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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Endovascular treatment of wide-necked aneurysms of the visceral and renal arteries using the double microcatheter technique via a single access route

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PURPOSE

We aimed to evaluate the utility of and complications associated with the double microcatheter technique for the treatment of wide-necked visceral and renal artery aneurysms (VRAAs).

METHODS

Nine patients (mean age, 58 years; age range, 42–69 years; 4 men, 5 women) with wide-necked VRAAs who underwent treatment with the double microcatheter technique from January 2016 to July 2018 were included in the study. For all patients, anatomical features were confirmed using cone-beam computed tomography (CT) with rotational angiography. The aneurysmal location, size, volume, neck-to-dome ratio, number of coils used, and coil packing density were investigated. Technical success, complications (coil migration and organ ischemia), changes in the complete blood count or serum creatine level, and recurrence were also evaluated.

RESULTS

Three renal artery aneurysms and 6 splenic artery aneurysms were treated by the double microcatheter technique. The mean size of the aneurysms was 26.09±4.76 mm, mean volume was 6.19±3.69 cm^3, and mean neck-to-dome ratio was 1.53±0.24. The number of coils used ranged from 7 to 16. The mean packing density was 11.32%±3.72%. Technical success was achieved in all 9 patients. Renal ischemia occurred in two patients with renal artery aneurysm, one of whom showed minimal scar formation on follow-up CT after infarction. No coil migrations or disease recurrences were observed.

CONCLUSION

The double microcatheter technique for the treatment of wide-necked VRAAs appears to be relatively safe and useful. However, complex renal artery aneurysm should be carefully managed in order to prevent infarction.

Visceral and renal artery aneurysms (VRAAs) are rare, with the reported incidence ranging from 0.01% to 2.5% in autopsy- and angiography-based studies (1–3). Most of them have no associated symptoms, and the rate of diagnosis is increasing with the widespread use of axial imaging (4, 5). The risk of rupture of true asymptomatic VRAAs increases when the maximum diameter is ≥2 cm, which is generally the size threshold for treatment. Symptomatic aneurysms require treatment, regardless of their size. Similarly, pseudoaneurysms, which can be caused by trauma, infection, and inflammation, often continue to grow in size or subsequently rupture, and therefore also need to be treated (5–9).

Treatment options for VRAAs include surgical or endovascular repair. Coil embolization is a widely used endovascular treatment method. However, conventional coil embolization of wide-necked aneurysms may result in migration of the coil, leading to difficulty in obtaining satisfactory results and complications such as infarction of the visceral organs. Therefore, it is mainly used to treat saccular aneurysms with a narrow neck (10). Endovascular treatment of wide-neck aneurysms mainly involves balloon- or stent-assisted coiling and stent grafting. Recently, multilayered flow diverting stents have also been used to preserve critical adjacent side branches (5). Stent-assisted coiling could increase the risk of bleeding because continuous anticoagulation is required after the procedure (11). In addition, stent grafts are rigid and difficult to deploy in patients with tortuous vessels

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(12). In 1998, Baxter et al. (13) introduced the double microcatheter technique as a method for reducing migration or coil impingement during coiling of cerebral wide-necked aneurysm, and it showed good results in several subsequent neurointerventional studies (14–16). This technique allows the use of microcatheters, which lowers the risk of aneurysmal rupture, thromboembolic events, and vessel injury, facilitates passage through tortuous vessels, and eliminates the need for anticoagulation after treatment. Although a few studies of patients with VRAAs treated using the double microcatheter technique have been reported in the English literature (10, 17), there is no large-scale study on the use of the double microcatheter technique in patients with visceral aneurysms, and follow-up results have not been described. The aim of this study was to describe the outcomes of 9 patients with VRAAs treated using the double microcatheter technique via a single access route.

Methods

Patients

This retrospective study was approved by Chonnam National University Hwasun Hospital Institutional Review Board (IRB number: CNUHH-2019-126). All participants provided written informed consent. The medical records of 9 patients (mean age, 58 years; age range, 42–69 years; 4 men and 5 women) diagnosed with wide-necked visceral aneurysms, defined as a neck-to-dome ratio of <2 (18), who underwent endovascular treatment with the double microcatheter technique via a single access route from January 2016 to July 2018 were retrospectively analyzed.

Main points

- During the treatment of complex renal artery aneurysms, sacrifice of the branch originating from the aneurysm or microembolism is possible. This can result in cortical infarction.
- The coil packing density in aneurysms measuring ≥2 cm may be lower than expected. However, in the treatment of large aneurysms, maximum coil compaction should be attempted to prevent recanalization.
- The double microcatheter technique is a safe and effective option for the treatment of wide-necked visceral and renal aneurysms with tortuous approach vessels.

Embolization technique

Coiling of wide-neck aneurysm using the double microcatheter technique was performed using an angiographic system (Allura Clarity FD20, Philips Healthcare). All 9 patients received local anesthesia in the right inguinal area, and access to the right common femoral artery was achieved using a 6 French (6 F) vascular sheath. For cannulation of the feeding artery of the aneurysmal sac, a 0.035-inch guidewire (Terumo Corp.) and a 5 F Yashiro type catheter (Terumo Corp.) or C2 Cobra catheter (Cook Medical) were used. Three-dimensional (3D) volume reconstruction images were obtained using angiography and cone-beam computed tomography (CBCT; Xper CT; Philips Healthcare) for more precise evaluation of the size and anatomy of the aneurysmal necks. CBCT with rotational angiography was performed with a delay of 2–4 s after the injection of 12 mL of contrast medium diluted with normal saline (1:1; iobitridol, 350 mg iodine/mL; Xenetix, Guerbet) at a rate of 3 mL/s. Multiplanar projection at several planes was used to locate the exact orifice of the aneurysm.

Using an exchange wire (Rosen wire guide, Cook Medical), we placed an 8 F Flexor® Ansel Guiding sheath (Cook Medical) at the orifice of the feeding artery. The first microcatheter (Renegade STC 18, Boston Scientific) tip was placed inside the aneurysmal sac using a 0.016-inch wire (Fathom ™ steerable guidewire, Boston Scientific). Subsequently, the double catheter technique was performed by inserting the second microcatheter through the previously inserted guiding sheath. This was done using the protective sleeve of the guidewire to prevent kinking of the proximal tip of the microcatheter during passage through the hemostatic valve of the guiding sheath. After positioning of the two microcatheters within the aneurysmal sac, the first microcoil was partially deployed through the first microcatheter for reference. A second microcoil was inserted through the second microcatheter. Subsequently, the two microcoils intertwined and supported each other to create a stable coil frame. If the coil frame was not stable because of parent arterial pulses or dislocation of some coils from the aneurysmal sac, one or both coils were pulled back and the coil frame was constructed again. Once a stable coil frame was achieved, one of the two coils was detached and the next coil was inserted. During advancement of the microcoil, if any segment of the coil herniated into the parent artery, it was pulled back and repositioned to achieve safe packing within the aneurysmal sac. This process was continued until the remaining lumen was almost completely filled with coils on fluoroscopic imaging. The Interlock detachable coil (Boston Scientific) or Concerto detachable coil (Medtronic) were used for packing.

During the procedure, continuous heparinized saline (0.01 mg/mL) was infused via the side port of the guiding sheath using a pressure infusion bag (Infu-Surg® pressure infusion bag, Ethox Medical) to prevent acute thrombus formation within the guiding sheath (Figs. 1 and 2).

Evaluation

Immediate follow-up abdominal CT was performed 1 to 7 days after the procedure for verification of complete exclusion of the aneurysmal sac. The absence of a remnant sac on the CT image was considered technical success. The patients' initial symptoms, location, size, volume, neck-to-dome ratio, number of coils used, coil packing density (ratio of the volume of inserted coils to the volume of the aneurysm) (19, 20), technical success, complications (coil migration, organ ischemia), changes in the complete blood count (CBC) or serum creatine level after treatment, recurrence, and mean follow-up period were evaluated.

Statistical analysis

Descriptive statistics were calculated using SPSS version 23.0 (IBM Corp.). The results are presented as mean ± standard deviation.

Results

Visceral artery aneurysms originating in the renal artery were observed in three patients (one man and two women), while those originating in the splenic artery were observed in six (three men and three women). The splenic artery aneurysms included one in the proximal splenic artery and five in the distal splenic artery. All VRAAs were true aneurysm (100%). The mean maximal size of the visceral aneurysm after treatment was 26.09±4.76 mm (range, 20–33 mm), while the mean volume was 6.19±3.69 cm^3 (range, 2.03–13.30 cm^3). The neck-to-dome ratio was 1.53±0.24 (range, 1.14–1.78). The average number of coils used for packing was 11.2±2.8 (range, 7–16). A total of 101 detachable coils were used. The mean packing density was 11.32%±3.72%. The results of CBC and serum creatinine level measure-

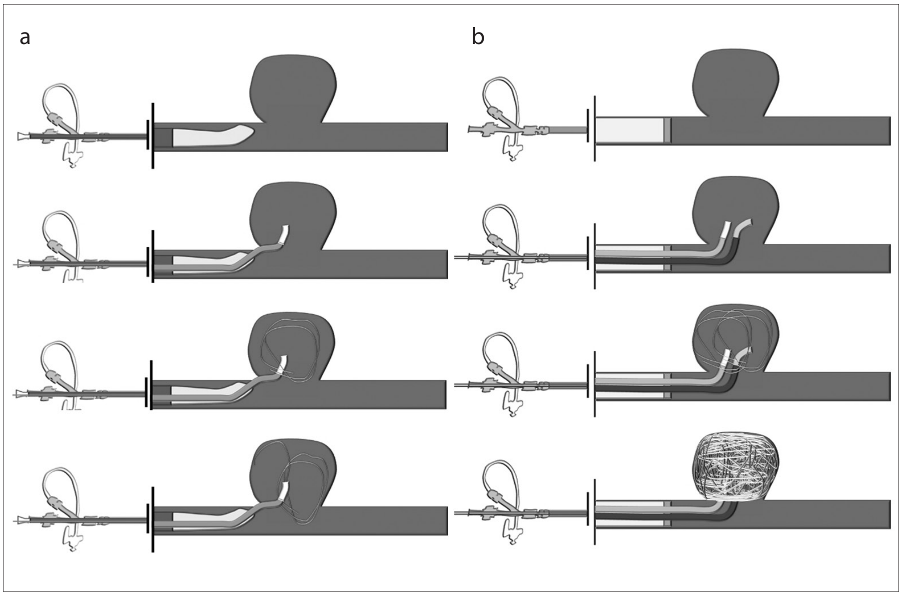

Figure 1. a, b. Schematics of the single and double microcatheter technique for visceral and renal artery aneurysms. In panel **(a)**, when a single microcatheter is used, the unstable coil can migrate to the parent artery after detachment of the first coil. Panel **(b)** shows placement of two microcatheter tips inside the aneurysm sac. The two microcoils intertwine and support each other, creating a stable coil frame. Alternatively, insertion of the microcoils until the inside of the aneurysmal sac is completely excluded can be performed. If the microcoil herniates outside the aneurysmal sac, it is removed and reinserted.

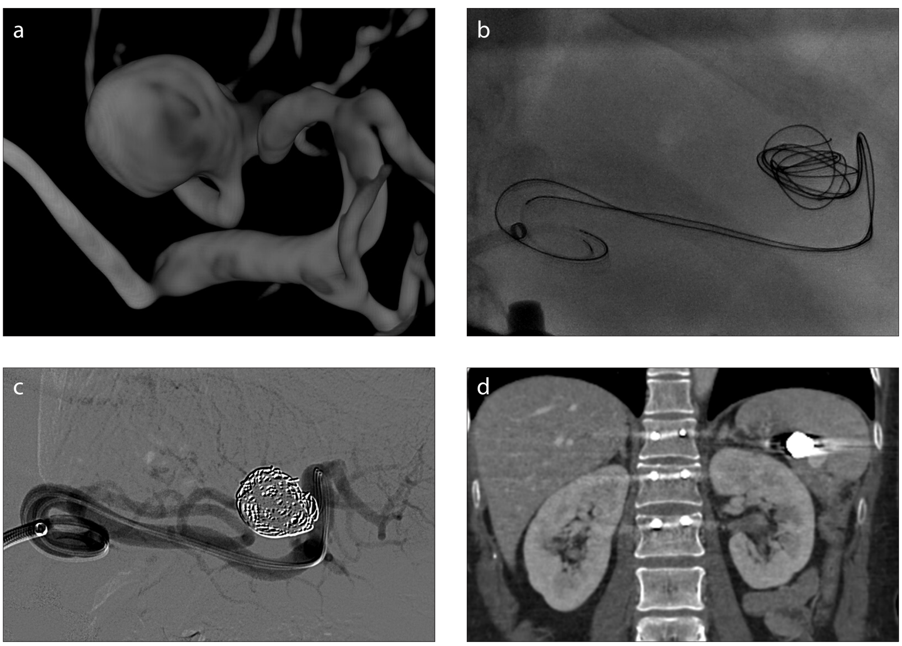

Figure 2. a–d. A 42-year-old woman with an incidentally detected 2 cm aneurysm in the distal splenic artery. Three-dimensional reconstruction **(a)** shows a wide-necked aneurysm in the distal splenic artery. Fluoroscopic image **(b)** shows two microcatheter tips inside the aneurysmal sac and entanglement of the coils for the prevention of coil migration. Follow-up digital subtraction angiography **(c)** shows stable coil packing inside the aneurysmal sac. Follow-up abdominal CT **(d)** performed after 1 week indicates the absence of coil migration, organ ischemia, or remnant aneurysmal sac.

ments before and after the procedure were within the normal ranges, and there were no significant changes after treatment. The mean follow-up period was 289 days (range, 7–807 days).

The technical success rate was 100%. Two patients developed minor complications after the procedure. One patient (Case 6) exhibited renal ischemic changes on follow-up CT imaging performed 1 week later, with the absence of clinical symptoms. The serum creatine level before treatment was 0.8 mg/dL (normal range, 0.5–1.3 mg/dL), while those immediately and 1 month after treatment were 0.9 and 0.8 mg/dL, respectively. The parenchymal ischemic changes resolved to a minor cortical scar on the 6-month follow-up CT images (Fig. 3). One patient (Case 7) exhibited two aneurysms in the left renal artery, one of which had a wide neck. The wide-necked aneurysm was treated using the double microcatheter technique, while the other lesion was treated with conventional coil packing using a single microcatheter. Immediately after the procedure, the patient complained of intermittent pain in the left flank for 6 days, and the initial follow-up CT image revealed partial renal infarction. The serum creatine levels before, immediately after, and 1 month after treatment were 0.6, 0.6 mg/dL, and 0.8 mg/dL, respectively. The patient did not undergo additional imaging studies, and her clinical symptoms improved during the hospital stay. Follow-up CT did not show a remnant aneurysmal sac or recurrence in any the patients. Each patient's details are summarized in the Table.

Discussion

Management of VRAAs includes surgical and endovascular treatment. According to Pulli et al. (3), surgical treatment of 55 VRAAs was associated with a 30-day mortality rate of 1.8% and a morbidity rate of 5.4%. Long-term follow-up revealed no aneurysm-related deaths. Other studies reported no significant differences in mortality and morbidity between endovascular and surgical treatment, although endovascular treatment shortened the hospital stay (21, 22). Recent studies reported a technical success rate of >94% for endovascular treatment of VRAAs, with >99% visceral organ preservation and <4% complication. Therefore, endovascular repair is considered as the first-line treatment for VRAAs (23).

Endovascular treatment includes coil packing to fill the aneurysm with a coil, the sandwich technique to isolate the inflow and outflow of the aneurysm using a coil or vascular plug, balloon or stent-assisted coil embolization, N-butyl cyanoacrylate embolization using liquid embolic agents such as onyx, and stent graft deployment (24). Balloon- or stent-assisted coiling can be used to prevent coil migration in patients un-

Table. Patient characteristics, coil packing density, complications, recurrence, and laboratory changes after coil embolization using the double microcatheter technique for visceral and renal artery aneurysms

Case no.	Age (yrs)	Sex	Initial Symptoms	Location	Size (mm)	Volume (mm^3)	Neck-to-dome ratio	Coil number	Coil packing density (%)	Recurrence	Coil migration	Organ ischemia	Post procedural symptoms	CBC and creatine change
1	64	F	No	Rt. main RA	30	8686	1.6	16	9.76	No	No	No	No	No
2	69	M	Abdominal pain	Distal SA	30.4	7176	1.6	10	7.41	No	No	No	No	No
3	42	F	No	Distal SA	20.9	2845.4	1.7	9	12.99	No	No	No	No	No
4	69	F	No	Distal SA	29	7283.6	1.3	14	9.27	No	No	No	No	No
5	68	F	No	Distal SA	26	7774	1.2	13	9.34	No	No	No	No	No
6	46	M	No	Lt. anterior segmental RA	20	2028	1.2	10	18.18	No	No	Yes	Frank pain	No
7	49	F	No	Lt. posterior segmental RA	21.2	2163.2	1.7	10	16.31	No	No	Yes	Frank pain	No
8	50	M	No	Distal SA	33	13299	1.6	12	8.21	No	No	No	No	No
9	65	M	No	Proximal SA	24.2	4492.8	1.7	7	10.4	No	No	No	No	No

F, female; M, male; Rt., right; Lt., left, RA, renal artery; SA, splenic artery; CBC, complete blood count.

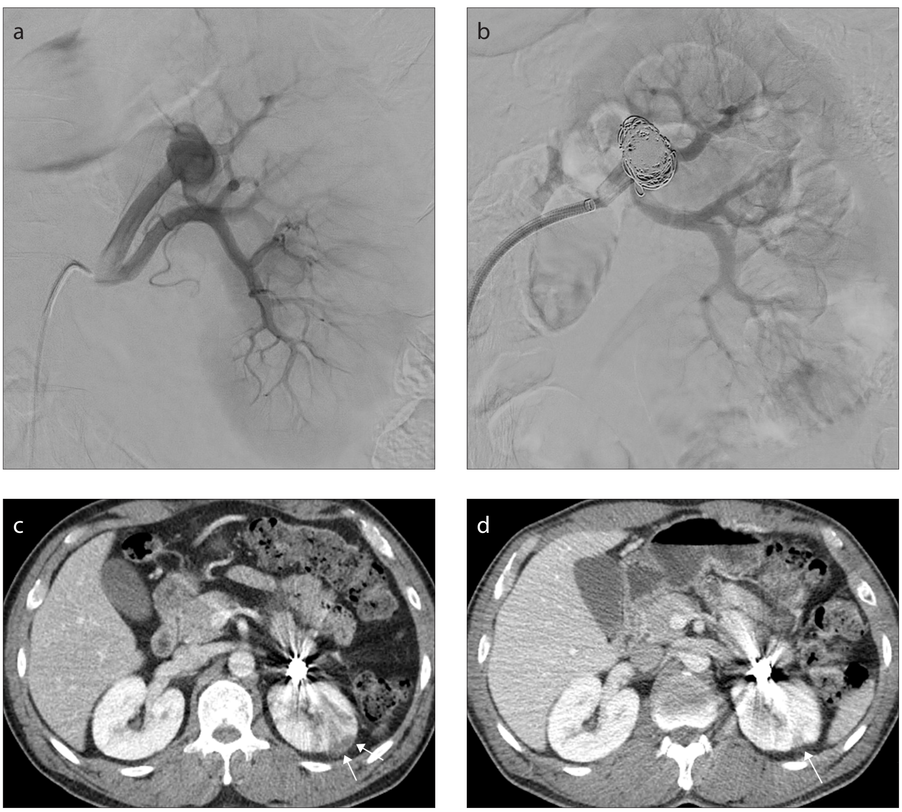

Figure 3. a–d. A 46-year-old man with a left renal artery aneurysm. Renal artery angiography **(a)** shows a 2 cm wide-necked aneurysm in the anterior segmental artery. Follow-up digital subtraction angiography **(b)** shows successful coil packing inside the aneurysmal sac. Abdominal CT **(c)** performed after 1 day shows ischemic changes *(arrows)* in the left kidney. Follow-up CT **(d)** after 6 months shows minimal scar formation of the ischemic lesion *(arrow)*.

dergoing treatment for wide-necked aneurysms, although it is associated with the risk of aneurysmal rupture, embolism caused by temporal obstruction, and increased bleeding due to continuous anticoagulation therapy (12). Coiling after temporary balloon occlusion may cause coil migration to the parent artery after deflation of the balloon. However, successful coil embolization through compact packing using a hypercompliant balloon catheter has been reported (25). Recently, modified stent-assisted coiling technique, such as the waffle-cone technique with the Solitaire stent, were introduced for the treatment of complex renal artery aneurysms and exhibited good results (26). Other endovascular treatment options including stent grafts, which are also safe and effective. However, vessel tracking is difficult in patients with tortuous vessels (27, 28). When stent grafts are used, exclusion of the aneurysm may lead to significant infarction due to undesired blockage of blood flow through the patent artery (29). In a meta-analysis of stent graft repair of 21 renal artery aneurysms, minor ischemic complications occurred due to side branch occlusion by the stent graft in 5 patients (23.8%) (30). However, another study of stent graft repair of 40 visceral artery aneurysms found no such ischemic complications due to stent graft coverage of the patent side branch (31). The double microcatheter technique is often used for intracranial intervention and offers advantages such as ease of use in tortuous vessels, prevention of coil migration in high-flow lesions, and effective treatment of complex aneurysms (10). The detachable coil system is useful for creation of the coil frame and filling of the residual lumen as it allows for intraprocedural repositioning in case of coil herniation into the parent artery. On the other hand, when the conventional pushing coil system is used, repositioning cannot be achieved if misplacement or protrusion of the coil into the parent artery occurs.

A few studies including patients with VRAAs treated with the double microcatheter technique have been reported in the English literature. Tanigawa et al. (17) used the technique in a patient with an anomalous splenic artery aneurysm originating from the superior mesenteric artery. Follow-up abdominal radiography did not show migration or compaction of the coils or clinical evidence of splenic infraction. Greben et al. (10) reported the successful treatment of 21 vascular lesions using the double microcatheter technique. Immediate technical success and complete exclusion was achieved in four visceral artery aneurysms and pseudoaneurysms. In the present study, follow-up examinations were performed using CT. The technical success rate was 100%, with complete exclusion of the aneurysm and absence of major complications. During the double microcatheter technique, a heparinized saline solution was infused through the side arm of the sheath in all patients. Continuous infusion of heparinized saline is mandatory for the prevention of acute thrombosis in the sheath, particularly during embolization of larger aneurysmal sacs, considering the high incidence of acute thrombus formation within the guiding sheath during prolonged procedures.

In a long-term follow-up study of coil packing for visceral artery aneurysms, a low packing density was found to result in coil compaction and recanalization. A packing density of >24% was recommended, and there was a significant difference in the packing density according to the size of the aneurysm (<20 mm, 22% vs. >20 mm, 15%) (20). In the present study, all aneurysms measured >20 mm, and the mean packing density was 11.33%. No coil compaction or recanalizations were observed during the follow-up period. However, according to previous studies on cerebral aneurysms (32), coil compaction or recanalization may occur more frequently in large aneurysms; therefore, maximum coil compaction is important in such cases.

Etezadi et al. (33) reported the endovascular treatment of 40 VRAAs, and 4 of 13 patients (31%) with splenic aneurysms and 2 of 17 with renal aneurysms (12%) showed end organ infarction. In the present study, no end organ infarction occurred in the 6 patients with wide-necked splenic aneurysms, although transient renal ischemia occurred in 2 of 3 patients with wide-necked renal aneurysms. One of these patients showed almost complete recovery on follow-up imaging. The presence of renal infarction was difficult to determine in the other patient, who rejected additional follow-up imaging studies. One aneurysm with no infarction after the procedure was located in the main renal artery. In the two patients with organ ischemia, the aneurysm was located in the bifurcation of the segmental artery. During coiling of the aneurysm in the segmental artery, the branch originating from the aneurysm could have been sacrificed. In general, however, microembolism cannot be ruled out during the procedure, because the procedural duration for large aneurysms is longer than that for small aneurysms. In the present study, the accuracy of the evaluation was limited by the presence of metallic artifacts on the follow-up CT images. Nevertheless, the overall frequency of end organ infarction or ischemia was similar to that in the study by Etezadi et al. (33).

This study has some limitations. The study population was small and the follow-up intervals were short and inconsistent. In patients who underwent follow-up examination using CT, the presence of metallic artifacts limited the accuracy of evaluation of the remnant aneurysmal sac or the overall status of the end organs.

In conclusion, the double microcatheter technique performed via a single access route is a relatively safe method for the treatment of wide-necked aneurysms. However, complex renal artery aneurysms should be carefully managed in order to prevent infarction.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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