efficacy and limitations of TR intervention for CVS, and to evaluate which lesions obtained more benefits under TR intervention.

**METHODS AND MATERIALS**

**Patient population**

Between 2001 and 2009, 2694 patients presenting with dialysis access problems including dialysis access failure (total occlusion, feeding artery or vein stenosis resulting in inadequate shunt flow), difficult needle cannulation of the dialysis access, prolonged post-hemodialysis bleeding, ipsilateral arm or neck swelling, were referred to our cardiac catheterization laboratory (Cath Lab). Over this period, there were 5174 percutaneous transluminal angioplasties (PTA) performed. Of these, 271 procedures were performed because of either a stenotic or occluded central vein. In the usual practice, trans-dialysis conduit or trans-femoral approach or both combined were used for CVS due to large sheath, even larger than 7Fr in size if only CVS was confirmed, while the TR approach sometimes would be considered priority if CVS was combined with peripheral lesions. In this study, a further subset of patients who underwent procedures using a TR approach was studied. All medical records of patients who received PTA for CVS were retrospectively reviewed. The intervention details were also obtained by review of radiologic reports and angiograms. This retrospective study was approved by the Internal Review Board of the hospital.

**Interventional procedure**

Written informed consent was obtained from all patients prior to the procedure. A TR puncture was performed after a negative Allen’s test. A 6-Fr 16-cm sheath (Terumo, Tokyo, Japan) was introduced into the radial artery distal to the arteriovenous fistula (AVF) anastomosis. To prevent thrombus formation and radial artery spasm, a solution of 3000 IU heparin and 200 ug nitroglycerin was administered via the artery sheath.

Diagnostic angiography was performed by injecting contrast medium (diluted 1:1 with saline) into the artery sheath to define the complete anatomy of the whole dialysis access and connecting vessels from the feeding artery to the central vein. The lesion was defined as significant stenosis if the residual luminal diameter was < 50% of the true luminal diameter. After the diagnostic angiogram was performed and significant stenosis was identified, the guidewire was advanced across the stenotic or occluded area and then advanced as far as possible. Balloon angioplasty was performed after the balloon catheter was passed across the lesion.

Peripheral lesions (Figure 1), usually discovered upon initial fistulography, were treated as previously described using a TR approach for dysfunctional dialysis access.\textsuperscript{15,16} In most situations, a 5-Fr or 6-Fr Judkins Right 4 (JR4) catheter was used to control the direction and provide backup support for the guidewire, while a 0.025- or 0.035-inch hydrophilic wire (150 cm in length, Terumo, Tokyo, Japan) was used to cross the lesion. After the guidewire crossed the lesion and was confirmed in the true lumen, a balloon catheter (Boston Scientific Ireland, Galway, Ireland) with a 1:1 balloon-vessel ratio was used for dilatation of the stenotic lesion. The balloon was positioned across the lesion and inflated until popping or until the maximum rated balloon pressure
was reached. The balloon was usually inflated to 8-16 atmospheres for 30-40 seconds the first time, and for 1-2 minutes if recoil occurred.

A central vein lesion (Figure 2) was treated as a peripheral lesion after advancing a 0.025- or 0.035-inch hydrophilic wire into the inferior vena cava (IVC). For occluded lesions, a smaller-sized balloon catheter (6, 7, or 8 mm) was generally used for predilatation. In some cases, a 7-Fr artery sheath was used for balloon catheters > 8 mm in diameter, and a stiffer wire (Amplatz wire, 260 cm; Boston Scientific, Natick, MA, USA) was typically used for better support. In some cases with very tight lesions or an extremely tortuous vessel, further backup was required, and the 0.035-in hydrophilic wire was changed to a 260 cm Amplatz wire to provide better support. After the Amplatz wire was advanced to the IVC, the whole procedure could be completed with excellent guidewire support (Figures 2, 3).

Thrombosed lesions were dilated with a 1:1 balloon-vessel ratio, and the balloon sequentially inflated downstream from the peripheral lesion to the CVS

Figure 1. The first step for intervention of central vein occlusion combined with an occluded graft. (A) Angiography following the transradial approach demonstrating graft occlusion from the arterio-graft anastomosis with only a small stump noted. (B) Complete restoration of flow with minimal residual thrombus after percutaneous transluminal angioplasty. (C) Reverse venous flow was noted under further angiography, and a central vein lesion was suspected. (D) An occlusion with thrombus formation was discovered over the junction of the brachiocephalic after injection of contrast medium from a Judkins Right 4 catheter.

Figure 2. The second step for intervention of central vein occlusion combined with an occluded graft. (A) A 0.035-inch hydrophilic wire was advanced to the inferior vena cava with the support of a Judkins Right 4 catheter. (B) Predilation procedure over the central vein stenosis (CVS) using a 6-mm balloon. (C) Dilation of a 14-mm balloon over the CVS supported by an Amplatz wire. (D) Complete restoration of flow with minimal residual thrombus after complete percutaneous transluminal angioplasty.

Figure 3. Intervention for central vein stenosis (CVS) with a tortuous vein. (A) A severely engorged and tortuous cephalic vein was discovered following contrast injection from a Judkins Right 4 catheter (JR4). (B) Amplatz wire was advanced to the inferior vena cava via a JR4 (not shown). (C) Dilation of a 14-mm balloon over the CVS supported by an Amplatz wire.
covering the entire graft or fistula. If the dialysis access condition did not improve after repeated inflation, an additional 3000-5000 IU of heparin was injected and angioplasty was performed again. In a few cases in which significant thrombus remained after repeated angioplasty, 60,000 to 120,000 U of urokinase was injected into the thrombosed area and angioplasty was repeated. If flow could not be restored after administration of a total of 120,000 U of urokinase, the procedure was aborted. Surgical intervention for dysfunctional dialysis access, or closing of the ipsilateral hemodialysis access was suggested in cases of failed intervention.

At the end of the intervention, the artery sheath was removed and the puncture site was compressed with gauze and 2 layers of adhesive tape to achieve hemostasis. The first layer of tape was removed 1 hour later if the puncture site was not bleeding, and the patient was discharged after an additional hour of observation if no bleeding was noted. The second layer of tape and gauze was removed the following day.

**Monitoring of patients**

Patients were regularly monitored in our outpatient clinic during the follow-up period by nephrologists or a hemodialysis team. If there were any symptoms or signs of restenosis of the central vein or dysfunction of the dialysis access, the patients were referred back to the Cath Lab for further evaluation. Follow-up data were gathered from clinical records and standardized telephone interviews. The follow-up end date was the mortality date recorded in the chart, the last clinic visit date prior to the study, or the date when another procedure was done for restenosis or reocclusion.

**Study definitions**

A central vein lesion was defined as a lesion over the subclavian vein, the brachiophallic vein, or the superior vena cava. A peripheral lesion was defined as a lesion in the dialysis system, but not the central vein. Procedural time was the interval between the insertion and the removal of the arterial sheath. Technical success was defined as imaging success (restored blood flow and < 30% residual stenosis for stenotic lesions) and clinical improvement (restored hemodialysis blood flow, decreased venous pressure and arm swelling). The primary patency rate was defined as the interval between a successful initial procedure and the first subsequent intervention for restenosis. The end point for primary patency assessment was 12 months.

**Statistical analysis**

Statistical analysis was performed using SPSS 15 Statistical Software for Windows (SPSS Inc, Chicago, IL, USA). Continuous variables are presented as the mean ± standard deviation, while discrete variables are presented as percentages. Primary patency rate was analyzed using the Kaplan-Meier curve and the life-table method. Follow-up was censored when the patient was lost to follow-up or death on or before the date 1-year follow-up occurred.

**RESULTS**

Baseline demographic data are summarized in Table 1. This study included 41 angioplastic procedures that were performed using a TR approach. The indications for angioplasty were access arm swelling in 24 cases and dysfunctional dialysis access in 17 cases. The study population included 22 males (53.7%) and 19 females (46.3%) with a mean age of 62.8 ± 12.1 years (range, 25

<table>
<thead>
<tr>
<th>Table 1. Patient baseline demographic data</th>
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<tr>
<td>Number</td>
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<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
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<tr>
<td>Clinical indication for angioplasty</td>
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<tr>
<td>Ipsilateral arm swelling</td>
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<tr>
<td>Dysfunction of dialysis access</td>
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<tr>
<td>Elevated venous pressure during hemodialysis</td>
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<tr>
<td>Low blood flow during hemodialysis</td>
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<td>Occlusion of dialysis access was suspected by examination</td>
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<tr>
<td>Diabetes mellitus</td>
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<td>Hypertension</td>
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<tr>
<td>Ischemic heart disease</td>
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<tr>
<td>Smoker</td>
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<tr>
<td>Body surface area (m²)</td>
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<tr>
<td>Nature and location of dialysis access</td>
</tr>
<tr>
<td>Graft</td>
</tr>
<tr>
<td>Native vessel</td>
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<tr>
<td>Forearm</td>
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<td>Upper arm</td>
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to 87 years). Dialysis access consisted of 12 arterio-
venous grafts (AVG) (29.3%) and 29 native arterio-
venous fistulas (AVF) (70.7%). Sixteen (39.0%) dialysis
accesses were located in the forearm and 25 (61.0%) were
located in the upper arm.

The lesion characteristics are shown in Table 2. The
distribution of CVS was similar in both sides, and the
major location was in the subclavian vein (61%). There
were no stenotic/occluded lesions located in the superior
vena cava in our series. Initial fistulography revealed 14
occluded lesions (34.1%) (Figure 1D) and 27 stenotic
(non-occluded) lesions (65.9%) of the central vein (Fig-
ure 3A). Of these, thrombi were found in 8 cases
(19.5%) (Figure 1D), while peripheral lesions were
present in 21 cases (51.2%) (Figure 1), which included 8
cases (19.5%) with occluded dialysis access and 4 cases
(9.8%) with occlusion of the anastomotic area of the
dialysis access (arterio-graft anastomosis [Figure 1A] or
arteriovenous anastomosis). The details of the combined
peripheral lesions are shown in Table 3. The average se-
verity of stenosis before management was 81.2 ± 16.6%.
The size of the balloon catheters used ranged from 7 mm
to 16 mm, and depended on the diameter of adjacent
non-stenotic vessels.

The technique was successful in 37 (90.2%) cases. No
immediate bleeding complications nor obvious ec-
ychymosis/hematoma over the puncture site occurred
after PTA. There were 2 cases in which target vessel
dissection occurred. There were 7 censored cases over
the 1-year follow-up period; 2 patients failed to keep fol-
low-up appointments and 5 patients died due to other
diseases without evidence of CVS or reintervention.
Two failed cases due to wiring failure were transferred
to surgical closure of dialysis access for creation of a
new access, while one failed case due to a remaining
large thrombus burden was transferred to surgical th-
rombectomy. The other failed case which was attribut-
able to recoil of vessel accepted surgical consultant but
hesitated surgical intervention and opted for clinical ob-
servation instead.

Figure 4 shows the Kaplan-Meier curve of the pri-
mary patency rate. The median primary patency time
was 8.4 months (range, 4.3-15.2 months). The primary
patency rates at 3, 6, 9, and 12 months were 81%, 64%,
57%, and 45%, respectively. Three patients with hand
numbness did not show any progression of their symp-
toms, and patients without hand numbness did not experi-
ence any after the procedure during the follow-up period.

<table>
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<th>Table 2. Lesion characteristics</th>
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<tr>
<td>Procedure time (min)</td>
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<tr>
<td>Condition of central vein lesion</td>
</tr>
<tr>
<td>Occluded</td>
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<tr>
<td>Non-occluded</td>
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<td>Thrombus formation</td>
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<tr>
<td>Combined lesions</td>
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<tr>
<td>Location of central vein lesion</td>
</tr>
<tr>
<td>Left</td>
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<tr>
<td>Right</td>
</tr>
<tr>
<td>Subclavian vein</td>
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<tr>
<td>Brachiocephalic vein</td>
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<tr>
<td>Severity of lesion before PTA (%)</td>
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<tr>
<td>Diameter of pre-PTA reference (mm)</td>
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<td>Lesion length (mm)</td>
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<tr>
<td>Residual stenosis after management (%)</td>
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<tr>
<td>Largest balloon size (number)</td>
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<tr>
<td>7 mm</td>
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<tr>
<td>8 mm</td>
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<td>9 mm</td>
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<td>10 mm</td>
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<td>12 mm</td>
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<td>14 mm</td>
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<tr>
<td>16 mm</td>
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<td>PTA, percutaneous transluminal angioplasty.</td>
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<tr>
<th>Table 3. Locations of combined lesions</th>
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<tr>
<td>Gore-Tex cases (n = 9)</td>
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<tr>
<td>Arterio-graft anastomosis area*</td>
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<tr>
<td>Graft-venous anastomosis</td>
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<tr>
<td>Intra-graft</td>
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<tr>
<td>Native vein distal to graft-venous anastomosis</td>
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<tr>
<td>Occluded graft</td>
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* Arterio-GoreTex anastomosis area means arterio-graft junction and peri-arterio-graft junction (< 2 cm distance to junction).17
† Arteriovenous anastomosis area means arteriovenous anastomosis and peri-anastomosis area (< 2 cm distance to anastomosis).17
DISCUSSION

The life span of hemodialysis patients has increased in the modern medical era. With this prolonged life expectancy, maintaining dialysis access patency and relieving symptoms related to dialysis access dysfunction have become increasingly important. CVS is not an uncommon problem in hemodialysis patients, and causes symptoms in the dialysis access hand or dysfunctional dialysis access.\(^1\,^2\) Surgery has traditionally been the intervention of choice for treating CVS. However, endovascular management has become favored due to its comparable efficacy and decreased associated risks.\(^6\,^18\) According to the recommendations of the National Kidney Foundation-Dialysis Outcomes Quality Initiative, endovascular management is the preferred approach for treatment of CVS.\(^7\)

Two predominant strategies have been employed with respect to endovascular management of CVS: PTA alone or direct stenting/post-PTA stenting with self-expanding stents. Some investigators have reported better results with stenting than angioplasty, and have concluded that stenting is favorable if the PTA results are inadequate.\(^8\,^19\,^20\) In contrast, other studies have found no difference in outcomes between direct stenting/post-PTA stenting and angioplasty alone, with technique success rates and 12-month primary patency rates ranging from 70% to 95% and 14% to 52%, respectively.\(^10\,^12\,^21\) In this study, angioplasty alone was performed in all cases, with technique success and 12-month primary patency rates of 90.2% and 45%, respectively. Our findings are similar to those previously reported.\(^10\,^12\,^21\)

There are several advantages in using TR intervention for CVS as opposed to conventional approaches. First, as noted in previous studies, only one puncture site is needed for clear visualization and intervention for all downstream lesions in the dialysis access apparatus.\(^15\,^16\) Although pre-operative duplex sonography should be performed in daily practice\(^7\) to confirm the lesion and select the puncture site, severe swelling of the arm/shoulder and tortuous vessels in some cases might decrease the accuracy of duplex sonography. Further, the double-sheath approach would be needed if the peripheral lesion closed to arteriovenous or arterio-graft anastomosis (< 2 cm distance to anastomosis) was confirmed. The benefit of TR approach would be obvious in these situations. In this study, there were 51.2% (21/41) of CVS patients who had peripheral lesions, particular in which have occluded dialysis access, lesions at the arteriovenous anastomosis area or arterio-graft anastomosis area (total cases: 57.1%; 12/21). In addition, the results of the TR approach in this study are comparable to those of transdialysis access combined with a transfemoral vein approach for treating CVS.\(^10\,^13\,^14\) Second, TR intervention for CVS may prevent the clot from being pushed into the arterial system due to antegrade angiography and intervention. In this study, the TR approach was used in 14 (34.1%) cases of central vein occlusion and 8 (19.5%) cases of thrombus in the dialysis access and central vein, and no arterial embolization was noted during the procedures. Third, compression of the radial artery minimally impacts the flow conditions of the dialysis access, and affects dialysis access less as compared with the conventional approach. In addition, two important devices were employed to maximize the success rate of the TR approach for treating CVS, the JR4 catheter and the Amplatz wire, in cases which the lesion was hard to approach or not clearly identified (Figures 1D, 3A) or if the vessel was extremely tortuous (Figures 3B, C). As discussed in our previous study,\(^15\)
the TR approach also has certain limitations: exception of anastomotic condition (side-to-end cephalic vein-to-radial anastomosis or anastomosis close to the wrist) and loop graft, stenting procedure is limited because TR approach cannot accommodate the big sheath (always ≥8-Fr sheath for CVS stenting). Therefore, transdialysis access or combined with trans-femoral approach will be considered if stenting is needed.

In recent years, the TR approach for endovascular intervention of coronary artery disease has become well-accepted because of the low incidence of complications, early ambulation, and shorter hospital stay. Although some complications are associated with the procedure, including radial artery damage and access hand ischemia, the incidence is low. In a study by Stella et al., it was reported that persistent radial artery occlusion occurred in <3% of patients and that none of these patients had clinical symptoms at the time of TR coronary angioplasty with a 6-Fr artery sheath. In addition, no clinical symptoms or signs of radial artery occlusion have been noted after TR endovascular management of dialysis access with a 6-Fr sheath. Therefore, the TR approach with a 6-Fr sheath is a safe and feasible procedure for management of CVS.

In this study, balloon catheters smaller than 8 mm were used in 11 cases, while balloon catheters larger than 8 mm were used in 29 cases. A 6-Fr sheath is small enough to pass balloon catheters 8 mm or smaller, while a 7-Fr sheath can pass balloons as large as 18 mm. In this study, 6-Fr sheaths were used initially, and 7-Fr sheaths were applied when larger balloon catheters were required. Although no data was available describing the use of 7-Fr sheaths in the TR approach for dysfunctional dialysis access, Saito et al. demonstrated that the increased incidence of severe flow reduction after TR coronary intervention was negatively correlated with the ratio of the radial arterial inner diameter to the outer sheath diameter. Specifically, flow decreased from 4.0% to 13.0% when the ratio of the radial artery inner diameter to sheath outer diameter was <1.0, and the incidence was 4.7% when using a 7-Fr sheath.

The hand has a dual blood supply formed by the ulnar artery, which originates in the superficial palmar arch, and the radial artery, which originates in the deep palmar arch, that protects it from ischemia in the occurrence of vessel occlusion. Therefore, it is very important to ensure adequate ulnar artery circulation before interventional procedures using the TR approach are performed. Greenwood et al. have described the dynamics of the collateral circulation of the hand. Through total mechanical occlusion of the radial artery in patients with a normal or even a mildly impaired Allen’s test, it was found that the immediate reduction in blood flow to the thumb was 67% to 100%. However, the blood flow can be restored to 93%-100% of normal, and pulse oximetry readings increased from 0% to 64% after 30 minutes of persistent mechanical occlusion. Thus, the effect of acute occlusion with respect to ischemia of the hand might be less than previously expected. Therefore, few clinical complications after coronary arterial intervention using the TR approach have been reported, and even cases of transulnar arterial intervention with an occluded radial artery have been described. In this study, no patient complained of hand numbness during the follow-up period, including those patients in which a 7-Fr sheath was used.

This study has several limitations due to its retrospective and investigative characteristics. First, the indications for the TR approach for CVS were not clearly defined because TR interventions are routinely performed in the Cath Lab due to the benefits of reduced bleeding complications, increased patient comfort, early ambulation, and shorter hospital stay in coronary intervention, including several additional benefits as described above in the treatment of dysfunctional dialysis access. In addition, preoperative duplex sonography was also lacking to detail the indication of TR approach compared with transdialysis access approach, due to the fact that pre-operative duplex sonography cannot always be made timely available in our hospital. Second, no preoperative or follow-up duplex sonography of the radial artery was obtained. Thus, correlation between the diameter of the radial artery and the artery sheath cannot be scientifically assessed, and long-term risks related to using the TR approach cannot be evaluated, especially in cases in which a 7-Fr sheath was used. The use of a 7-Fr sheath was dependent on the feeling of the resistance during the push and extension of the 6-Fr sheath. Besides, no radial pulsation was recorded, so objective results arising from radial artery occlusion were hard to evaluate. Although no local complication was noted clinically in this study, and low radial artery occlusion
rate (4.7%)\textsuperscript{27} presented in the literature, the small number of patients using the 7-Fr sheath may be a limitation to our ability to exhibit statistically reliable evidence in low risk of access site complications. Third, we are unable to show the assisted patency rate because the re-interventions were not all performed via the TR approach.

**CONCLUSION**

In this study, the success and primary patency rates of TR intervention for the treatment of CVS were comparable to those using a conventional approach. Furthermore, no adverse events caused by radial artery occlusion were noted, even in cases in which a large sheath was used. Therefore, we concluded that the TR approach should be an alternative choice for percutaneous intervention without stenting for CVS in hemodialysis patients, and we suggest that it may be a good alternative approach when the peripheral lesion is over the arteriovenous or arterio-graft anastomosis area (< 2 cm distance to anastomosis).

**REFERENCES**


